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## 01 - Surface Water Flood Investigation in Suburban Catchments

Anthony McCloy (McCloy Consulting Ltd.)

### Abstract

Urban drainage catchments are complex, particularly whenever the local drain capacity is exceeded and flows cannot enter the drainage system. The excess runoff flows uncontrolled across the surface of the catchment, causing untold damage to buildings and distress to residents and business owners. Many problem flood areas can be subjected to flooding on an annual basis.

To fully understand the hydraulic and hydrological processes at play can require a significant degree of software sophistication in addition to engineering knowledge. Ongoing advancements in software development, improvements in computer processing and increasing accessibility to highly detailed datasets now allow engineers to more fully assess and understand flood mechanisms, more accurately represent the problem and increase the degree certainty of the proposed solution.

This paper considers a real life project in Hatfield and is set within a suburban catchment in the greater London area. The study focuses on a part of Hatfield where residents have been repeatedly affected by surface water flooding. The urbanised catchment has a relatively high housing density with a number of open green spaces. Drainage is provided by a partially combined piped drainage network.

The hydraulic and hydrological assessment is based on integrated 1D / 2D analysis using Innovyze Integrated Catchment Modelling (ICM) software. Fully representing flood routing across the surface of an existing urban catchment is not straightforward and there are many factors and physical elements such as buildings, boundary fences and walls, street furniture and kerbs which all have potential to affect the routing of overland flooding. Careful consideration is also required to determine the response from green areas due to different rainfall patterns and antecedent conditions and how this might affect runoff rates into the drainage network.

Using the numerous datasets made available by the Local Authority, Environment Agency and Thames Water; augmented with the local catchment knowledge, observations from local residents and survey information, an investigation was undertaken to fully understand the mechanism of flooding and then identify the most appropriate method(s) to alleviate the risk of flooding to the properties.

Reducing the risk of flooding is not simply a matter of providing pipe upgrades; with more cost effective and environmentally sustainable options high on the agenda. Options considered for reduction in flood risk include;

- Provision of catchment attenuation within green space upslope of the properties to reduce flow rates within the drainage system following peak rainfall.
- Routing of excess flood flows through an existing green corridor.
- Provision of property level protection.

Selecting a preferred flood alleviation option is not simply a matter of identifying the least expensive approach either and there are many other factors to consider; including timeframe required for implementation, funding mechanisms, buy in from the residents and potential impact on others.

The following areas will be explored by this paper;

- How the resources of different authorities can be pulled together to deliver the right outcome.
- Software platform – what considerations informed selection.
- Validating the quality of datasets and identifying requirements for data cleansing.
- Consideration of rainfall patterns and depths and how this affected the runoff response from the suburban catchment
- Level of certainty / uncertainty which can be placed on hydraulic model outcomes.
- Practical aspects of implementation of low tech solutions at both property level and using the catchment landscape to deliver cost beneficial solutions.

The paper will identify the benefits and limitations of the modelling approach adopted along with the key learning outcomes from the study.

## 02 - Analysis of parameter uncertainty in a conceptual rainfall runoff model to wet and dry calibration periods

Victoria Ramsey (McCloy Consulting Ltd., NUI Maynooth)

### Abstract

Conceptual rainfall runoff models have become important tools in climate change impact assessment and inform decision making in hydrological issues including water resource management, flood protection or managing water quality (Beven, 2012). Hydrological models provide a generalisation of a naturally dynamic and complex system resulting in simplified assumptions to be made about key catchment processes which can introduce uncertainty into the modelling process (Murphy *et al.*, 2011; Beven, 2012).

The Hydrologiska Byråns Vattenbalansavdelning (HBV) Light conceptual rainfall-runoff model simulates daily discharge based upon inputs of precipitation, temperature and potential evaporation.

It has been shown that the identifiability of model parameters may change depending on the type of climatological data contained in the calibration period used to develop the model (Wilby, 2005; Merz *et al.*, 2011; Bastola *et al.*, 2011; Herman *et al.*, 2013). Parameter sensitivity and temporal transferability of model parameters has been analysed for other hydrological models, but few have been conducted on the HBV Light model (Wilby, 2005; Merz *et al.*, 2011; Bastola *et al.*, 2011; Herman *et al.*, 2013).

The research undertaken considers HBV Light applied to seven study catchments in Ireland under a full calibration period and two sub-calibration periods of wet and dry climatological conditions to assess changes in parameter sensitivity. The transferability of model parameters calibrated on wet and dry sub-periods is also tested for their ability to simulate wet and dry periods within validation.

