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Classification and assessment of water bodies as adaptive structural measures for flood risk management planning

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ABSTRACT

Severe rainfall events have become increasingly common in Europe. Flood defence engineering works are highly capital intensive and can be limited by land availability, leaving land and communities exposed to repeated flooding. Any adaptive drainage structure must have engineered inlets and outlets that control the water level and the rate of release. In Scotland, there are a relatively high number of drinking water reservoirs (operated by Scottish Water), which fall within this defined category and could contribute to flood management control. Reducing the rate of runoff from the upper reaches of a catchment will reduce the volume and peak flows of flood events downstream, thus allowing flood defences to be reduced in size, decreasing the corresponding capital costs. A database of retention basins with flood control potential has been developed for Scotland. The research shows that the majority of small and former drinking water reservoirs are kept full and their spillways are continuously in operation. Utilising some of the available capacity to contribute to flood control could reduce the costs of complying with the EU Flood Directive. Furthermore, the application of a previously developed classification model for Baden in Germany for the Scottish data set showed a lower diversity for basins in Scotland due to less developed infrastructure. The principle value of this approach is a clear and unambiguous categorisation, based on standard variables, which can help to promote communication and understanding between stakeholders.

1. Introduction

1.1. Background and flood risk management

The most recent climate change projections for the United Kingdom for 2080 indicate a 10–20% increase in winter precipitation for the east coast and a corresponding increase of between 10% and 30% for the west coast (Department of Food and Rural Affairs, 2009). Applying these estimates to current United Kingdom rainfall patterns, a potential increase in precipitation of between 40 and 160 mm per annum for the east coast and between 285 and 1200 mm for the west coast of Scotland can be predicted based on the data provided by the Meteorological Office (2007). Moreover, the remaining regions of the United Kingdom are expected to face similar changes and challenges (Department of Food and Rural Affairs, 2009). The United Kingdom government has recognized the adverse impacts of flooding as a policy priority and has therefore doubled its flood defence spending since 1997 (Department of Food and Rural Affairs, 2009).

Reflecting on the current policy in the United Kingdom and other European Union member states, the European Union has introduced the Flood Directive 2007/60 EC (European Union, 2007), which requires each member state to develop flood risk management plans. The concept of sustainability has only recently been applied to flood defences and this implies that the use of all available infrastructure and resources contribute towards this process for societies gain (Shih and Nicholls, 2007).

Environmental classification and assessment required by this directive is a resource intensive process requiring additional expert staff and laboratory facilities. Flood risk management is often an equally resource intensive process; for example, the development of detailed flood risk maps available to the public on a user-friendly geographical information system is costly (Scottish Environment Protection Agency, 2009). It follows that a new rapid assessment methodology supporting the work associated with the directive would help to reduce costs.

A logical assessment system to classify and assess flood defence structures, which includes consideration of their sustainability, is of value for the flood risk management process. A standard classification system providing definitions and examples for all SFRB types, which is based on clear and relevant

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characterisation variables, will support communication between stakeholders including practitioners and the general public (Scholz and Sadowski, 2009). To be widely accepted, such a system should allow for rapid screening of existing infrastructure and should ideally be neither labour nor resource intensive. The classification of Sustainable Flood Retention Basins (SFRB) to optimize flood control is a novel approach addressing this problem.

A SFRB is defined as an impoundment or integrated wetland, which has a predefined or potential role in flood defence and diffuse pollution control that can be accomplished cost effectively through best management practice, supporting sustainable flood risk management and enhancing sustainable drainage, pollution reduction, biodiversity, green space and recreational opportunities for society. The word sustainable in SFRB means capable of being maintained at a steady level without exhausting natural resources, harming the environment and causing severe ecological damage. Moreover, the use of natural impoundments such as lakes and reservoirs for flood control purposes reduces costs, because less flood retention basins and sustainable drainage systems would need to be built, and the combined sewage system would receive less runoff requiring storage and subsequent treatment.

The SFRB methodology moves away from traditional engineering solutions, which rely predominantly on hard engineering control variables, towards soft variables (Scholz, 2007). This approach readily lends itself to solving multi-disciplinary challenges.

