Residence Times in Vegetated Stormwater Ponds

J. R. Hart, I. Guymer and V. R. Stovin
James.hart@warwick.ac.uk

Introduction
Storm water ponds are used to reduce the negative environmental impact of pollutants within runoff from urban areas, highways and agricultural land through detention and water treatment. Water treatment is undertaken through chemical and biological process in the pond, but is also a function of the pond’s hydraulic residence time, as pollutants need to reside in the pond for sufficient time to be treated effectively. Thus, it is important to be able to estimate the pond’s residence time accurately. Current estimations rely on the nominal residence time (pond volume/discharge). However, it has been shown that this provides a poor estimate of the pond’s residence time. Vegetation, which has a positive effect on water treatment, can have a negative effect on the pond’s residence time, by reducing the ponds effective volume, causing the system to ‘short circuit’. Thus, an understanding of how vegetation affects the residence time is required to improve the design of storm water ponds.

Laboratory Work
Aims of experimental work:
1) Quantify the vegetation’s bulk porosity and flow resistance
2) Quantify longitudinal mixing within the vegetation and in the open flow adjacent to the vegetation
3) Quantify transverse mixing within the vegetation, and at the interface between the vegetation and the open flow
4) Measure three component velocity data transversely across the channel at several longitudinal locations

Field Work
Aims of field work:
Measure residence time distribution and mean residence time as a function of discharge for a range of vegetation densities and configurations over the seasonal growth cycle.

Project Aims
1) To collect comprehensive new laboratory data on the bulk porosity and flow resistance of different pond vegetation types – emergent, floating and submerged – as a function of seasonal growth cycles over a range of typical pond flow velocities.
2) To conduct laboratory solute tracer studies to quantify the mixing (transverse, longitudinal & residence time distribution) within, and the exchange coefficient between, clear and vegetated flow zones.
3) To utilise the laboratory data to validate CFD modelling procedures and quantify parameters appropriate for describing the influence of vegetation on velocities and mixing.
4) To perform field measurement of residence time distributions in mature vegetated ponds over seasonal growth cycles to validate the 3D CFD methodology.
5) To conduct scenario modelling to explore the sensitivity of residence time distributions to vegetation mosaic, discharge and pond shape.
6) To facilitate the dissemination of the validated modelling methodology, together with appropriate parameter values for the flow resistance and mixing processes.

The above aims refer to the overall project aims, the scope of this poster covers aspects of the aims relevant to the laboratory and field work side of the project, i.e. aims 1) - 2).

Laboratory methodology for tracer work:
1) Inject fluorescent dye as either a pulse (Figure 3) or a continuous injection (Figure 4)
2) Use laser light beam to image concentration distribution of dye at an up and downstream location, data which can be used to quantify longitudinal (Figure 3) and transverse (Figures 3 and 4) mixing

Field-work methodology for tracer work:
1) Survey the pond and measure discharge
2) Inject dye at pond inlet
3) Use instruments installed at ponds inlet and outlet to measure the flows mean concentration as a function of time, and thus the ponds residence time distribution

Figure 3: Example of expected results for pulse injection from laboratory tracer experiments
Figure 4: Example of expected results for continuous injection from laboratory tracer experiments
Figure 5: Example trace from field site for case with no vegetation, and a strip of vegetation at ponds bound. Note, shorter mean residence time for vegetated case highlighting problem of ‘short-circuiting’.
Figure 6: Example of survey for field site