The outcomes of this research will be presented in the poster. Under future climate change scenarios for Ireland, some catchments are projected to experience increased winter flows and decreasing summer flows (Steele-Dunne *et al.*, 2008). As a result, when using rainfall runoff models for impact assessment and decision making, it is important to take into account the uncertainty in simulations and the model's ability to capture changing climatological conditions within the catchment.

## 03 - Pilot project to investigate potential applications and benefits of satellite imagery and earth observation (EO) data for coastal flood and erosion hazard and risk management

**Marina Cumiskey**, Ronan Synnott, Rosemarie Lawlor and Jim Casey (OPW)

### Abstract

The Office of Public Works (OPW), Hydrology and Coastal Section, is currently undertaking (during 2015) a pilot project to investigate the potential applications and benefits of satellite imagery and earth observation (EO) data primarily for coastal flood and erosion hazard and risk management.

The European Space Agency is currently developing a number of satellite missions called 'Sentinels' to support the operational needs of the EU Copernicus programme. The first of these missions, Sentinel 1A, was launched on 3rd April 2014 and carried an advanced radar instrument to provide all-weather, day-and-night supply of imagery data of the Earth's surface whilst the subsequent Sentinel 2A mission was launched on 23rd June 2015. This data together with many other sources of satellite data are being investigated and evaluated under this project to identify particular OPW business applications.

Over the past few months Hydrology and Coastal Section has researched the EU Copernicus programme and other sources of earth observation data (up to 633 international past, present and future satellites e.g. US, European etc.) and has identified those that are considered most likely to be relevant to our business needs. A number of relevant case studies and publications have also been sourced and are currently being reviewed.

Based on our research to date it is considered likely that there will be some innovative engineering uses for the OPW arising from this data which will be identified further during the remainder of this project and in the final project report due by end of 2015.

## 04 - The Hydro-Ecological Modelling of Habitats, a Tool for a more Environmentally Sustainable Design

Jon Whitmore, Jonathan Cooper and **Ethan McGowan** (JBA Consulting)

### Abstract

Hydro-Ecological Modelling is now been used a tool to develop a more environmentally sustainable design. One such example is the impact of weirs on habitat development. Man-made weirs are usually obstructions to fish passage and create highly modified river habitats. However in some situations, weir pools are considered to be important habitats. Weir pools (defined as the area downstream of a weir, usually characterised by complex flow patterns before the river returns to a more typical hydro-morphological pattern) can provide varied habitat for a variety of fish and macroinvertebrate species. Furthermore, the fish populations often associated with weir pools are considered, by some, to represent valuable recreational amenity.

As a result, a hydropower development that utilises existing weir structures has the potential to alter flow regimes around weir pools that could have an impact on weir pool ecosystems, their hydraulic habitats, as well as the recreational value it provides. Is this understanding correct however and what evidence is there to support it?

This paper will report on the findings of a study for the Environment Agency that explores the evidence behind our understanding of weir pool environments including:

- the features that make weir pools ecologically important,
- the legislation that protects weir pools and their ecological features,
- changes in migration, spawning and predation as a result of changes to weir pool flow regimes,
- what methods exist for assessing the ecological significance of weir pools, and,
- what tools exist that can be used to assess the impact of altered flows on weir pool features.

This research and the tools developed have been used in the assessment of the hydraulic impacts of installing a fish pass and hydroelectric power (HEP) station on the river Shannon at Tarmonbarry. A 2D hydraulic model was used to assess the flow, velocity and shear stress patterns within the weir pool. This was led to a revised design of the fish pass and location of the HEP tail race being considered following consultation with Inland Fisheries Ireland.

## 05 - Technologies for monitoring and treating overflows from urban wastewater networks

**David Morgan**, L. Xiao, and A. McNabola (Trinity College Dublin)

### Abstract

In Ireland, the majority of urban areas are drained by combined sewer systems, which convey wastewater and stormwater in a single pipe. During rainfall events the capacity of the combined sewer system may be exceeded. A combined sewer overflow (CSO) is a structure designed to divert excess flows from the sewer network either directly, or via a storm sewer system, to the receiving water. The excess flows contain a mixture of raw sewage and storm water and are thus a source of high concentrations of biological oxygen demand, pathogens, nutrients and gross solids. CSO discharges have been recognised as a potential cause of receiving water impairments including beach closures, contamination of drinking water supplies, and reductions in chemical and ecological status. Overflows may also arise at sewer pumping stations due to mechanical or electrical failure. These failures are difficult to predict, and because the overflow may operate in dry weather, or to a small watercourse, their impact can be significant.

