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Natural Flood Management - Beyond the evidence debate

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Abstract:	Globally flood frequency has increased over the last three decades. Natural Flood Management (NFM) is considered a progressive holistic flood management approach, using 'natural' hydrological processes to slow and store water, delivering multiple benefits including water quality, biodiversity and amenity improvements. Although there are existing evaluations of NFM, they remain insufficient for drawing conclusions as to its effectiveness at catchment scales. However, without this evidence base and because of the domination of the natural sciences in the framing and research agenda catchment wide interventions have not been implemented. In acknowledging the importance of understanding and data gaps (and attempts to fill them), this paper argues that there is an opportunity to deliver NFM more widely by capitalising on widespread interest in different land and water management sectors, supported by interdisciplinary policy relevant research. This paper illustrates how multi-stakeholder collaborative partnership is suited to the dynamic complexity of NFM delivery. It is proposed that, through championing NFM delivery at catchment scales and the work of established catchment partnerships in England and Wales, there is the opportunity to more widely deliver NFM as an integrated component of flood risk management.

Natural Flood Management: An introduction

Globally flood frequency has increased over the last three decades (Kundzewicz et al., 2014). Annual flood losses in the European Union are projected to be c. €23.5 billion by 2050, increased from €4.9 billion between 2000-2012 (Jongman et al., 2014). Traditional flood protection methods of large engineered structures are costly to construct, expensive to maintain and linked to poor water and ecological quality (Collentine & Futter, 2016; Thorne, 2014). Policy makers and scientists are increasingly interested in natural landscape retention and storage capacity as a complementary flood risk technique (Ran & Nedovic-Budic, 2016) used alongside traditional hard engineering flood defence approaches (Pitt, 2008; Rouillard et al., 2013; Waylen et al., 2017). However, this move towards more holistic catchment flood management and natural flood water retention has been hindered by a lack of policy relevant research with a diversity of disciplinary inputs from both the physical and human geography traditions. Given the complexity of working at reach to landscape scales and across water and land management sectors, effective decision making requires an integrated approach, rather than fragmentation and compartmentalisation, as such the Geography discipline is well situated to support and develop more holistic approaches to catchment flood management. Several high profile Natural Flood Management (NFM) projects have been constructed in the UK, such as Belford (Barber & Quinn, 2012), Pickering (Nisbet et al., 2011) and Holnicote (National Trust, 2015). Nevertheless, despite over a decade of government policy support (Barlow et al., 2014; DEFRA, 2004; Environment Food and Rural Affairs Committee, 2016; Evans et al., 2004), NFM has still not been a widely adopted as a flood risk management strategy.

NFM harnesses *natural* hydrological processes to slow water flowing through the landscape, thereby mimicking natural environmental conditions, aspects often lost within traditional flood risk management (FRM) paradigms of moving water rapidly through the system (Werritty, 2006). The technical challenge involves an awareness of erosion, sediment transfer and water storage alongside managing biological inputs, such as, plant growth and nutrient cycling in multiple locations within catchments (Beechie et al., 2010; Hooke, 2015). NFM is linked to improved biodiversity (Cook et al., 2016), water quality (Barber & Quinn, 2012; Howe & White, 2003) and public health and well-being (de Bell et al., 2017; Maas, 2006; Postnote, 2016); a feature referred to within regulatory and practitioner communities as delivering multiple benefits (Barlow et al., 2014; Forbes et al., 2015).

An agreed model of defining principles concerning NFM does not exist, either from a European or UK perspective. Disagreement on the essential properties of NFM can be found in legislative positioning. In contrast to England and Wales, the concept of NFM in Scotland is enshrined in law in the Flood Risk Management (Scotland) Act, Section 20(1) (4) b, with delivery focused on natural features and their contribution to FRM. In England, 36% of water bodies are classed as heavily modified, compared to 14% in Scotland (FOI request SEPA June 2017), resulting in a greater emphasis on incorporating engineered structures into NFM delivery. 'Working with Natural Processes' (WWNP) has become the favoured term of regulatory authorities in England (Barlow et al., 2014), but lacks clarity resulting from its interchangeable use with NFM (Burgess-Gamble et al., 2017). WWNP is described as emulating natural regulatory functions and applies to any method harnessing hydrological processes within the water cycle, including engineered land forms. WWNP or NFM employs a wide range of techniques applied in diverse settings and across different catchments types, which vary both spatially and temporally (Figure 1). In this paper the broader definition will be used and referred to as NFM. The action of working with the water cycle to increase resilience of the system is taken as the foundation of the NFM paradigm.

