WHAT WILL FRESHWATER MANAGEMENT REFORM MEAN FOR STORMWATER MANAGEMENT?

Annette Semadeni-Davies[1], Jonathan Moores[1] and Malcolm Green[2]
National Institute of Water and Atmospheric Research, NIWA, Auckland
National Institute of Water and Atmospheric Research, NIWA, Hamilton

ABSTRACT

Freshwater management in New Zealand is undergoing a fundamental change. Reforms to the management of freshwater bodies, which includes freshwater bodies in urban areas, are set out in the National Policy Statement for Freshwater Management (NPS-FM), the Freshwater Reform 2013 and Beyond draft document which gives guidance on how the reforms could be implemented, and proposed amendments to the NPS-FM released late last year (Ministry for the Environment, 2011; 2013a, b). The NPS-FM requires councils to set freshwater objectives and limits, MfE (2013a) proposes three action points to achieve these which are adopted in MfE (2013b):

- Planning as a community to include a diverse range of stakeholders in freshwater management.
- Development of a National Objectives Framework whereby objectives are the desired environmental outcomes and limits refer to the amount of water available for use.
- Managing catchments within water quality and quantity limits.

Discussion to date has focused on rural water allocation and agricultural runoff. However, the reforms also require setting objectives and limits for urban water bodies - how to do so needs to be addressed. Here we overview the pathway to reform and initiate a discussion on the implications of the reform for stormwater quality management in urban areas.

KEYWORDS

National Policy Statement for Freshwater management (NPS-FM), National Objectives Framework (NOF), values, attributes, limits, stormwater quality, community planning

PRESENTER PROFILE

Annette Semadeni-Davies has been a member of NIWA’s Urban Aquatic Group since 2006. Her interests include stormwater management for water quality and quantity control and modelling of stormwater systems. She has also researched the impacts of climate change on urban drainage systems both in New Zealand and Sweden.

1 INTRODUCTION

Access to clean freshwater is at the heart of New Zealand's economic, social, cultural and environmental wellbeing. Water is an essential part of brand New Zealand that underpins our farming, manufacturing and tourism industries. Yet the way in which we use water has put increasing pressure on our freshwater resources. Deteriorating river water quality and over-allocation of water resources in some catchments, and the need to safeguard the health of our waterways while maintaining economic output, has driven reforms of freshwater management in New Zealand. The 2011 National Policy Statement for Freshwater Management (NPS-FM) released by the Ministry for the Environment (MfE 2011) signals a shift towards limits-based freshwater management, integrated catchment management and increased opportunities for community collaboration with councils and other stakeholders. Two other key documents are the Freshwater Reform 2013 and Beyond (MfE 2013a) working document which gives guidance on how the NPS-FM could be implemented and proposed amendments to the NPS-FM released late last year (MfE 2013b) that draw on MfE (2013a) and public submissions to that document. Although the debate over reform has focused on rural activities, the documents also recognise issues relevant to cities and towns. Our growing urban populations are at increasing risk of water scarcity in drought years and urban water bodies have become degraded by increased erosion and high discharges of untreated urban runoff.

Ongoing and legacy problems associated with poor stormwater quality in urban freshwater bodies include habitat loss and degradation, reductions in biodiversity, and loss of the water resource for full and partial contact activities. It is only within the last twenty years or so that stormwater treatment has become established practice in New Zealand's cities, indeed, outside the main centres, many councils still do not currently require stormwater treatment. Where treatment devices are in place, they tend to be associated with green and brown-fields developments. Retrofitting is comparatively rare. Depending on local regulations, developers may need to demonstrate that they have planned adequate treatment to meet effluent water quality criteria or load reduction guidelines, but there is generally little compliance monitoring. Outside of consultation processes associated with resource consent applications and statutory plan development, examples of community engagement in stormwater management have been limited.

Given current approaches to stormwater management in New Zealand, the reforms to freshwater management have the potential to have a profound impact on the way existing urban drainage systems are operated and capital works and new developments are planned. Thus, the purpose of this paper is to give an overview of the reforms and to initiate a discussion amongst urban water managers on what we need to do to implement the reforms with respect to stormwater management to improve the water quality of urban freshwater bodies. Finally, we suggest that since freshwaters ultimately flow to the sea, urban catchment managers could also consider setting limits and objectives for coastal environments (i.e., estuaries and harbours).

2 THE PATHWAY TO FRESHWATER REFORM

2.1 THE NATIONAL POLICY STATEMENT ON FRESHWATER MANAGEMENT

Freshwater management in New Zealand under the Resource Management Act (RMA, New Zealand Government 1991) follows an effects-based approach whereby the effects of activities are managed rather than regulating the activities themselves. The realisation that there has been a decline in the state of many waterways, including urban streams, over the last 30 led to a review of freshwater management culminating in the NPS-FM which came into effect in July 2011. Since that date, decision-makers under the RMA must have regard to the NPS-FM in consenting decisions. Moreover local authorities are required to amend operational or proposed regional policy statements, and operational or proposed regional plans to give effect to any provision in the NPS-FM that affects those documents. The goals of the NPS-FM are to maintain or improve overall water quality within a region and to safeguard the life-supporting capacity, ecosystem processes and indigenous species (including their associated ecosystems) of fresh water.

