Catching Up with Catchment Monitoring

Flooding versus droughts. Water issues have affected the UK and been the focus of the media recently. However, it is not just the volume of available water in catchments which matters - the quality of natural waters also affects their ecological health, recreational value and the amount of treatment needed to make water potable. Our catchments are under pressure from agriculture, industry and climate change. With the second cycle of action plans to manage water catchments across Europe due to commence in September 2015, it is timely to take stock of some of the technology which has been used to monitor catchments and potential future technology developments.

> *"There is a continuing need to manage our catchments, and meet the requirements of the Water Framework Directive to improve the water quality for both ecology and for the benefit of humans."*

So which sensors are currently used for catchment monitoring? What kinds of new monitoring technologies are under development for the future? What can be achieved using the knowledge gained about sources of pollution in catchments? And how will our understanding of inputs to catchments improve over time? The Sensors for Water Interest Group (SWIG) held a workshop on 18 March 2015 at Rothamsted Research, North Wyke to bring together specialists in the field of water monitoring in catchments and address all of these questions.

The toolbox of technology for catchment monitoring includes sensors for monitoring water level, flow and water quality; automatic samplers and integrated wireless telemetry can be useful for transmission of results as explained by Wavelength Environmental. Monitoring equipment needs to be low maintenance, require low power input and have a small ecological footprint. The choice of sensors will of course depend upon the monitoring requirements and budget of each end user.

The West Country Rivers Trust (WRT) have used monitoring or a combination of monitoring and modelling to investigate reasons for failure (RFF) under the Water Framework Directive by producing a detailed assessment of status and identifying key pressures on a catchment and sources of pollution. On the Fingle Brook on the Upper Teign, by taking sediment samples as well as water quality monitoring, they were able to ascertain that: there was a clear gradient of lead below road drains (above the environmental quality standard for lead), contamination was bound to sediment creating a legacy of lead being released in addition to chronic inputs from a historical mining site, and there was evidence of an early flush of solutes below road drains. Improving the functioning of the existing attenuation wetland helped address these issues.

The WRT undertook a study for Natural England in the River Camel SSSI, with the aim of targeting Catchment Sensitive Farming (CSF) to help tackle soil erosion. The study used a combination of field data and fine sediment risk modelling (using SCIMAP (Figure 1) diffuse pollution risk mapping software). Assuming that turbidity would be proportional to suspended solids, then suspended solids were estimated from turbidity measurements, and an estimate (in Kg) of the amount of sediment lost from fields was calculated – a pretty powerful statistic when approaching farmers. Catchment Sensitive Farming Officers then targeted the key areas and discussed the 'value' of soil loss. There was therefore an incentive for farmers to undertake CSF to prevent soil loss, which would also benefit the rivers – a 'win-win' situation.

Looking to the future, Alex Taylor, Data, Evidence and Communication Team, West Country Rivers Trust said:

"In future we would like to improve the spatial resolution of our monitoring in a cost effective way, so low cost sensors and sampling devices would be valuable to us. We are exploring the use of cheap and easy to use passive samplers, for example ChemCatcher™ (developed by the University of Portsmouth), to help identify pollution hotspots. With regard to sensors, in future, the ultimate aim would be to place a dense network of low cost sensors, potentially at the farm-scale, to measure some basic parameters such as conductivity and turbidity. From this we would like to engage stakeholders using live data feeds, and citizen science apps (such as that being developed by Dr Liz Bagshaw (Cardiff University)) so that people can both download real-time data and upload their own monitoring data. We hope that this will increase public awareness of catchment systems and provide a sense of ownership and interest in the quality of natural waters."