This study will review current and emerging technologies for overflow event monitoring and communication, including the application of low-cost sensors. An important output of the project will be a decision support tool which considers a number of factors, including the sensitivity of the receiving waters, in determining the level of monitoring provided. The decision tool will incorporate Irish CSO data collected under the Waste Water Discharge (Authorisation) Regulations. The study will also review international experience and best practice for CSO retrofit to ensure compliance with the Water Framework Directive and other relevant legislation.

## 06 - An Investigation of Groundwater Recharge Estimation Reliability at the Small Catchment Scale in Ireland

**Ahmed Nasr** and Paul Hynds (DIT)

### Abstract

The first national groundwater recharge map (GRM) for Ireland was developed in 2005 by the Eastern RBD and CDM, since when numerous amendments have been made via increased input data coverage, enhanced algorithms and improved recharge coefficient estimates (Hunter Williams, 2009; Misstear et al. 2009; GSI, 2011; Hunter-Williams et al., 2011). The overarching objective of the map is estimation of groundwater recharge to the deep groundwater system, thus enabling assessment of the impact of groundwater abstractions on catchment hydrodynamics and subsequent compliance with the Water Framework Directive. GRMs may also be used to assess and predict resource sustainability in the context of current and future meteorological conditions (Hunter-Williams et al., 2011). The maps have been derived from existing spatial hydrogeological and meteorological datasets; more specifically, development has been achieved via overlaying data layers pertaining to annual rainfall, annual estimated actual evapotranspiration, soil drainage, subsoil permeability, groundwater vulnerability, peat, sand/gravel aquifer, bedrock aquifer class. Guidelines outlined by the Irish Working Group on Groundwater have been used for interpretation.

Numerical groundwater models represent a useful tool for quantification of catchment and aquifer hydrodynamics, in addition to delineation of hydrologically distinct sub-catchments and source protection zones. Relevant examples include the Hydrologiska Byrans Vattenavdelning (HBV) model, the Nedbør-Afstrømnings model (NAM) and the Soil Moisture and Accounting Routing (SMAR) model. The primary driving force of these models is effective aquifer recharge estimation; accordingly, it is critical that recharge dynamics are thoroughly understood and accurately simulated. This is particularly important at the small catchment scale due to aggregate small catchment (or delineated sub-catchment) recharge typically providing a better estimate of total recharge for associated (adjacent or nested) large catchments than the use of a lumped approach to estimation.

The current paper investigates groundwater recharge prediction reliability at the small catchment scale, as characterized by a catchment area <30 km2 and relatively homogenous hydrogeological settings, via application of the current GRM. Estimated recharge from GRM at two hydrogeologically distinct small Irish catchments were compared with values from calibrated and validated HBV models developed for the same catchments. HBV models were calibrated and validated using daily values of rainfall, estimated evapotranspiration and river flows for the period 2001-2006. Results indicate that while the GRM provides a relatively accurate estimate of groundwater recharge at the large catchment scale, numerical modelling of small catchments resulted in higher recharge estimates than values from the GRM. Findings point to a potentially systematic underestimation of recharge values at small catchment scale when predicted by the GRM. Further work will seek to elucidate if this is indeed the case and, if so, the associated magnitude and catchment characteristics via inclusion of additional hydrologically and topographically diverse small Irish catchments, followed by analyses of a range of calibrated numerical models (HBV, NAM and SMART).

## 07 - Comparative Analysis of Multiple Baseflow Separation Methods in Four Small Irish Catchments

**Paul Hynds** and Ahmed Nasr (DIT)

### Abstract

In-depth evaluation of the hydrodynamic behaviour of small catchments in Ireland may be used to inform previous and existing research carried out in larger catchments including the Flood Studies Update (FSU) Programme and the development of HydroTool. A framework for catchment hydrodynamic analyses in Irish catchments has been developed (Archbold et al., 2010), and subsequently simplified to comprise (i) overland flow, (ii) interflow, (iii) shallow groundwater flow and and (iv) deep groundwater flow (O'Brien et al., 2013). Water flux between these pathways may be estimated by one of two approaches, namely hydrograph separation and numerical modelling.