Some of the reforms given in the NPS-FM were put forward by the Land and Water Forum (LWF), which consists of a diverse group of organisations including scientists, primary industry representatives, NGOs and Maori. The LWF was asked by the government in 2009 to conduct a stakeholder-led collaborative process to consider reform of New Zealand's freshwater management system. In September 2010, the LWF produced the first of three reports which identified shared outcomes and goals, and options to achieve them (LWF 2010). The forum found that as far as diffuse-source contaminants go, the Achilles heel of the RMA is the failure to account for cumulative effects: those effects that either arise over time or that occur in combination with other effects.

A key recommendation made in the first LWF report, which has been incorporated into the NPS-FM, is the adoption of integrated catchment management whereby catchment-scale freshwater objectives are set, and limits to resource use which enable those objectives to be met are determined. The LWF also recommended collaborative methods as a means of setting enduring freshwater objectives the balance community desires for their water bodied

Following the release of the NPS-FM, the *Second Report of the Land and Water Forum* (LWF 2012a) discusses the need for, and barriers to, setting catchment water quality objectives and limits. The establishment of national minimum objectives with respect to a range of biometric, physiochemical, human health and fish productivity indicators, is recommended. It is noted that since each catchment is different, limits to achieve the objectives may vary regionally and between catchments. Moreover, it is noted that collaborative decision making is essential to enable trade-offs between different stakeholders, including Māori, in order to achieve long term solutions what are more resilient and adaptive to change.

The *Third Report of the Land and Water Forum* (LWF 2012b) overviews the tools and approaches required to set and meet objectives and limits. Key to the report are recommendations for the implementation of the NPS-FM. It is noted that there are already a range of methods and programmes being developed around the country to improve freshwater management which need to be evaluated and where appropriate, reinforced, improved, disseminated and integrated into catchment planning. These include monitoring and modelling methods to assess water quality and management techniques to reduce contaminant yields and loads. The *Third Report* has a brief discussion on issues related to urban water management (i.e., water supply, wastewater and stormwater) which reiterates that urban fresh water bodies should be managed within limits in the same way as rural catchments albeit with a different set of objectives and limits specific to urban values and contaminants.

2.2 FRESHWATER REFORM 2013 AND BEYOND

The Freshwater Reform 2013 and Beyond working paper (Mfe 2013a) proposes a set of reforms for the implementation of the NPS-FM. This document calls for transparent and adaptive management systems and notes that to be successful, these systems need to be supported by stakeholder communities and a good scientific and economic understanding of processes operating within a catchment. A number of challenges to freshwater management in New Zealand are recognised including declining water quality in some catchments, lack of robust information on the impacts and outcomes of management decisions, management systems which are insufficiently adaptive or dynamic and failure to fully consider the interests and values of Maori in planning and decision making.

To ensure the sustainability of freshwater resources and to meet these challenges, action is proposed in three key areas:

- **Planning as a community** – starting by introducing a collaborative planning option as an alternative to the current system under the RMA 1991. Collaborative planning means that councils should consult and collaborate with community groups including Maori to ensure inclusive, democratic and transparent decision making which reflects the diverse range of community values and interests.

- **A National Objectives Framework** (NOF) – this action point requires councils to set objectives and limits at the catchment level in their regional plans. Freshwater objectives are the intended environmental outcomes for a freshwater body (i.e, lakes, rivers, wetlands) that will provide for the water values the community considers important at the catchment-scale. Limits refer to the maximum amount of the resource available for use which allows a freshwater objective to be met. With respect to water quality, *"limits to use are derived from the specified freshwater objectives for each catchment and refer to the total amount of contaminants that can be discharged into it without jeopardising the desired outcomes".* Setting limits requires knowledge of the impacts of contaminants discharges on water quality at the site and catchment-scales and requires an understanding of contaminant dynamics and the response of ecosystems to those contaminants.
  Values include a range of water uses and activities. For each value there will be a number of water quality attributes (e.g., turbidity, periphyton, temperature, pH, Dissolved Oxygen, contaminant concentrations) and associated indicator bands. The bands will represent the range of environmental states A to D (e.g., excellent, good, fair and unacceptable) with respect to each attribute and will vary depending on the value. For each attribute, the threshold between bands C and D represents the national minimum state or bottom-line. The NOF will have a standard list of values for which a water body could be managed. While the values chosen for a particular water body would be a community decision, the associated attributes and bands would be set at a national level.