Figure 1. Catchment wide NFM interventions categorised as the initial step in the hydrological cycle – Interception: A1 bunded ditches, A2 vegetative cover, A3 green roofs and walls, A4 interception ponds, A5 managed realignment, A6 rain gardens, A7 restoring peatlands, A8 swales, A9 beach nourishment, A10 habitat promotion, A11 reef creation **Infiltration:** B1 woodlands , B2 filter/buffer strips, B3 hedgerows, B4 managing soil quality, B5 no and low till agriculture, B6 permeable paving, B7 reduced stocking density **Water storage:** C1 ponds, C2 rainwater harvesting, C3 reservoirs, C4 wetlands and reed beds **Channel flow:** D1 de-culverting, D2 increase channel roughness, D3 regulated washlands, D4 remeandering, D5 restore functioning floodplain, D6 setting back flood defences, D7 woody material dams D8 species reintroduction (e.g. beavers). Each intervention uses a number of hydrological processes to slow the flow of water for example interception, infiltration and water storage in wetlands and surrounding vegetative cover will result in reduced surface run-off.

Evidence

One of the factors purported to be behind limited adoption of NFM is lack of evidence of its efficacy (Dadson et al., 2017; Spray et al., 2009; Waylen et al., 2017). Dadson *et al*. (2016) cite a lack of demonstrable effects beyond small-scale local benefits, observing that an absence of evidence exists of interventions tested at large-scales. Difficulties in translating findings between sites/catchments are compounded by the inherent low frequency of flood events, with each flood characterised by a number of variables. As such, gathering sufficient data to draw statistically robust conclusions at catchment scales may take decades, or be unachievable (Pattison & Lane, 2012).

FRM investment is informed by risk based predictive modelling (Woodward et al., 2009), that quantifies current and future risk (Environment Agency, 2016b). Multiple sources of flooding – fluvial, pluvial, coastal and groundwater – are often analysed in isolation when, in reality, they act in combination. Hydrological response is determined by spatial processes e.g. land use, geology, vegetation, urban drainage capacity and structures and temporal processes of antecedent conditions and rainfall event sequencing (Miller et al., 2014). The physical processes a model represents - whether statistical, conceptual or physically based – are simplified system representations, requiring at times, ill-fitting simplified generalised parameters (Redfern et al., 2016). The level of complexity e.g. data requirements, computational power, model parameters and functions, rapidly escalates as catchment features and interactions are combined to create increasingly realistic replications of catchment process and responses (Mcintyre & Thorne, 2013; Metcalfe et al., 2017). Therefore, catchment size becomes important. As NFM is an *integrated* system of local interventions performed at varying scales, predictive methods need to move between field and catchment scales. The data inputs required when mapping or modelling catchment processes are influenced by required output scales, but also consideration of the efficiency of integrating spatial data (Medcalf, *et al.* 2014). Methodologically, it is difficult to demonstrate any single individual NFM interventions contribution to flood risk, as hydrograph changes may be hard to detect at short temporal or above local scales (Metcalfe et al., 2017). This makes separating causal factors from natural or human induced catchment or meteorological changes challenging.

The influence of computational limitations to modelling are creeping into NFM practitioner guidance; demonstrated with the recommendation that suitability is limited to small catchments in rural headwaters of ≤10km^2 (Environment Agency, 2016a; National Trust, 2015; Westcountry Rivers Trust, 2014). The overriding factor leading to a focus on small catchments alone comes from a need to demonstrate a measurable benefit to flood risk reduction through, monitoring, hydrological modelling or a cost-benefit analysis. As such, guidance is not leading practitioners to understand the catchment *as a system*, or to increase resilience by building capacity into the landscape and maintaining desirable hydrological regimes (Liao, 2012).