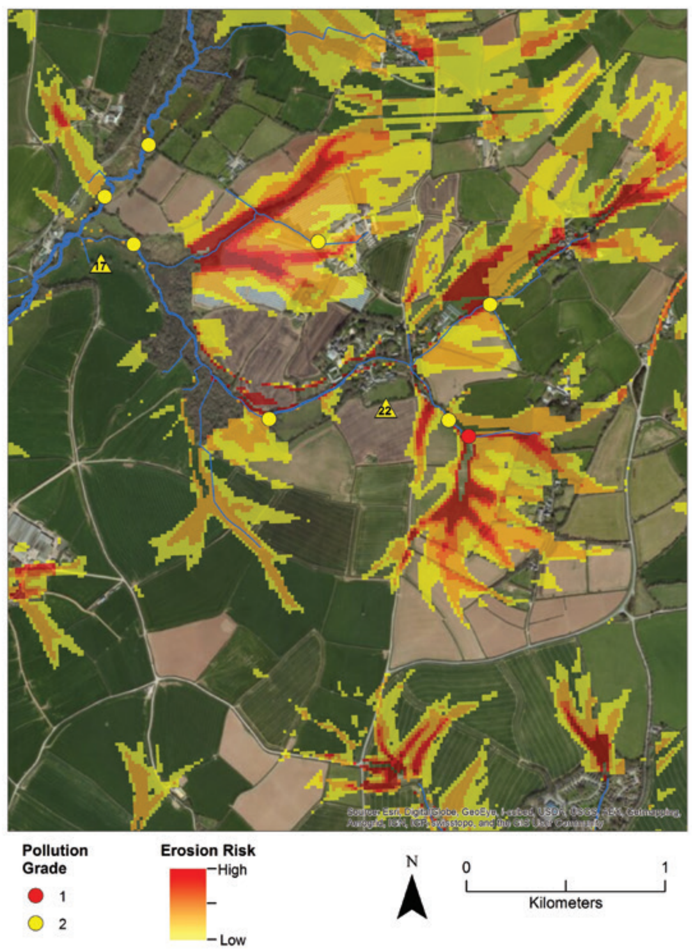

Figure 1: Map of SCIMAP sediment modelling data on the River Camel SSI

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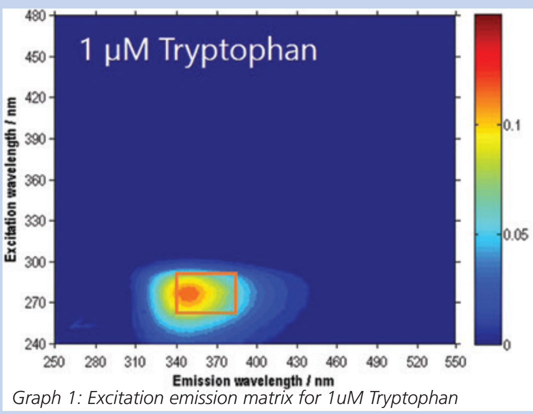
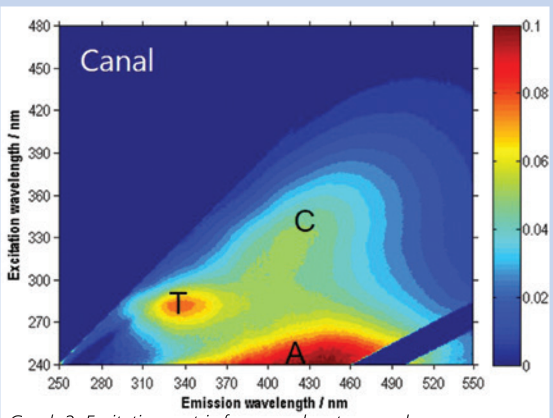
The Science Behind Fluorometers

Fluorometers measure the fluorescence of a water sample by sending two excitation beams of known wavelength light through it. The water sample absorbs light and emits light of specific wavelength which the fluorometer reads. If the excitation and emission wavelengths are plotted onto a fluorescence contour map or 'excitation emission matrix', then the peaks that can be seen are characteristic of the molecules present in the sample. The peak or band for pure Tryptophan has an excitation wavelength of 280 nm and emission wavelength of 350 nm (graph 1). However, in an environmental sample there can be 'noise' from other substances present. Researchers including those at the University of South Florida at St. Petersburg, USA found that humic substances and other coloured dissolved organic matter (CDOM) have bands which can overlap with Tryptophan's fluorescence signal and therefore confuse the measurement of the Tryptophan present. Graph 2 shows the additional CDOM fluorescence (labelled peak C and A) in addition to the Tryptophan-like fluorescence (T).



Graph 1: Excitation emission matrix for 1uM Tryptophan



Graph 2: Excitation matrix for a canal water sample

Tryptophan fluorometers are one new technology which the WRT have tried out. This relatively new technology shows good potential for measuring organic pollution (see box). Wherever there is organic pollution there will likely be microbial communities, and the cell walls and waste products of microbes contain the amino acid Tryptophan (Tryp). In theory tryptophan readings should therefore correlate well with bacterial load and other parameters such as BOD, ammonia and phosphate.

Adam Gilbert at the Environment Agency (EA) has been trialling the use of tryp flurometers and presented examples of successful deployments including investigating the source of a sewage pollution incident (Menalhyl), investigating the source of a phosphate failure (Seaton) and for inferring bacterial loads and linking this with bathing water alarms at a seaside resort (Porthluney). The results were promising, and Adam Gilbert (EA) said that fluorometers are particularly useful to identify point sources of pollution and for triggering pollution alarms.

