SPATIAL PLANNING AND HYDROLOGY AT DIFFERENT SCALES

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Introduction

The past 15 years has seen unprecedented development of Dublin and its environs. This paper explores the impact of this development upon the Liffey catchment and the issues confronting future water management. Both the macro scale (the Liffey catchment) and the micro scale (a specific locality along the course of the river) will be addressed.

White and Greer (2006) have suggested that the greatest flood threat to expanding urban centres at the macro scale comes from changes in the upper reaches of a catchment. The impacts of modifying the upper reaches will be felt within the entire hydrological system. When the vegetation, such as forest or grassland, is replaced with the impermeable materials of buildings and roads (Whiteford et al, 2001) the river itself will experience changes in its flow regime, with lower flows in summer as the base level diminishes and higher flows after precipitation as the transition time of the rain event to enter water-courses is reduced. Riparian ecology will also change in response to these greater hydrological fluctuations as well as the consequences of reduced bank stability (Hellmund and Somers Smith, 2006; White and Greer, 2006). Sediment to water ratio of the entire system may also occur bringing about changes in the fluvial structure and form. (Knighton, 1998).

Unplanned and localised modification of the river, particularly in the upper reaches can cause problems several magnitudes greater than the original localised alteration. In the1450's Venice had already recognised the dangers to the city arising from deforestation. The resultant increase in silt brought down by the rivers represented a threat to the Venetian Lagoon. The replanting of the woodland along the edges of flowing streams was her remedy (Grove, 1995). During the next century, in a time of increasing agricultural development of the Terrafirma (Venice's mainland territory), with its attendant drainage and irrigation schemes and the use of water power for milling, planning permission was not granted for river modification until it could be proved that the economic benefits of the changes were five times greater than the damage it would cause (Cosgrove, 1993). Thus including the impacts that any river modifications would have on the river system within planning.
Now as then important for spatial planning is the necessity to examine the river in its entirety and plan at the macro scale and to understand the large scale implications of local interventions.

MOLAND and the MACROSCALE

Expanding cities are a global occurrence as populations grow and agriculture becomes less economically viable at a small scale. Schneider and Woodcock (2008) conducted a study on 25 cities in various geographical and economic areas around the world. Results show that all cities are growing, though not all at the same rate. They deduced that there are four different patterns of growth "*expansive growth, frantic-growth, high-growth and low-growth cities*" (Schneider and Woodcock, 2008). Dublin would appear to be an area of *high growth* as the majority of the development is at the fringes of the city. It is critical to the preservation of fresh water and of flood risk prediction and prevention that the spatial distribution of the growth of cities be understood.
In order to make informed decisions about future hydrology policies for expanding cities, it is crucial to determine where change to the landscape is likely to occur. Some insights may be offered by MOLAND, a raster-based predictive model that maps land-use change at the macro scale. The changes that are predicted to occur are implemented pixel by pixel giving a resolution of 1ha for urban areas and 3ha for non-urban areas.

Whether a pixel changes is largely dictated by the neighborhood effect corresponding to one of the earliest assertions in geography, "*Everything is related to everything else, but near things are more*

related than distant things" (Tobler, 1970). The predictions are based on actual land-use change from 2000 - 2006 (Engelen et al, 2004) A simulation was run using moderate population change (see Engelen et al (2004) for further details). yielding two output maps, one each for 2013 and 2026 (figure 1 shows the output for 2026).

There are 24 classifications. Four types of urban environment that are considered relevant to this research are: continuous dense urban fabric, continuous medium dense urban fabric, discontinuous urban fabric, and discontinuous sparse dense urban fabric (the various shades of pink). These types are considered the biggest threat to the form of the river system as they are set to grow fastest and cover the largest area. Those likely to have the biggest impact on the quality of the river water are the classifications shaded in green: industrial, commercial, roads and rail networks and associated lands, public and private services, and mines and dumps.