The risk, in delaying adoption of catchment wide NFM until ‘sufficient’ empirical evidence exists means the full potential of NFM will not be realised and its application as a technique in FRM will remain ‘*ad hoc*’. This paper argues - given longstanding interest from policy makers and practitioners, and consensus around delivery of multiple benefits - research and resources should be expanded beyond a principles, evidence and efficacy debate to mechanisms of NFM delivery. The natural sciences dominate NFM research literature, with limited social science analysis. It is against this backdrop, of translating policy into practice, that a review of sectors relevant to NFM delivery is undertaken with the aim of understanding their roles and interactions and the strength and weaknesses of associated policy objectives. Rather than viewing NFM as a unique environmental management challenge, synergies with other water management frameworks have been investigated, particularly those with links to relevant sectors, with the aim of identifying existing forums that can be utilised to encourage wider delivery.

Who should contribute to the delivery of NFM?

UK water management and regulation is divided amongst different organisations into functional elements of water quality, quantity, freshwater ecology, hydro-power and recreational activities, resulting in fragmented regulatory and administration duties (Howarth, 2017). NFM as a flood management technique could be assumed to be an exclusive concern of the Flood and Coastal Risk Management (FCRM) sector, however, as NFM requires multiple interventions across the landscape (Figure 1), a range of land uses and stakeholders are essential in delivery. The chief sectors are: urban planning and development (Ellis, 2013), FCRM (Thorne, 2014), water supply (Kidd & Shaw, 2007), agriculture and nature conservation (Acreman & Holden, 2013; Howe & White, 2003). These sectors need to interact cooperatively, but effective large scale change usually requires collaboration and coordination, the scale of which can be evaluated through shared policy objectives, planning and delivery mechanisms (Robins et al., 2017).

The principal aspiration of the Department for Communities and Local Government is to increase housing supply (DCLG, 2016), conversely the Environment Agency aims to reduce flood and coastal erosion risk (Environment Agency, 2015). Inevitably this can place the two organisations in opposing perspectives, as development sites are often on floodplains adjacent to watercourses. The continued expansion of floodplain developments to build new homes (CCC, 2012) results in an increasing number of properties at risk, which the Environment Agency must assess for protection. Planning authorities must take the probability of flooding into account when determining applications, therefore all planning applications within a designated flood zone or area with critical drainage problems must also include a flood risk assessment. Nevertheless, construction has grown in areas of high flood risk at a rate of 1.2% since 2011 (CCC, 2015). If the planning system was employed to designate, protect and reinstate functional floodplains fewer homes would require flood protection, reducing downstream flood risk, and communities could enjoy the multiple benefits provided by green spaces.

The sewer network is probably the most familiar, yet overlooked, rain water management system. In the UK, private water companies manage the majority of the sewer network (Blackburn et al., 2017).

By employing NFM measures in developments, such as swales, basins, ponds and wetlands, volumes of water entering the sewerage system and its associated costs can be reduced (Stevens & Ogunyoye, 2012). In this context NFM techniques are most commonly referred to as SuDS (Sustainable Drainage Systems) (Figure 1: Interventions A3, A4, A6, A8, B6, C2). Water companies are supportive of making changes to the drainage infrastructure necessary to employ SuDS more widely (Lieberherr & Truffer, 2015; Water UK, 2015). Initially, the *Flood and Water Management Act* 2010 was to drive this change and make SuDs a legal requirement in new developments (Walker et al., 2011). However, the government maintained existing arrangements through the planning system and introduced non-statutory technical standards instead, which removed reference to improved water quality, biodiversity or access to green space. Currently SuDs are an expectation rather than a legal requirement for developments of 10 properties or more (Lewis, 2014). The implementation of Schedule 3 of the *Flood and Water Management Act* 2010 can be considered a missed opportunity for SuDS delivery and unlikely to deliver the desired change. A survey in 2014 showed only a quarter of planning applications specified the inclusion of any SuDS measures (CCC, 2014). Rather than regulatory measures encouraging collaborative working, current policy relies on developers to act voluntarily, causing water companies to publicly express discomfort, whilst distancing themselves from implementation (CIWEM., 2017; Water UK, 2015). If SuDS were a statutory requirement in new developments, there would be an opportunity to deliver their multiple benefits (Walker et al., 2011). Furthermore, the adoption of national SuDS standards, would facilitate the incorporation of interventions into existing integrated sewer networks, permitting it to function as one integrated system (Jones & Macdonald, 2007).

