

Developing Deconvolution Challenges of including unsteadiness and bifurcations

The project **aims** to perform preliminary studies geared to providing a robust technique for the analysis of data describing mixing processes within urban drainage structures. This will facilitate long time series modelling of an urban drainage system to produce probable concentration/duration exposure envelopes, allowing ecological impacts to be assessed.

The specific aim of this project is to extend the application of a **Maximum Entropy Deconvolution**¹ algorithm to manhole solute mixing and transport data to ascertain its efficacy across a variety of experimental conditions. Preliminary studies have shown that such a data-driven, system identification approach can provide excellent fits to experimental upstream/downstream data in a more reliable manner than previous studies using conventional modelling approaches. This approach will be extended to investigate the whether similar techniques can be developed to characterise a variety of perturbation scenarios, (e.g. single input:multiple outputs, SIMO), dynamic/unsteady flows (e.g. due to time varying rainfall events) and attempt to qualitatively understand bifurcations in the dynamics that exist with such flows under certain physical conditions.

For laboratory and field data, deconvolution is required to convert the recorded temporal concentration profiles into their fundamental instantaneous responses. For recorded data which contain noise, signal filtering processes may be required to identify the 'true' response. Madden *et al.*¹ compare six alternative deconvolution approaches, with one based on maximum entropy showing particular benefits for eliminating noise typically associated with laboratory measurements. Preliminary applications of this approach to the laboratory manhole datasets have confirmed the feasibility of identifying cumulative residence time distributions from experimental data under steady hydraulic conditions.

Laboratory studies have been performed to measure the 'system response' of several different urban drainage structures^{2,3}: manholes, storage tanks and combines sewer overflows under steady conditions. All these systems are single input:single output systems (SISO) and conventional analysis has quantified their response. These responses are however not true 'fundamental responses' and are therefore not-scalable, limiting their adoption. Preliminary work on applying a deconvolution technique to this data set has shown considerable potential. Data are available under steady conditions in (SIMO)systems and an engineering PhD student is currently collecting new data under time-varying dynamic (unsteady) conditions in the laboratory. There would be an opportunity to assist with this study to gain a stronger qualitative understanding of the system dynamics and responses.

A familiarity with conventional analysis of solute dispersion data and modelling of environmental mixing processes would be beneficial, summary notes are available from module ES427. The **techniques required** will primarily be modelling, qualitative analysis and numerical simulation. The student will have access to development work by a previous PhD student and current MEng students who have produced bespoke MATLAB software. In particular, the deconvolution algorithms will be enhanced to cater for time-varying inputs and will be extended to consider the case of data collected from single-input-multi-output (SIMO) and multi-input-multi-output (MIMO) experiments, using an appropriate selection of blind deconvolution techniques and multi-component objective functions.

Long term **project deliverables** will enhance one-dimensional urban drainage network models that have the potential to predict the transport of sediments and dissolved substances. The current generation of network models provides robust engineering tools for the prediction and management of sewer flow hydraulics. However, the quality modelling capabilities of these models have not been adequate to meet requirements. A long-term goal of the project will be to generate a validated one-dimensional modelling methodology to characterize solute mixing in urban drainage structures. This will provide an improved modelling capability that will help urban drainage engineers (the Water Utilities and their consultants); local authorities and regulators (the Environment Agency) predict and assess the risk from discharges from sewer overflows. This should contribute to improved management decisions relating to the quality of urban watercourses.

This project has **excellent prospects for leading into a PhD** project. A current PhD student (Amy Jones @ 15 months) has completed the construction of a new laboratory facility to measure the system response to time-varying flow conditions. The facility, instrumentation and control have been designed to facilitate future (SIMO) bifurcation analysis studies (manhole overflow, urban flooding effects) to be performed. This will permit the collection of a unique data set for which currently there are no validated analytical or interpretive numerical tools available.

References

- 1 Madden, F.N., Godfrey, K.R., Chappell, M.J., Hovorka, R. and Bates, R.A. (1996) "A comparison of six deconvolution techniques", *J. Pharmacokinet. Pharmacodyn.* 24:283-299.
- 2 Guymer, I., Dennis, P., O'Brien, R. and Saiyudthong, C. (2005). "Diameter and surcharge effects on solute transport across surcharged manholes", *J. of Hyd. Eng.* 131(4), 312-321.
- 3 Shepherd, W.J., Guymer, I. and Saul, A.J. 'Solute retention and mixing characteristics in CSO structures', ASCE World Water and Env. Res. Cong., May 20-24, 2001, Florida, USA.