- **Managing within water quantity and quality limits** – with respect to water quality, the goal of this action is to achieve the catchment objectives by either improving or maintaining water quality. Where limits are not exceeded, managing to limits will allow communities to identify where there are opportunities for enhanced water use. Where water quality limits are already or will be exceeded following development, measures, such as those listed by the LWF (2012b) are required. The choice and level to which these measures are applied requires councils to identify and quantify all sources of contaminants within a catchment and to know the environmental, social and economic impacts of the measures at the catchment level. Where the measures could have an impact on existing activities or infrastructure, adequate adjustment timeframes for their implementation should be introduced.
  It is noted that managing water quality is complex with multiple contaminants and sources which have a cumulative downstream impact. There is also limited

information on many freshwater bodies and getting information can be costly necessitating cost effective monitoring. Moreover, it is hard to measure or estimate the levels of contaminants discharged and there are potential costs to stakeholders in reducing these discharges. Thus it is essential to have community support for the objectives chosen and that limits are set with regard to readily understandable, good quality scientific and economic data. Stakeholders should also have clarity and certainty on what they are entitled to and their roles and responsibilities in freshwater quality management. To this end, MfE states that new research will be required including the development of improved water quality monitoring methods and modelling tools.

Proposed amendments to the NPS-FM were put forward in November 2013 (MfE 2013b) on the basis of MfE (2013a) and public submissions to the that document. These include *the adoption of a NOF with a suite of national freshwater values, description of associated attributes and a process to use the NOF to support and guide the setting of freshwater objectives*. The NOF would have a menu of values that are important to communities. The values of ecosystem health and human health for secondary contact would be compulsory for all water bodies. National bottom-lines would be set for the attributes associated with each of the compulsory values. There is also a proposed requirement to monitor progress towards achieving the objectives. The proposed reforms are illustrated in Figure 1Figure 1 along with the steps proposed for freshwater management under the reforms.

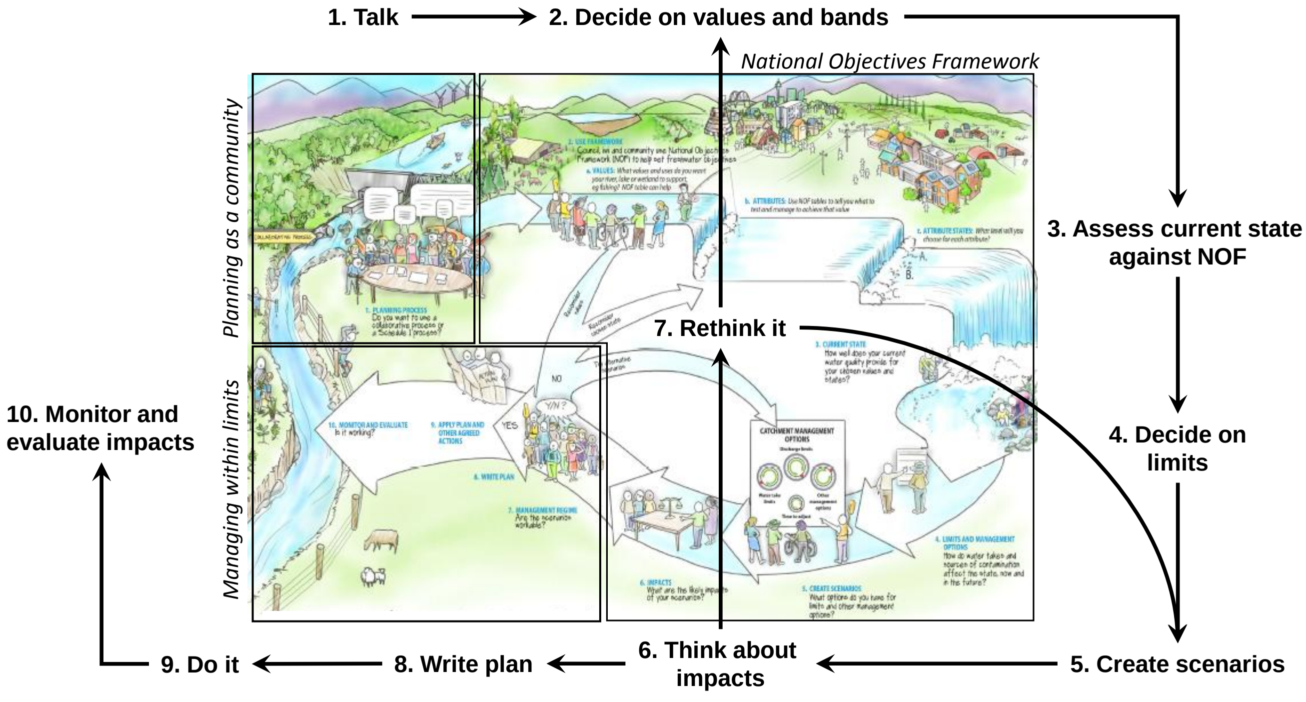

Figure 1 Managing freshwater in New Zealand showing key action areas and steps to choosing objectives and setting limits (Adapted from MfE 2013b)

3 IMPLICATIONS OF REFORM FOR STORMWATER MANAGEMENT

In this section we discuss the implications for urban stormwater managers in implementing the reforms outlined above with respect to each of the key action areas. We also discuss the need for catchment-scale model development as modelling is an integral part of the freshwater management process under the reforms. Finally we argue that urban water management in coastal centres should also consider the objectives for the management of coastal receiving environments.