Responding to growing evidence of freshwater habitat degradation and impacts on communities and livelihoods, principles were developed, for a co-ordinated approach to manage water and land as one system, ensuring equitable availability and sustainable use; providing the basis for the international movement of Integrated Water Resource Management (IWRM) (Calder 2005). In Europe IWRM translated into legislation through the *Water Framework Directive* (Directive 2000/60/EC) (WFD) and river basin planning (Rahaman et al., 2004; Richter et al., 2013); followed seven years later by the *EU Floods Directive* (FD) (2007/60/EC). The EU Environment Ministers agreed that member states should "*maximise the synergies*" through integrated approaches to directive delivery (Neuhold, 2014) aligning objectives through the planning instruments of River Basin Management Plans (RBMP) and Flood Risk Management Plans (FRMP); which use the same geographical boundaries and share similar 6-year planning cycles (Environment Agency 2015). With clear targets for improving the ecological status of waterbodies, the delivery of WFD has been the sole focus of RBMP, but the scope to do more has always existed (Robins et al., 2017); in contrast FD is procedural. How flood protection is achieved is devolved to the member states (Newig et al., 2014). Therefore, the commitment to change to an integrated catchment system approach must come from organisations managing flood risk, rather than guided directly by the directive. The integration of water provisioning organisations and FCRM through the synergies of WFD and FD provides an opportunity to promote NFM and delivery of multiple benefits (Barlow et al., 2014; Collentine & Futter, 2016) but the operational integration of the two directives is not subjected to a formal review within the UK.

To combat the decline in biodiversity, agri-environment schemes were introduced in 1987 to encourage farming systems that enhance and conserve biodiversity (Batáry et al., 2015; Boatman et al., 2008). Through review and reform, the schemes' initial emphasis on preventing species loss evolved to maintenance and improvement of ecosystem services (Batáry et al., 2015). The agri-environment schemes in England, known as Countryside Stewardship, were introduced in 2016 and includes NFM interventions (Defra et al., 2016), and encouraged landowner/ farmer participation (Riley et al., 2018). However, contributions of agri-environment schemes to delivering catchment wide NFM is being overlooked by the wider FRM community. In recently published FRMPs (Environment Agency, 2016a) only one of seven plans explicitly mentions agri-environment schemes. The majority note greater future engagement with the agricultural sector; however, two plans fail to link farming and flood management at all (Environment Agency, 2016a).

Harnessing synergies

The shift from the dominance of hard engineered flood defences, designed to defend individual communities, to an integrated system operating at a catchment level, requires an increased number of professionals and organisations working together. As illustrated, cross-sectoral scope does not fit neatly into existing working patterns and governance mechanisms (Rouillard et al., 2013). Accordingly, NFM and the WFD are identical (Collentine & Futter, 2016) and require coordinated action of the same sectors to manage water and land as one system .

In 2011 the English government piloted an integrated water management initiative, 'The Catchment Based Approach' (CaBA). Following two years of trials, the scheme was extended (Defra, 2013b). Catchment partnerships are led by host charitable organisations, with little guidance from government and have considerable freedom to develop collaborative arrangements focused towards local circumstances and conditions (Watson, 2015). They are encouraged to produce a catchment plan enabling them to implement a range of interventions to realise their goals including strategy planning over a long-term horizon, codes of working, mission statements and project based activities