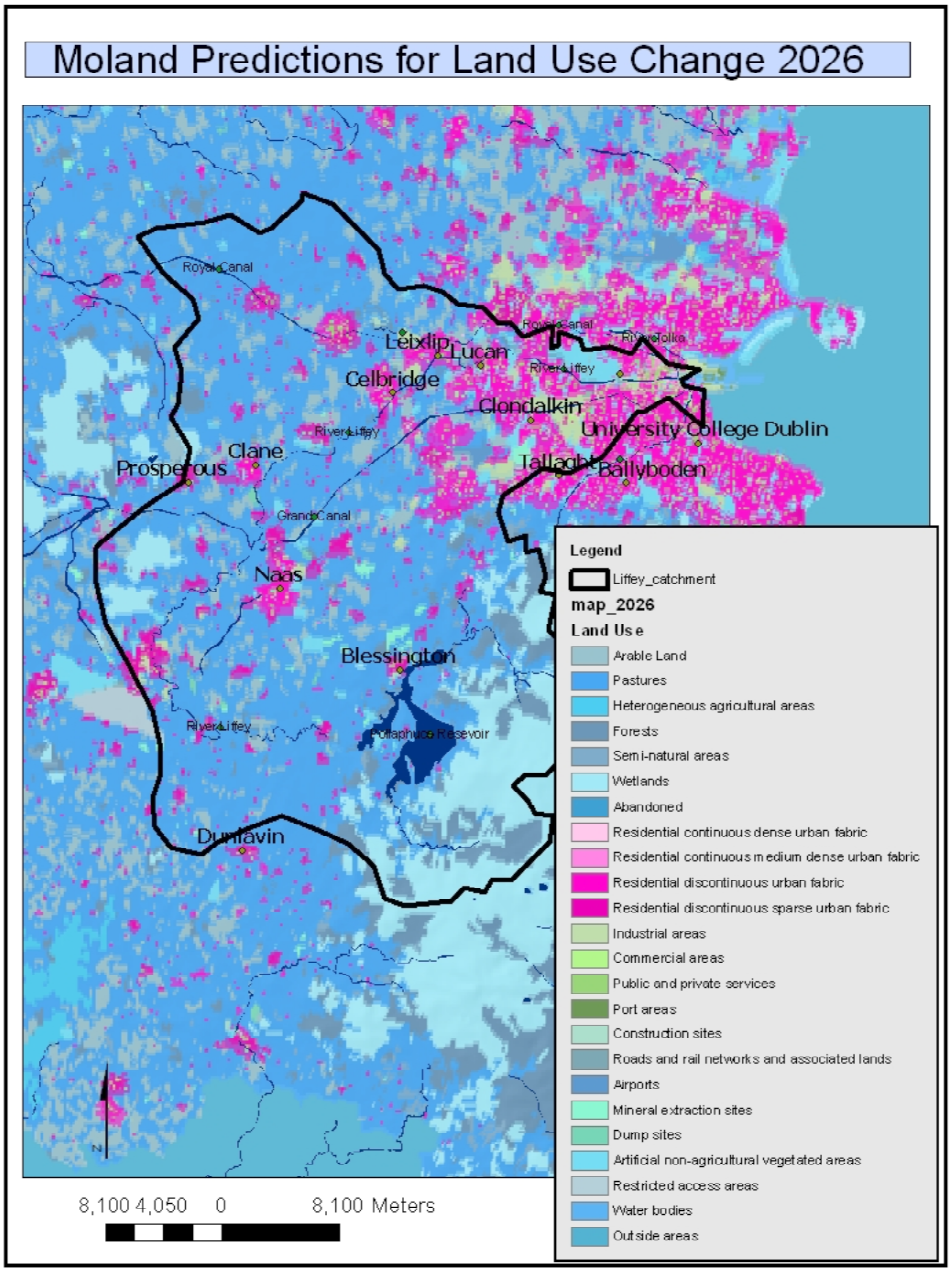

Figure 1 MOLAND predictions of land use change in 2026

Water is *both a vein and artery* (Schneider et al, 1973) to urbanised societies. Fresh water is required for the basic functions of drinking or cleaning. It is brought to specific locations for these purposes and at the same time water is required to dispose of waste. Yet the nature of urban environments frustrates these demands. The majority of surfaces within a city are sealed preventing the infiltration to groundwater and aquifers, and increasing the possibility of flood that may endangering the quality of the water supply.
Furthermore there are additional behavioural changes arising from lifestyle choices and fashions. Although small in scale and localised they can have significant cumulative effects. An example of this is the current trend of having paved driveways for second cars and lower maintenance gardens employing impervious or semi-impervious membranes for weed suppression.
Outputs from MOLAND suggest, that there is little cause for concern at the macro scale. There is no significant disruption along the headwaters of the Liffey that would cause the flooding issues, as the figures show the growth is along the fringes of the predefined suburbs, areas that have already been developed. However, at these points of urban growth and densification, localised or small-scale flooding may occur with greater intensity and frequency. Such events have occurred recently possibly resulting from disruption to smaller watercourses in the catchment area.