3.1 PLANNING AS A COMMUNITY

A number of barriers to the setting of objectives and limits in urban areas are listed in the LWF *Third Report (2012b)*, these include inconsistent enforcement practices between councils and between contaminants, high costs involved in mitigation (particularly with regard to retrofitting or replacing existing infrastructure) requiring long implementation timeframes, gaining agreement between stakeholders for management measures and the level to which they are applied and balancing community expectations for water management and other community services. Under the reforms, it is intended that community planning could resolve some of these issues, however it is acknowledged that there is a general need for collaborative planning mechanisms.

MfE (2013a) notes that the use of sustainable urban drainage systems (SUDS) and improved roading design could be a means of mitigating against stormwater contamination of urban freshwater bodies. This is in keeping with a general understanding over recent years that adoption of Water Sensitive Urban Design (WSUD) and associated installation of SUDS, amongst other benefits, can be an effective means of reducing contaminant loads from urban sources. Indeed, the proposed Auckland Unitary Plan (Auckland Council 2013), encourages the use of WSUD as a strategy for implementing the NPS-FM. The need for community planning and stakeholder engagement is not new to proponents of WSUD and there has been much written on the subject in Australia over the last decade. For instance, Brown et al. (2005) state that stakeholder participation is essential for the implementation of sustainable stormwater management. Taylor and Fletcher (2005) identify 12 steps in the planning, implementation and evaluation of stormwater management options under a triple-bottom-line framework, eight of which require some form of stakeholder communication. Dahlenburg and Morison (2009) give examples from Sydney at the river catchment (Botany Bay) and local-scales (Cooks River) which show how communities can become involved in urban water planning. Information booklets, visioning sessions, workshops and questionnaires were used to successfully engage the community and to determine community values and preferred methods of stormwater management. In both cases, the community showed commitment to WSUD. However, a review of public and municipal commitment to WSUD (Morison and Brown 2011) in Melbourne found that commitment varied according to population density, demographics and socio-economic status which highlighted a need to enable greater community involvement in areas of limited or partial commitment. Bos et al. (2013) and Bos and Brown (2012) argue that changes in urban water management have been largely driven by technical development and that a socio-technical transition in governance which allows community participation is required for widespread acceptance of WSUD. Such a transition will require experimentation in governance and opportunities for social learning.

The discussion above raises the question of how community planning for the purpose of stormwater management should be achieved in New Zealand towns and cities. There have been several successful examples of community planning for integrated catchment management of rural fresh water bodies in New Zealand such as Motueka River[1] and its tributary Sherry Creek (Nagels et al. 2012). Indeed, successful community management of the latter won the inaugural NZ River Stories Award in 2013. While there have been some community engagement programmes involving urban freshwater

[1] http://icm.landcareresearch.co.nz/ (date of last access, 13 February 2014)

management and stream restoration (e.g., Project Twin Steams[2]), these have not been undertaken explicitly for catchment planning purposes and many councils currently do not have collaborative planning processes in place. MfE (2013a) recognises that community planning can be challenging and complex. Moreover, communities will need to meet new demands and responsibilities as they commit to collaboration. As noted by the LWF (2012b), the diverse range of urban stakeholders, which include homeowners, council planners and resource managers, consultants, developers and industry - each with its own knowledge base and set of values and expectations with respect to environmental outcomes, costs and timeframes for implementation - means that meeting consensus for the management of urban water bodies could be particularly difficult. Councils will need to consider how to choose stakeholder groups and representatives from those groups, at which steps the various stakeholders will be engaged in planning and to what capacity, and how to facilitate a working relationship between stakeholders in an equitable manner.

To this end, MfE proposes to provide national guidance and supporting material on the implementation of community planning for freshwater management. In the meantime, there are a number of other sources of guidance available in New Zealand such as the Community Planning Toolkit[3], Landcare Research's Sustainable Business and Living programme[4] and the International Association for Public Participation (IAP2)[5] which has a presence in New Zealand and regularly runs training courses for facilitators. The NIWA Climate Change Urban Impacts of Toolbox[6] and Coastal Adaptation to Climate Change[7] websites also contain information on facilitating decision making workshops with multiple stakeholders.

In addition to developing mechanisms for collaboration with stakeholders, community planning also requires consistent and robust scientific information in a form that is readily understandable by non-professionals in order to facilitate communication. Up-to-date tools, such as models, including decision support systems (DSSs), and visualisation methods (e.g., charts, diagrams, graphics, photos, 3-D computer generated imagery, animations and videos) are also required to allow stakeholders to understand the issues and evaluate a range of solutions. Modelling needs in this context are discussed further below.

3.2 NATIONAL OBJECTIVES FRAMEWORK

A clear message from MfE (2013a, b) is that the NOF cannot be fully populated at present for all values and water body types and will progress as information becomes available. Both documents state the need for objectives and limits to be underpinned by good quality data and robust science with the ability to incorporate new information and techniques over-time.