1.2. Traditional and adaptive structural measures and their classification

There are a wide range of traditional engineering solutions, which can be applied to provide flood defences in urban and rural areas. These traditional approaches predominately use hard engineering solutions such as barriers and dykes to protect the public from the economic and social costs of flooding (Kendrick, 1988). More recently, sustainable drainage systems, which generally operate by absorbing water and slowing the rate of runoff from urban areas, are used in Europe. Sustainable drainage systems can also assist in diffuse pollution control by providing large surface areas for biochemical reactions to take place and retaining the first foul flush of pollutants released during significant rainfall events (ATV-DVWK, 2001; Scholz, 2006).

Most natural and constructed retention basins retain runoff for subsequent release, thus reducing downstream flooding problems. Some basins such as wetlands perform other tangible, albeit less ‘visible’ roles, including diffuse pollution control and infiltration of treated runoff, promoting groundwater recharge. The diversity of retention basin types is therefore high and further complicated by often multiple and competing functions that these structures fulfil.

A classification system is therefore beneficial in allowing clear communication between stakeholders such as politicians, planners, public interest groups, engineers and environmental scientists. The absence of a universal classification scheme for retention basins results in potential confusion about the status of individual structures and their functions. This can lead to conflicts between stakeholders concerning the management of retention basins including wetlands as discussed by Scholz and Sadowski (2009) who therefore proposed a conceptual classification model based on 141 SFRB located in the River Rhine Valley, Baden, Germany. Six SFRB types were defined based on the expert judgment of engineers, scientists and environmentalists.

The European Union has acknowledged that member states may face significant challenges in complying with the flood directive. Therefore, member states have financed programs such as the Strategic Alliance for Water Management Actions (2009) to develop guidance on adaptive measures such as SFRB to assist the member states in developing flood risk management plans.

1.3. Aim and key objectives

The aim of this research paper is to characterise types (i.e. subclasses) for SFRB in Scotland with the help of a revised rapid conceptual classification model, originally proposed by Scholz and Sadowski (2009). The key objectives are as follows:

- to aid stakeholder communication by avoiding misunderstandings with respect to planning and legal matters concerning the purpose of different Scottish SFRB types;
- to determine and characterise all relevant and particularly the key independent classification variables using a principal component analysis (PCA) and a sensitivity analysis using the Wilcoxon test;
- to develop a conceptual classification methodology with the support of a large and detailed example case study data set;
- to compare the Scottish with the German data set (Scholz and Sadowski, 2009) to verify the validity of the methodology and to improve the research approach; and
- to illustrate and discuss examples of the most dominant Scottish SFRB types that are also highly relevant for water and environmental engineers, and landscape planners.

2. Methodology

2.1. Overview of the methodology

Previous work by Scholz and Sadowski (2009) has established a draft classification system for SFRB based on a database of approximately 180 sites in Baden. A revised version of this method has been applied to a wide range of 167 water bodies in the wider central Scotland region. The database combines engineering features with landscape and catchment attributes to produce a holistic classification.

A mathematically sound methodology has been developed to justify the very concept of classifying SFRB. Six SFRB subclasses were defined based on expert judgment provided by groups of British, German, Swedish, French, Irish and American professional engineers, scientists, environmentalists, and landscape and urban planners during informal consultation workshops held in Germany (2006) and Scotland (2007 and 2009).

Moreover, a set of water body characterisation parameters that relate to real SFRB were required and these had to capture the multi-national groups' conceptual classification. The variables were obtained during informal brain storming and consultation sessions and compared with those obtained via a previous literature review (Scholz, 2007) and site visits in Germany, UK, Sweden, Ireland and Denmark held between 2006 and 2010. These parameters have been named ‘classification variables’ and are intended to be a reasonable compromise between the accuracy and rapidity required in their assessment.

The methodology also makes use of two powerful statistical techniques, notably cluster analysis and PCA. The latter can help to discover the relationships between variables and identify the most important variables. The cluster analysis involves the forceful grouping of the results of the classification surveys of all SFRB into distinct clusters. Then, based on the clustered groups and expert judgment, it is possible to identify which cluster relates best to which SFRB definition.