In addition, climate change is going to increase the intensity and frequency of floods in Ireland (Dunne et al, 2008). Warmer oceans mean that storm events are going to become more intense as they cross the Atlantic (IPCC, 2007). In addition to this, the warmer atmosphere allows it to hold more water vapour, leading to an increase in mean precipitation over Western Europe (Barry and Chorley, 1998; IPCC, 2007) and in particular Ireland (Dunne, 2008). Dunne et al (2008) simulated rainfall from the climate predictions in several catchments in Ireland. Their results demonstrated that there is over amplification of seasonal cycle. Also the changes in winter precipitation will mean that stream flows will increase by 20% between October and April by 2060.

Thus, on the fringes around Dublin there is a great threat of both flooding and lower base levels due to a warming climate and surface sealing. It is therefore imperative to examine the local landscape and examine the pre-existing drainage systems that currently are operating and look at means of improving this to cope with changing climates and surfaces.

THE MICRO-SCALE

The river Liffey in the Celbridge area in Co Kildare as elsewhere was subjected to control and management for productivity and pleasure. Its current form and the remnants of cultural, agricultural and industrial activities bare witness to a long and layered history. On its banks lay the remains of tower houses, churches, monasteries, mills, and pleasure grounds and gardens, and to the north and south agriculture and silviculture activities demanded drainage and water control.

Adjacent to the town of Celbridge a number of designed landscapes of large and small demesnes border the Liffey. Within the demesnes the waters of small tributaries have been manipulated and managed over centuries for function and amenity. The lands have been subjected also drainage to maximise productivity either for grasslands or silviculture. In the eighteenth century, Emily, Duchess of Leinster, neighbour and sister to Louisa Conolly, writes that Castletown wood *is worth a million to people who live here in winter, besides the beauty of it in the summer, for to have so charming a walk or ride where no winds come nor wet underfoot is delightful*.

Since the decline and fragmentation of these demesnes this coherent management has been disrupted and fragmented. Within the low-lying agricultural land to the north and south of these demesnes, fields are often bounded by drainage ditches whose waters augment the flow in natural courses which themselves are manipulated and redirected and sometimes divided to produce multiple streams leading through the demesnes. Within the demesnes they are then managed both for function and to create ornamental water features. The overall result is not a dendritic flow system but a network. The network allows for a set of alternative routes for flow and, because of the flatness of the terrain, under certain circumstances there may be reversal of flow within a given channel. This produces a system

with redundancy and inherent water retention capacity that we might expect to give greater flexibility to deal with inputs at different parts of the local catchment and local blockages.

Taking the example of the Castletown demesne, the extant watercourses and drainage system are plotted from historic maps and surveys and from fieldwork investigations. Figure 2 shows extant watercourses. Many of these are also fed by land-drains of varying form and construction. The demesne has a network of ha-has. A ha-ha is a sunken fence that created a barrier to animals while allowing unobstructed views out over the parkland. It consists of a ditch, one side of which there is a vertical masonry retaining wall. The main house, the largest neo-Palladian eighteenth-century house in Ireland, is in effect, encircled by a ha-ha. This serves in part along with land-drains from the enclosed area to protect the basements of the house from flooding in this landscape with a high water table.