---

[2] http://projecttwinstreams.com/ (date of last access, 13 February 2014)

[3] http://www.communityplanningtoolkit.org (date of last access, 13 February 2014)

[4] http://www.landcareresearch.co.nz/science/living (date of last access, 13 February 2014)

[5] http://www.iap2.org.au/ (date of last access, 13 February 2014)

[6] http://www.niwa.co.nz/climate/urban-impacts-toolbox (date of last access, 13 February 2014)

[7] http://www.niwa.co.nz/our-science/coasts/research-projects/coastal-adaption-to-climate-change (date of last access 8 March 2014)

In addition to the two proposed compulsory values, many of the suggested national values in MfE (2013a, b) are transferable to urban water bodies (e.g., boating, swimming, food gathering/mahinga kai). While heavy metals are in the potential list for food gathering in MfE (2013b), other the key urban contaminants such as, hydrocarbons and Polycyclic Aromatic Hydrocarbons (PAHs), gross pollutants, and emerging contaminants are not yet listed by MfE as potential attributes. The implementation of the NPS-FM in urban catchments will therefore need to determine which of these are of most concern on a case-by-case basis and at what level they have an impact on the various values. The process will also need to consider whether other attributes, such as habitat provision or whether the stream is natural or channelized, should also be included as attributes for specific values. For example, the freshwater objectives set out in the Proposed Auckland Unitary Plan (Auckland Council 2013) use the Macro-invertebrates Community Index (MCI) as an interim measure to assess water quality rather than a multifactor water quality standard. The MCI is a site specific, time-integrated measure of the life-supporting capacity of freshwater habitats and it is used on the understanding that if macro-invertebrate health is maintained, other values such as food gathering and recreation will also maintained. The Stream Ecological Valuation (SEV, Storey et al. 2011) method, which provides quantitative measures of stream hydrology, water quality, habitat provision and biodiversity, could also be an option for the setting of objectives and targets as it includes a number of factors specific to urban streams (e.g., connectivity with stormwater discharges, presence of gross pollutants).

It is also important that implementation of the NPS-FM takes account of the influence of different physical environments on water quality. For example, while periphyton is a suitable nutrient indicator for stony-bed stream river reaches and is listed as a potential attribute for ecosystem health (MfE 2013b), the indicator is not appropriate for soft substrates. Similarly *chlorophyll a* is listed by MfE (2013b) as an appropriate nutrient indicator for lakes. This means that there may be a range of attributes that need to be evaluated along the stream network as one moves from headwaters to the catchment mouth.

3.3 LIMITS SETTING

While limit-based freshwater management is key to the reforms, there is little information in the reform documents on how limits should be set or achieved in practice. Indeed, MfE (2013a) states that methodologies for deriving limits need to be developed. Setting water quality limits requires knowledge of the impacts of contaminants discharges on water quality at the site and catchment-scales and requires an understanding of contaminant dynamics and the response of ecosystems to those contaminants. Moreover, impacts can be cumulative, such that management decisions may need to consider downstream effects. Consider the case of headwaters streams; setting limits for first order streams may improve water quality to the desired level locally, however, it may not be enough for second order streams if the assimilative capacity of these streams is exceeded by the total load from all their tributaries. Clearly, the setting of load limits to achieve objectives in first-order streams must also be cognisant of the objectives in the second-order stream that they feed into and so on down the stream network. However, it should not be assumed that limits should be set for the highest order stream due to the effects on water quality of dilution and decay in the main-channel.

A potential solution is to identify for each catchment a “critical point”, which is the location that has environmental objectives which require stricter contaminant load limits to be achieved than any other place in the catchment. Managing the catchment for the critical-point load limit will ensure that the objectives are being met catchment-wide. However, managing for the critical-point load limit may also lead to over-achievement of objectives at other places in the catchment. As a result, stakeholders may be mitigating or paying for outcomes that are not necessarily local to them. This is a potential source of conflict that could be resolved by the collaborative model of catchment management envisaged by the NPS-FM. There are also theoretical difficulties in the "critical point" approach (Semadeni-Davies et al. 2009). For instance, how should attributes for different types of water body in the same stream network be evaluated and compared? And should the critical point be determined solely on the basis of current water quality or should the process assess the sensitivity of different points along the water body, which may currently meet the water quality objectives but are vulnerable to change? The latter is particularly pertinent to urban streams where future development in headwater streams could have profound effects on downstream water quality. Moreover, how should the ecological, economic, social and cultural significance of certain points along a river (e.g., location of swimming holes, taniwha and fishing spots) be assessed and how are these considerations weighted against each other?

A further challenge is that while attributes are expressed as either long-term average contaminant concentrations or water quality indicators, limits are most likely to be imposed on contaminant loads coming from various sources in a catchment. Setting limits thus requires a transformation of loads to concentrations or indicators or vice versa. Elliott and Snelder (2011) outlined a possible loads-based approach for rural runoff that could be adapted to urban water bodies. They suggest using a model, such as the Catchment Land Use for Environmental Sustainability (CLUES), to estimate annual E. coli, sediment and nutrient (total nitrogen and total phosphorus) loads reaching rivers for current land use. These loads are then equated to the observed long-term average water quality as indicated by nutrient concentrations, bacteria, clarity, periphyton and trophic levels for lakes assuming a linear relationship between contaminant loads and the indicators. For each of these attributes, if the current level is greater than the target level, then the associated contaminant loads must be reduced proportionally. In contrast, if the current level is less than the target, the difference represents the capacity for change in the catchment. In order to maintain water quality, any change in loads associated with land use change must be mitigated.