However, the EA found challenges associated with freshwater applications of fluorometers. For example in terms of the sensitivity of the fluorometers. Tryp would only be picked up in very polluted samples (more 24,000 bacteria per 100ml), so Adam Gilbert (EA) thought that a fluorometer would not currently be useful at lower levels of organic pollution where there are lots of other factors involved. Also turbidity can cause a 'quenching' effect on the Tryp measured – if turbidity increases above 250 NTU then Tryp decreases even during a pollution event. In this case monitoring for ammonia would pick up the pollution event, but measuring Tryp would not. The EA found that light interference affected the measurement of Tryp, so there is a definite need for a cover or cap over the sample. The guard for the fluorometer was susceptible to getting fouled by rags, seaweed etc which stopped the sample from flowing through, this could be addressed by regular checking or removing the guard, guarding from light but still allowing the sample through. Further to this. particulates caused interference with the measurement of Tryp, but this could be remedied by the use of a 100 µ filter (tights!) over the sensor to prevent particulates from getting through. Of particular concern was the fact that there was interference from other parameters and other fluorescent substances for example Optical Brightening Agents (OBAs). Temperature may also affect the measurement of Tryp as the literature states that the higher the temperature the lower the Tryp measured. Finally, the Adam Gilbert (EA) said there was a need for a common unit of measurement for fluorometers, as currently different fluorometers use different units and the data is not directly comparable.

Some solutions to the above issues were suggested during the workshop. A specialist UK sensor manufacturer has recently adopted a fluorescence standardisation procedure in-house which could be used more widely. Rather than reporting fluorescence in units of ppb of a particular compound, the fluorescence can be reported in Quinine Sulphate Units (QSU). 1 QSU is equivalent to the fluorescence recorded from 1 ppm quinine sulphate (a certified reference standard for fluorescence) at an excitation wavelength of 347.5 nm and an emission wavelength of 450 nm. To aid with CDOM background assessment, the sensor manufacturer has developed a two fluorometer solution, consisting of Uvilux Tryptophan and CDOM fluorometers. The manufacturer in question has found that with two fluorometers, taking a ratio of the Tryptophan:CDOM fluorescence signal effectively 'smooths out' variations in CDOM background, providing a more stable fluorescence baseline above which Tryptophan anomalies can be detected. The ratio also helps to prevent the problems with 'quenching' caused by turbidity identified above.

"Fluorometers show great potential for monitoring organic pollution. They are certainly useful for catchment walkovers and pollution alarms" said Adam Gilbert, Technical Specialist in water quality monitoring at the Environment Agency. "However, some work needs to be done on increasing their sensitivity and finding solutions to the other problems we encountered. It would be really useful to have a standardised unit of measurement for fluorometers, so that results from different fluorometers could be compared. Fluorometers should be marketed honestly as to what they can and can't do - including their limitations, otherwise end users will lose confidence in them."

Another interesting development which could be of interest to end users such as the River Trusts were two wireless sensors which could meet the panacea of a low cost method for monitoring at high spatial resolution. The sensors currently being adapted for use monitoring rivers, have until now have been used to monitor glaciers by Cardiff University. By incorporating water quality sensors (temperature, pressure and electrochemical sensors) and wireless technology into a small plastic 'egg' case monitoring can be undertaken in formerly inaccessible locations and data acquired remotely using radio transmission, including long term datasets and high spatial resolution. There are two protypes which have been developed: 'E-Tracers' - buoyant sensors the size of a Christmas bauble which collect data along a flowpath, and the 'Cryoegg' for long term deployments in situ – a larger platform with multiple sensors (as needed) and a larger transmitter. Both types would need to be recovered after use to prevent causing their own environmental problem of waste plastic and components. There is potential for these sensors to be used for citizen science with the public accessing the monitoring data from nearby sensors via their mobile phone. There are currently trials of the WISECAM phone app to manage water quality data received from ETracers or other sources of water quality data.

One thing is for sure, with the continuing pressures of land use and climate change on our waterbodies, monitoring using well established and new techniques will definitely be needed going forward. There is a continuing need to manage our catchments, and meet the requirements of the Water Framework Directive to improve the water quality for both ecology and for the benefit of humans.

Practitioners of catchment monitoring and catchment management may be interested in the results of two current ongoing projects which will improve knowledge and understanding about the inputs to catchments, and will therefore help aid analysis, modelling and management of catchments. We heard about the NERC DOMAINE project and had a tour of the fascinating and impressive Rothamsted Research North Wyke Farm Platform project.