In the current study, eight hydrograph separation techniques were employed in four hydrologically distinct small Irish catchments and compared with results of the *Hydrologiska Byrans Vattenavdelning* (HBV) conceptual model and physical catchment indicators. The following small benchmark catchments were selected and employed for analyses:

1. Ballygoly, Co Louth (Station 6030, Upland Rural, 10.4 km$^2$, Poorly Drained, Pl)
2. Frankfort, Co Dublin (Station 9011, Urban, 5.5 km$^2$, Made Ground, Pl)
3. Rochfort, Co Westmeath (Station 25034, Lowland Rural, 10.8 km$^2$, Well Drained, Ll)
4. Ballyhaunis, Co Mayo (Station 30020, Rural, 21.4 km$^2$, Peat/Well Drained, Rkc)

A suite of hydrological tools including FDC 2.1 and *BFI+ 3.0* (HydroOffice 2015), *BFI* (*Excel 2013*), *EcoHydRology* (R) and HBV Light were used to quantify small catchment water balance dynamics. In all, eight hydrograph separation techniques were applied for comparison with results of HBV modelling. It is important to note that baseflow separation results are typically employed to guide numerical model calibration, however, in the current study both approaches have been undertaken independently, with hydrological modelling representing a more data-driven approach.

As shown (Table), the range of estimated baseflow indices resulting from the application the various separation was significant, for example, within the primarily urban Frankfort catchment, an estimated range of 0.407 to 0.831 was encountered. As previously reported by Misstear *et al*. (2009), hydrograph separation frequently results in high baseflow estimates in the presence of indicators suggesting significantly lower groundwater contributions, which would seem to be the case in this catchment. Results indicate that the HBV model performs well in all rural catchments ($R_{eff} \geq 0.7$), with a low level of performance associated with the Frankfort catchment ($R_{eff} = 0.568$). Accordingly, it is considered that the conceptual structure of the HBV model may not be appropriately employed in urban catchments.

With respect to physical indicators (aquifer importance, soil drainage group), the simpler "interval-based" separation techniques (including the frequently employed IoH local minima technique) provided the most realistic results within catchments 25034 and 30020, while the Lyne & Hollick algorithm (BFLOW) also provided reasonable results within the Rochfort (25034) catchment. The IoH method and HBV modelling would seem to be most reasonable within the Ballygoly (6030) catchment. The interval-based separation approaches resulted in significantly higher baseflow estimates than recursive filtering techniques.

Results of hydrograph/baseflow separation methods and HBV modelling from selected small catchments

| Separation Meth. | 6030 | 9011 | 25034 | 30020 |
|---|---|---|---|---|
| Fixed Interval | 0.585 | 0.777 | 0.867 | 0.806 |
| Sliding Interval | 0.637 | 0.831 | 0.913 | 0.853 |
| Local Minima | 0.399 | 0.551 | 0.727 | 0.662 |
| 1 Parameter Al. | 0.507 | 0.500 | 0.531 | 0.526 |
| Boughton Al. | 0.507 | 0.500 | 0.531 | 0.526 |
| IHACRES | 0.474 | 0.488 | 0.542 | 0.547 |
| Chapman Al. | 0.581 | 0.498 | 0.517 | 0.509 |
| Lyne & Hollick | 0.381 | 0.430 | 0.730 | 0.530 |
| Exp. Smoothing | 0.401 | 0.407 | 0.608 | 0.541 |
| HBV | **0.361** | **0.741** | **0.811** | **0.742** |

## 08 - Water level fluctuations in some Southern African transboundary river basins derived from Envisat satellite altimetry

Luiz Guerreiro Lopes, **Débora Sousa**, Joecila Santos da Silva and Stéphane Calmant

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### Abstract

Mozambique is the downstream country of nine transboundary river basins of Southern Africa. The region is periodically affected by extreme hydrological events, such as floods in the central wet lowlands of Mozambique and droughts in the mountainous and low-lying dry areas. Although the regular monitoring of river basins is a fundamental requirement for the adequate transboundary water resources management, the major river basins in this region of Southern Africa are poorly gauged. Satellite radar altimetry, due to its regular spatial coverage and acceptable temporal frequency of measurements, can contribute to the monitoring of water levels of rivers and other inland water bodies with a few hundred or even only some tens of meters wide, providing observations in areas where data are scarce or unavailable. In this work, we present some results of a study of the water level fluctuations in some poorly gauged transboundary river basins of Southern Africa using satellite radar altimeter measurements. For this study, the hydrographic basins of the Pungwe, Buzi and Save rivers, in central Mozambique, were chosen. Water level time series were extracted from the reprocessed Envisat RA-2 GDR data from cycles 6 to 94 (June 2002 to October 2010) provided by the Centre for Topographic Studies of the Oceans and Hydrosphere (CTOH). The satellite-derived water level time series were constructed at virtual gauge stations defined in the intersections of the Envisat tracks with the main rivers studied and their major tributaries. The results obtained in this study confirm the potential of Envisat satellite radar altimetry in monitoring the temporal and spatial water level fluctuations in the poorly gauged Southern African river basins that were studied.

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