Ideally, objectives and limits should be set using up-to-date and reliable water quality data from a number of locations across a catchment. Where data is not available, models could be used to assess water quality. Ongoing monitoring of water quality attributes following protocols relevant to urban freshwater bodies is required to determine their current state and to provide data for decision making and model development. MfE (2013a) acknowledges that monitoring has been inconsistent around the country and it can be costly for councils to put in place monitoring programmes. Indeed, some urban centres do not currently monitor urban water quality. Recognising that information on contaminant concentrations is important for effects-based assessments, NIWA, in partnership with the University of Auckland and Auckland Council, has been developing an on-line searchable database of concentration-based data from urban centres around the country (Gadd et al. 2013)[8]. The datasets have been collected over the last 15-20 years by organisations such as regional councils, territorial authorities, roading agencies, research institutes and universities. The data can be queried and analysed by region, urban centre, land use type, water body type and, where appropriate, method of stormwater treatment. At present, the database is populated with data mainly from Auckland, with data also provided from, amongst other regions, Wellington, Southland, Taranaki, Northland and Canterbury. These data could

[8] http://urqis.niwa.co.nz/

prove valuable in providing information for the setting objectives and for evaluating the effectiveness of catchment management interventions implemented under the NPS.

3.4 MANAGING WITHIN WATER QUALITY LIMITS

Managing within water quality limits requires both the management of contaminant yields (i.e., source control) and controlling the loads of contaminants reaching freshwater bodies, for instance through stormwater treatment. In urban areas, there is a need to investigate how best to achieve the limits that have been set at a catchment-scale, including choice of building materials and urban form (i.e, housing density, land use zoning, transportation links and nodes) as well as the choice and design of stormwater management systems. As noted above, SUDS and improved roading design are specifically mentioned by MfE (2013a) as mitigation options within urban catchments. WSUD too has been seen as a means of improving stormwater water quality in New Zealand and is likely to become an integral part freshwater management in the urban sphere under the reforms. Installation of SUDS at present tends to be associated with new developments or urban renewal programmes, making stormwater treatment patchy within mixed land use catchments. While there is more scope for WSUD and SUDS in green- and brown-field developments, the achievement of limits in areas of historic urban development is likely to require a significant retrofitting commitment.

A challenge to management within limits in urban catchments is that most of the research into the efficiency of stormwater treatment, using either SUDS or proprietary devices, has concentrated on determining the performance of a single device. These studies have often been carried out for pilot devices, often during product development, or soon after installation rather than with fully operational devices *in situ*. There have been comparatively few studies into the performance of multiple devices either arranged in parallel (i.e. as modules, each serving a small area) or as treatment trains. With the exception of end-of-pipe treatment devices, there have been no quantitative studies in New Zealand which examine the effects of catchment-wide implementation of SUDS on receiving waters. Thus, stormwater managers are challenged to understand how well stormwater treatment performs at the catchment-scale. While it may be reasonable to assume that, if each device is functioning as designed, there will be a cumulative improvement of water quality at the receiving waters the level of improvement will depend on the proportion of stormwater runoff treated, the number and type of devices installed, and their location in relation to contaminant sources and each other. While modelling of urban catchments can help to determine how best to choose and locate SUDS throughout catchments, implementation of the NPS will also need to consider what and how to monitor in order to assess the success of contaminant reduction interventions at the catchment-scale.

Managing to limits will also require the development of catchment-scale evaluation tools and DSSs capable of simulating a range of water management and land use scenarios. These tools should be based on our understanding, to assess whether the objectives and limits set are feasible and to determine the economic, social and cultural implications of the measures proposed. That is, what are the trade-offs required to meet the objectives and are these acceptable to the wider community, or do the objectives need to be altered? An overview of modelling tools currently available for stormwater management is given in the section below.

3.5 MODELS FOR FRESHWATER MANAGEMENT

Modelling and the need for model development have been mentioned above with respect to each of the reform action points. MfE (2013b) allows for models to be used as part of freshwater management. MFE (2013a) notes that models can be used for a variety of purposes within the regulatory context including to estimate contaminant loads and concentrations and to evaluate the effectiveness of water quality improvement options and the environmental and economic impacts of those options.

Operational urban drainage models such as MIKE URBAN and InfoWorks are already widely used in New Zealand towns and cities. While these models could have a role in managing to limits, for example in the design phase of development planning there is also a need for appropriate catchment-scale models and planning tools (LWF 2012b). Such tools should be capable of:

- estimating contaminant loads reaching urban freshwater-bodies and can also assess the extent to which targets based on contaminant concentration and associated environmental effects within those water bodies are met;
- running land use and mitigation scenarios which can be quickly and easily developed in order to evaluate different management options to achieve limits, the models should operate with minimal data requirements and set-up and run times to allow multiple iterative runs; and
- displaying results in forms that are readily understandable by non-experts to to promote good communication between practitioners and other stakeholders.