(Hurlimann & Wilson, 2018). The Environment Agency administers funding on behalf of Defra, with activities expected to support partnerships to help deliver RBMP objectives (Defra, 2015), foster local collaboration, and deliver multiple benefits (Cascade, 2013; Defra, 2013a). Through mutual recognition of the interdependence each partnership organisation has on a healthy water environment, sufficient motivation should exist to resolve conflicts of interest (Smith, 2015) and deliver more ambitious environmental improvements. CaBA has always been intended to be a mechanism for better integration of FRM into integrated catchment management (Defra, 2013a), couple this with the fact that they already deliver many NFM interventions (figure 1) (CaBA, 2017) motivated by objectives other than FRM. Yet the scale, efficiency, outputs and outcomes of delivery compared to rhetoric are unknown. It is suggested that without statutory reform, and increased funding, catchment partnerships are limited in ability to deliver IWRM with or without FRM (Robins et al., 2017; Watson, 2015). Whilst the collaborative catchment model is not yet proven in England a review of such partnerships, principally in USA and Australia, identified factors that promote successful outcomes; including the necessity of adequate funding, effective leadership, trust, and commitment of partners (Leach & Pelkey, 2001). It is unknown whether CaBA has embedded these lessons into partnerships but it is likely that the success of promoting delivery of WFD and FD through NFM will be heavily influenced by these factors.

Catchment partnerships, whilst not responsible for WFD delivery, are aligned to the directive as illustrated by 100% of projects undertaken by 25 pilot CaBA catchments focused on water quality. Catchment partnerships often frame collaborative catchment management as an effective means for delivery, with a focus on tackling specific ‘local’ issues for improving water or habitat quality, rather than a holistic whole systems approach (Watson, 2015). If reflected in the delivery of NFM, CaBA is in a strong position to deliver multiple benefits, however, limited evidence exists that suggests that NFM objectives of preventing, protecting and mitigating flood risk are well understood by catchment partnerships in their current form. Therefore, the recommendation to increase delivery of NFM through catchment partnerships is dependent on strong engagement with the FCRM sector.

The House of Commons Environment Food and Rural Affairs Committee reviewed current flood risk management delivery in England (Environment Food and Rural Affairs Committee, 2016; Howarth, 2017) and concluded that NFM type measures were needed and wider scale adoption through local stakeholder partnerships encouraged. Catchment partnerships are referenced within the report, but only as a source of information or as a contractor to deliver projects, illustrating a lack of understanding of their current purpose and potential in delivering a resilient hydrological system, overlooking synergies in FD and WFD. No formal UK assessment of whether the delivery of the two directives have been integrated operationally has been undertaken, a 2017 review of catchment partnerships reported 99% contributed to WFD objectives. Whilst a similar figure is not given for contributing to FD, 91% of catchment partnerships report engaging with FRM (CaBA, 2017). It is our proposal that CaBA is well placed to realise the integration of FRM into IWRM in England but is yet to be tested in practice and an area for future research.

Conclusion

When the word natural in NFM is taken to refer to hydrological processes rather than related to the idea of the naturalness of a feature, the catchment can be considered as an integrated system. NFM is designed to increase the resilience within the system by creating capacity for slowing and storing water, rather than moving it as quickly as possible. However, over ten years of policy documentation and a widespread interest in NFM-type interventions has not resulted in NFM being adopted as a mainstream FRM strategy. To date NFM is typically implemented on a small scale, *ad hoc,* unsystematic basis, despite the benefits to wildlife and society. The lack of widespread adoption could be due to the focus of research and resources to increase the evidence base; a complex and lengthy process and paradoxically unobtainable if NFM is not applied at the catchment scale. Moreover, rather than embracing the notion of creating a more resilient system, the computational complexities of increasing our knowledge base almost entirely through modelling is leading to a narrowing of the scope of NFM away from a systems approach to small rural catchments.

Catchment wide NFM collates expertise and responsibilities from a wide range of sectors requiring collaborative working. This review of sectors has revealed policy objectives are not presently aligned, with a divergence in activities rather than coordinated cooperative planning and working. This divergence is further fuelled by a paucity of interdisciplinary relevant policy research, capable of binding together physical observations and projections with long term policy planning and water management frameworks. The unsystematic informal NFM delivery to date could be tied to a lack of research into delivery mechanisms.