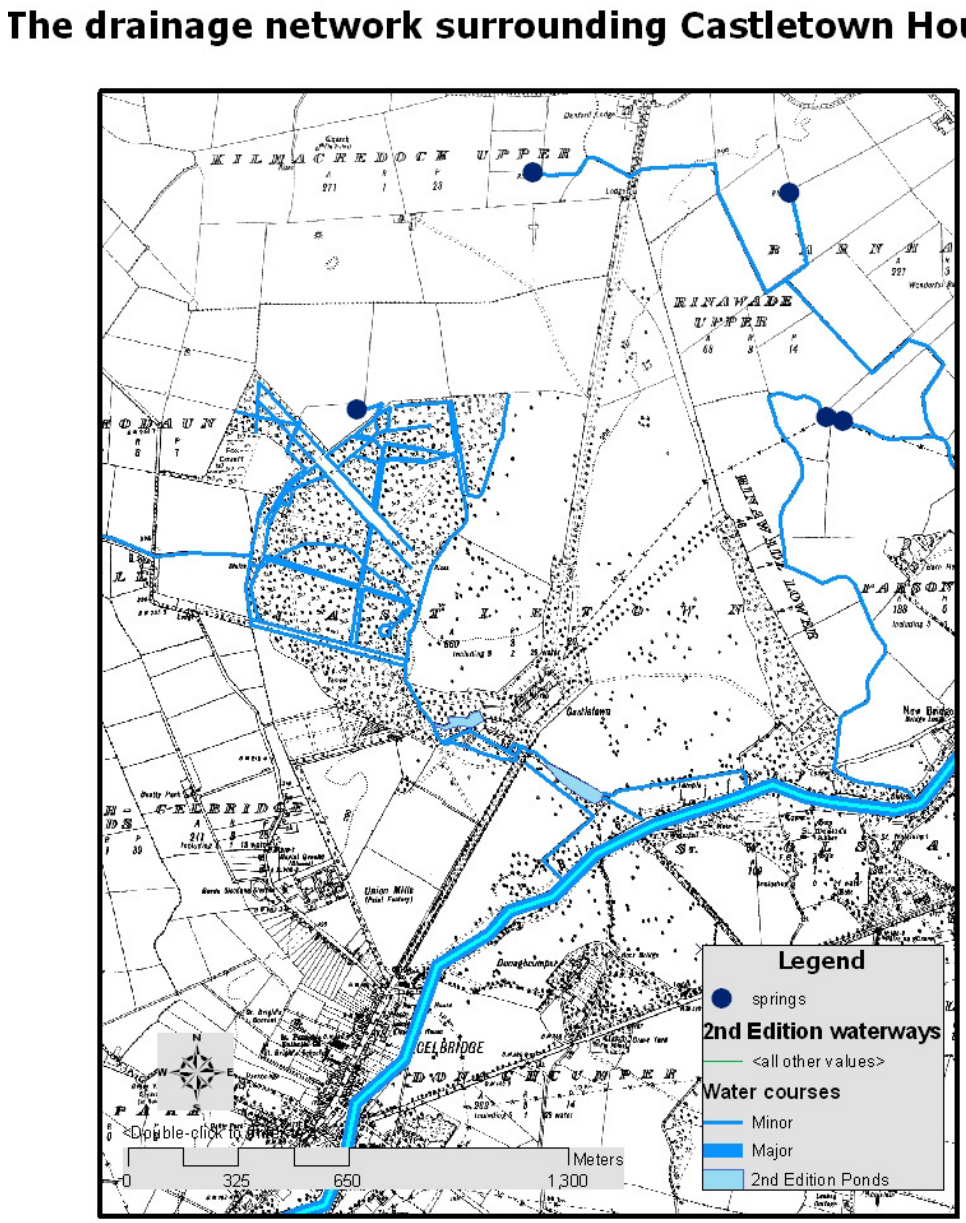

Figure 2: The drainage network surrounding Castletown House

The lands of this demesne, like those of others along the Liffey have entered periods of decline and neglect and have changed their uses. At Castletown, the majority of the woodland was acquired by Coillte and turned over to commercial forestry. The network of drainage and watercourses has been disrupted and fragmented through neglect and by damage arising from forestry operations. A significant area of the plantation has failed, apparently due to waterlogged conditions. Furthermore, in the recent past, neglect of maintenance of the drainage network has led to surface-water flooding on the back lawn and threatened Castletown house and its outbuildings.(**Figure 3**)

In addition, over recent decades, development for housing of the walled garden and lands adjacent to the woodlands has again changed the hydrological balance within the catchment of the stream that flows through the demesne - replacing the land materials with hard landscape.

Figure 3

Current research is underway to investigate the performance of a network structure of drainage and watercourses in comparison to that expected from dendritic forms. Simulation is being used to test the network's sensitivity to inputs from precipitation events in order to reveal the rates of flow and the retention capacity. In addition the consequences of disruption and fragmentation of the network is being sought.