A review of urban stormwater management models for decision support currently available (Semadeni-Davies 2011) found that there are currently no tools which meet all of these criteria. Instead, it is most likely that councils will need to use a range of interoperable tools for different tasks within the planning process (e.g, tiered modelling at different scales to estimate the impact of neighbourhood stormwater management on the wider catchment and coupling of water management and life-cycle costing models to enable cost benefit analysis). The review found three broad categories of tools: 1. deterministic models; 2. comparative models; 3. visualisation and guidance tools. The first make quantitative predictions about water quality and quantity based on physical conditions by simulating the drainage network and are similar to urban drainage models for other applications with the addition of planning tools. SUSTAIN (Shoemaker et al. 2009), for example, is based on the SWMM model and has routines to assess the likely effectiveness and costs associated with water management, however, SUSTAIN requires considerable effort and expertise to set up and run. The second make qualitative comparisons on the relative costs and benefits of different water management options based on *a priori* knowledge held in libraries, such as the DayWater Multi-Criteria Comparator (Scholes et al. 2008) and Landcare Research's CostNZ[9] model, which allow stakeholders to compare and contrast the choice of stormwater management options at a specific location. These costs and benefits are often expressed in terms of social, economic and environmental indicators. There are additionally tools with deterministic and comparative elements such as the such as Auckland Council spreadsheet Contaminant Loads Model (Timperley et al. 2010) and the related GIS Catchment Contaminant Annual Loads Model (C-CALM, Semadeni-Davies et al. 2010). Tools in the third category contain information for stakeholders on different water management options, such as photos, diagrams, design criteria and case-studies, but do not provide evaluation or comparative tools (e.g., Auckland City's Water Sensitive Design case-study website[10]). Their purpose is to give background information to support decision making.

---

[9] http://www.costnz.co.nz/index.aspx (date of last access 4 March 2014)

[10] http://www.acwsd.org/Home.aspx (date of last access, 19 February 2014)

Many of the tools are location specific and may not be applicable to New Zealand conditions.

The successful use of models within the community planning process very much depends on the way they are applied and presented to stakeholders. Stakeholders need to be aware that all models are subject to errors and uncertainties and are limited by their choice of spatial and temporal scales and the processes that they simulate (e.g., Walker et al. 2003). Voinov and Brown Gaddis (2008) discuss their experiences of using watershed models as part of community catchment planning which are relevant to stormwater management. They state that decision alternatives based on purely analytical models can be rejected by decision makers, particularly if they are unpopular or are likely to result in conflict, as they do not take into account the values, knowledge or priorities of the human systems that affects and is affected by the system being modelled. They use case studies to illustrate a number of rules for successful participation using models which are summarised below:

- Gain trust and establish neutrality as a scientist, the structure of the model must be scientifically sound and defensible to maintain credibility among decision makers, scientists and stakeholders.
- Select appropriate modelling tools to answer questions that are clearly identified.
- Incorporate all forms of stakeholder knowledge to help identify hydrological, ecological or social processes that should be included in the model. The model should be flexible enough to add new knowledge as it comes to light.
- Gain acceptance of the modelling methodology before presenting model results. Model transparency and clear documentation is essential.
- Develop scenarios that are both politically feasible and cost effective. The decision alternative which has the best environmental outcome may not be viable politically, socially or economically.
- Interpret results in conjunction with stakeholders. Community planning is iterative and stakeholders can develop further decision alternatives on the basis of model results.
- Treat the model as a process. The model is only part of decision making. Use the experiences gained in decision making to further develop the model for future use.

3.6 EXTENSION TO COASTAL RECEIVING WATERS?

MfE (2013b) notes that there were a number of public submissions supporting the view that coastal receiving environments should also be considered as part of the reforms since these are the ultimate receiving environments for contaminants from land that are conveyed by freshwater runoff. Indeed, an important consideration for stormwater management in coastal cities at present is that the 'sink' for contaminants (namely sediments and particulates) is often an estuary or natural harbour which has led to deterioration of these environments (Kelly. S. 2010; Mills et al. 2012). Moreover, the LWF *Third Report* (2012b) suggests that limit setting in coastal cities may be influenced by community objectives for coastal and estuarine environments. Similar to the example of limits being set for head water streams given above, not considering coastal environments when limits for freshwater water quality are being determined increases the risk that the limits may fail to deliver healthy coastal ecosystems.

A possible approach, similar to the idea of critical points discussed earlier, involves setting objectives, targets and limits for both the coastal receiving waters and the freshwater bodies which drain to them. Limits on the discharge of contaminants can then be adopted as the more stringent of those required to meet the objectives for both the coastal and freshwater bodies.

Current circulation poses a particular challenge to limit setting in coastal receiving environments. This is because the sediment delivered by a stream may be transported to and deposited in a different section of the coastal receiving environment. Similarly, an estuarine sediment sink may contain sediments originating from a number of streams. For example, work carried out by NIWA in Auckland's central Waitemata Harbour (Green et al. 2010), found that much of the contaminated sediments in Shoal Bay off Birkenhead originated from Henderson Creek and the Whau River on the other side of the harbour. Thus, freshwater limit setting in contributing streams will need to take into account the relationship between sediment sources and sinks in the coastal receiving environment.