The NERC DOMAINE project (characterising the nature, origins and ecological significance of Dissolved Organic Matter IN freshwater Ecosystems) is due to be completed in 2018. The DOMAINE project will assess the origins, transport and downstream export of dissolved organic carbon, nitrogen and phosphorus and also the ecosystem functional significance and wider environmental and human health impacts of DOM flux. Led by the University of Bristol, the DOMAINE project is currently monitoring the Hampshire Avon as an example of a lowland agricultural catchment; and the Conwy as an example of an upland catchment comprising mountain moorland, peat and commercial forestry.

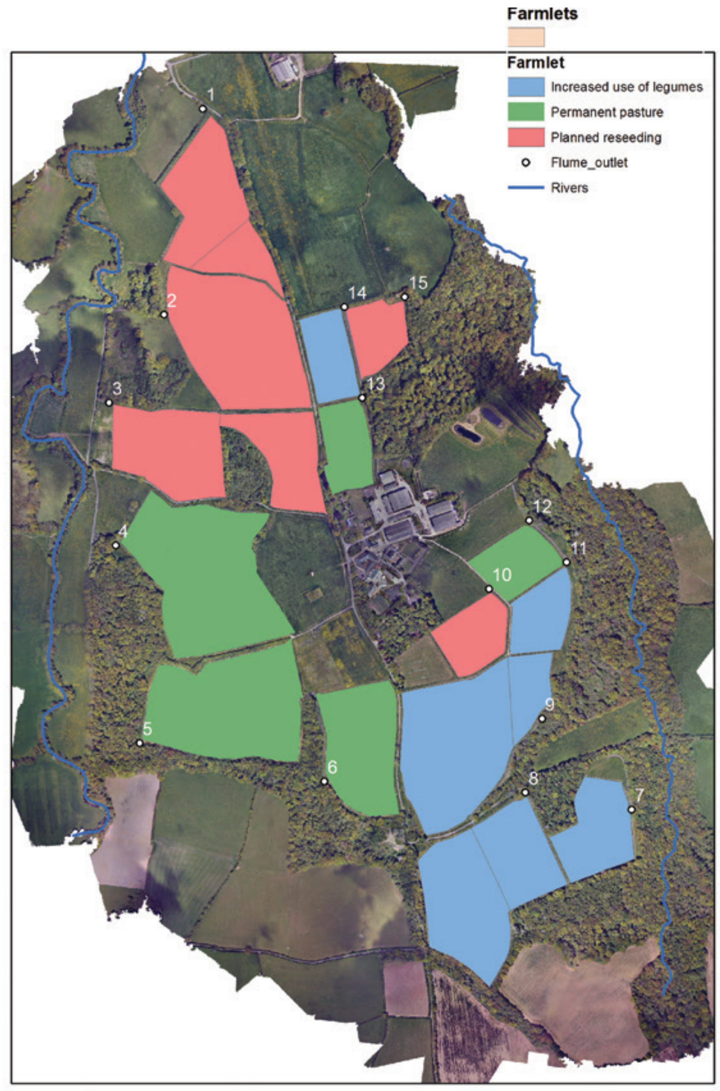


Figure 2: The North Wyke Farm Platform project 'farmlets' (red, blue and green) and 15 sub catchments with topography mapped.

The Rothamsted Research North Wyke Farm Platform project is a unique agri-environment project aiming to address the challenges of water scarcity, climate change and improving the efficiency of food production using fewer inputs. The project focuses on grassland systems. The effects on water, air and soil from differently managing 3 'farmlets' each of approximately 25 hectares is being measured. Run-off is monitored from each 'farmlet' comprising 5 sub catchments – hydrologically controlled fields where all water leaving individual fields is channelled through a flume (15 in total) through French drains (figure 2). Each of the 15 flumes is monitored for flow rates and water samples are automatically collected and analysed – quite a feat. The grassland is being used for the production of beef and sheep. The management scenarios being compared are: sustainable intensification of permanent grassland (Sward improvement through use of artificial fertilisers) vs increased use of legumes vs planned reseeding. The Farm Platform project aims to provide research to enable innovations in sustainable agricultural production and evidence-based policy for sustainable agriculture and land use change. Data will be available through a Farm Platform Data Portal due to be launched in June 2015, during the UN Food and Agriculture Organisation International Year of Soils, and no doubt awaited with much global interest from researchers in this area.

About SWIG

The Sensors for Water Interest Group (SWIG) is a not for profit, knowledge-exchange and networking group with a diverse UK-wide membership. We hold workshops covering all aspects of water sensing (www.swig.org.uk).

About the Author

Rosa Richards is an Independent Environmental Consultant specialising in water policy. She is Programme Manager of the Sensors for Water Interest Group (SWIG), a freelance science writer, distance learning tutor of Integrated Environmental Management at the University of Bath, and volunteers for the Bristol and Avon Rivers Trust (BART).