DISCUSSION

Within the demesne at Castletown, water was also used for ornamental features of reflecting ponds and cascades. The lower pond between the Celbridge Avenue and the Liffey was also used as a fishpond.(Figure 3) This feature was provided with a bypass watercourse using the ha-ha. This would have facilitated the management of the pond and also deal with exceptional volumes of water entering from the feeding stream so as not to allow the flushing through of the fishpond to the degree that will lead to the loss of fish. Such a structure has within it the potential to be adapted to current planning demands for the management of run-off from new development, providing the necessary retention, sedimentation and isolation tanks and to provide bypasses to deal with 100-year events. Minor design adjustments are obviously required to satisfy segregation to allow removal of pollutants before returning water to the freshwater channels.

Figure 4

It is of importance to identify historic water-management systems operating within areas of proposed development. Their mode of operation should be established and their potential for revival and incorporation into hybrid systems can be pursued. In addition existing matrix of watercourses are importance to ecological networks. This needs to be acknowledged and respected in order to promoted biodiversity. Currently, as part of multidisciplinary research at Castletown, a detailed ecological survey of the demesne is being carried out and the existence of ecological corridors and networks is being assessed.

At Castletown and elsewhere, traditional systems of water management form part of the cultural heritage of these designed landscapes. They survive today even if fragmentary in nature and form part of the existing functioning hydrological landscape. Within the demesne designs, water was an element manipulated for aesthetic purposes to enliven the landscape. These features continue to function today and are recognised for their amenity value. The designed landscape of Castletown and the centrality of the grand eighteenth century house are undergoing restoration both as a tourism focus as well as a

continuing amenity for the local community. The water features on the demesne are an integral and prime heritage asset and their continuity is dependent on the overall hydrology of the area.
Finally we may look to the logic of the historic hydrological systems to seek alternatives to water management strategies that function effectively and contribute to the aesthetic enjoyment of the landscape.

Bibliography

Barry, R. G. and Chorley, R. J. (1998) Atmosphere, Weather and Climate - seventh edition, Routledge, Great Britain

Cosgrove, D., (1993) The Palladian Landscape: *Geographical Change and its Cultural Representation in Sixteenth Century Italy* pp 286 Leicester University Press

Dunne S., Hanafin J., Lynch P., Mc Grath R., Nishimura E., Nolan P., Ratnam J. V., Semmler T., Sweeney C., Wang S., (2008) *Ireland in a Warmer World, Scientific Predictions of the Irish Climate in the Twenty- First Century*. National Development Plan, Dublin.

Engelen, G., White, R. & Uljee, I. (2004) *The MOLAND for Urban and Regional Growth*. RIKS (reserach instituut voor kennissysyemen bv), Maastrict.

Grove, R.H., Green Imperialism, p.27 Cambridge University Press

Knebl, M.R. et al. (2005) Regional scale flood modeling using NEXRAD rainfall, GIS, and HEC-HMS/RAS: a case study for the San Antonio River Basin Summer 2002 storm event. *Journal of Environmental Management*, **75**, 325-336.

Pistocchi, A. & Mazzoli, P (2002) Use of HEC-RAS and HEC-HMS models with ArcView for hydrologic risk management. *Proceedings from iEMSs conference 2002*, 6.

SCHNEIDER, W.J.R.I.C.K.E.R.T., DA SPIEKER, AM (1973) Role of water in Urban Planning. *GEOLOGICAL SURVEY CIRCULAR 601-H,*

Schnieder, A. & Woodcock, C.E. (2008), Compact, Dispersed, Fragmented, Extensive? A Comparison of Urban Growth in Twenty-five Global Cities using Remotely Sensed Data, Pattern Metrics and Census Information. *Urban Studies*, **45**, 659-692.

Uhel, R. (2006) Urban Sprawl in Europe - the ignored challenge. *EEA Report No 10/2006*,

UN. (2005) *United Nations Statistical Yearbook(49th issue)*. United Nations Publication, New York.

White, M. D. and Greer K. A. (2006) *the effects of the watershed urbanization on the steam hydrology and riparian vegetation of Los Peñasquitos Creek, California,* Landscape ad urban planning (74_ pp 125 – 138 Elsevier

Whitford, V., Ennos, A.R., Handley, J. F. (2001) *City form and natural processes – indicators for their ecological performance of urban areas and their application to the Merseyside, UK,* Landscape and Urban Planning 56 pp 91 – 103, Elsevier