The two philosophies behind CaBA and NFM are comparable and compatible; working at the catchment scale and delivering multiple benefits. Moreover, the contributing sectors are identical. This is a solid base from which to coordinate delivery. Therefore, rather than creating a new partnership, an opportunity exists to utilise and develop existing synergies between the FD and WFD and seek to champion NFM through established catchment partnerships. If CaBA is supported through research into the mechanisms of delivery, NFM could be realised at the required catchment scale, which would enable wider recognition of NFM and assessment as a mainstream flood risk management strategy.

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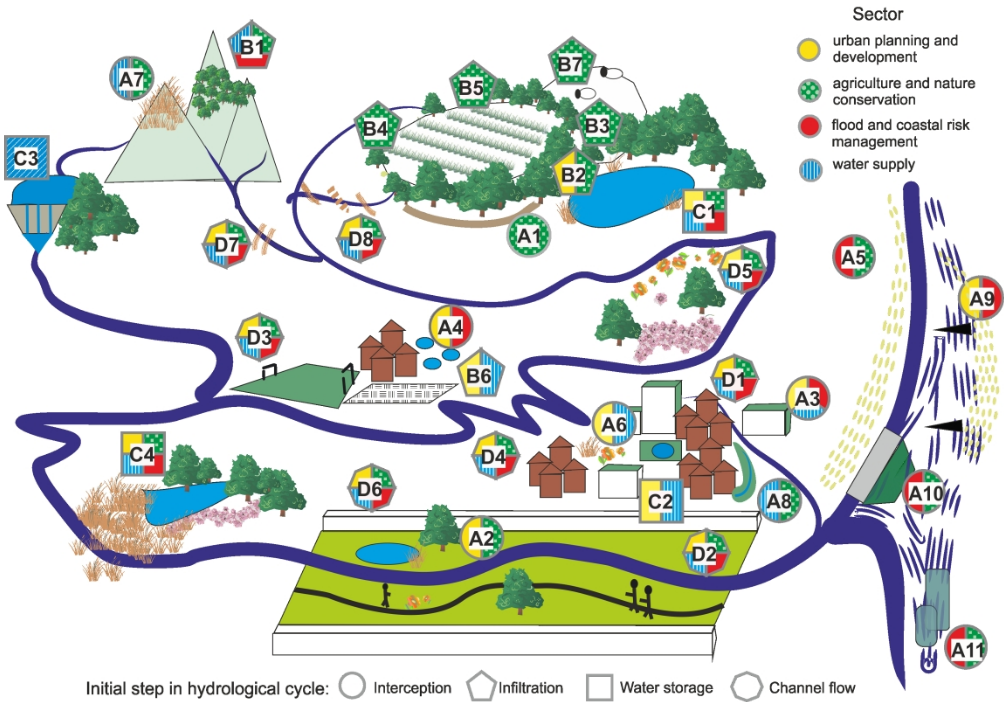

Figure 1. Catchment wide NFM interventions categorised as the initial step in the hydrological cycle – Interception: A1 bunded ditches, A2 vegetative cover, A3 green roofs and walls, A4 interception ponds, A5 managed realignment, A6 rain gardens, A7 restoring peatlands, A8 swales, A9 beach nourishment, A10 habitat promotion, A11 reef creation Infiltration: B1 woodlands , B2 filter/buffer strips, B3 hedgerows, B4 managing soil quality, B5 no and low till agriculture, B6 permeable paving, B7 reduced stocking density Water storage: C1 ponds, C2 rainwater harvesting, C3 reservoirs, C4 wetlands and reed beds Channel flow: D1 de-culverting, D2 increase channel roughness, D3 regulated washlands, D4 remeandering, D5 restore functioning floodplain, D6 setting back flood defences, D7 woody material dams D8 species reintroduction (e.g. beavers). Each intervention uses a number of hydrological processes to slow the flow of water for example interception, infiltration and water storage in wetlands and surrounding vegetative cover will result in reduced surface run-off.