4 CONCLUSIONS

Under the NPS-FM, the way in which freshwater is managed in New Zealand is set to change. The main drivers for reform have been concern over continued poor water quality in rivers and lakes due to agricultural runoff and over-allocation of freshwater resources. However, urban freshwater bodies will need to be managed in the same way as their rural counterparts. In this paper, we have overviewed the pathway to reform and have initiated a discussion into the implications of reform on the urban stormwater management with respect to water quality. The paper addresses each of the key action areas proposed in MfE (2013a) as well as modelling for freshwater management and discusses the implications for stormwater managers in implementing the reforms with respect to water quality. We also make the case for including coastal receiving environments in freshwater reform. Specific requirements to successful freshwater management in urban areas include:

- development of guidelines for community planning and capacity building in councils to allow collaborative catchment management. The guidelines will need to take into account the diverse range of stakeholders found in urban areas such as residents, land owners, business owners, developers, Māori and council;

- development of methods for setting objectives and limits within urban catchments which take into account urban contaminants not currently listed by MfE (2013a, b);

- ongoing monitoring of water quality attributes in a range of urban stream environments in order to assess the current state of urban freshwater bodies and to monitor the effectiveness of the NPS-FM implementation;

- assessment of attributes, levels and bands that best represent objectives for urban water bodies, based on existing and continuing research into the impact of urban contaminants on freshwater environments;

- assessments of the effectiveness of measures that can be used to reduce contaminant loads to urban receiving waters at the site and catchment-scales; and

- development and application of water quality models and other tools which are appropriate to the tasks involved in urban catchment planning as discussed above.

ACKNOWLEDGMENTS

We would like to thank our colleague Dr Helen Rouse (NIWA Christchurch) for editing this paper and for her comments on the reform documents.

REFERENCES

Auckland Council (2013) Draft Unitary Plan (web-portal http://unitaryplan.aucklandcouncil.govt.nz/pages/xc.enquire/default.aspx).

Bos, J.J. and Brown, R.R. (2012) Governance experimentation and factors of success in socio-technical transitions in the urban water sector. *Technological Forecasting and Social Change*, 79(7): 1340-1353. http://dx.doi.org/10.1016/j.techfore.2012.04.006

Bos, J.J., Brown, R.R. and Farrelly, M.A. (2013) A design framework for creating social learning situations. *Global Environmental Change*, 23(2): 398-412. http://dx.doi.org/10.1016/j.gloenvcha.2012.12.003

Brown, R., Sharp, L. and Ashley, R. (2005) Implementation impediments to institutionalising the practice of sustainable urban water management. . *10th International Conference on Urban Drainage*, Copenhagen, Denmark, 21-26 August 2005

Dahlenburg, J. and Morison, P. (2009) Tapping into our biggest resource: Engaging with the community in water quality objective setting and WSUD planning. *6th International Water Sensitive Urban Design Conference*, Perth, Western Australia, May 2009.

Elliott, S. and Snelder, T. (2011) Options for assessing remaining capacity for land use intensificatoin in New Zealand before key water quality criteria are exceeded, Prepared for the Ministry for the Environment, NIWA Client Report No: HAM2011-125

Gadd, J., Semadeni-Davies, A., Moores, J., Garton, C. and Trowsdale, S. (2013) An urban runoff database for New Zealand. *8th South Pacific Stormwater Conference & Expo*, Auckland, New Zealand, 2013

Green, M., Moores, J., Timperley, M., Kelly, S. and Davis, M.D. (2010) Predicting long-term contaminant runoff and accumulation in the Central Waitemata and Southeastern Manukau Harbours (New Zealand). *Proceedings of the IAHR-APRD 2010, 17th Congress of the Asia and Pacific Division of the International Association of Hydro-Environment Engineering and Research, incorporating the 7th International Urban Watershed Management Conference*, Auckland, New Zealand, 21–24 February, 2010.

Kelly. S. (2010) Effects of stormwater on aquatic ecology in the Auckland region, Prepared by Coast and Catchment, Auckland Regional Council Document Type 2010/021.

Land and Water Forum (2010) *Report of the Land and Water Forum: A Fresh Start for Freshwater*. http://www.landandwater.org.nz/Site/Resources.aspx

Land and Water Forum (2012a) *Second Report of the Land and Water Forum: Setting Limits for Water Quality and Quantity, and Freshwater Policy- and Plan-Making Through Collaboration*. http://www.landandwater.org.nz/Site/Resources.aspx

Land and Water Forum (2012b) *Third Report of the Land and Water Forum: Managing Water Quality and Allocating Water*. http://www.landandwater.org.nz/Site/Resources.aspx

Mills, G., Williamson, B., Cameron, M. and Vaughan, M. (2012) Marine sediment contaminants: Status and trends assessment 1998 to 2010, Prepared by Diffuse Sources Ltd , Auckland Council Technical Report TR2012/041.,

Ministry for the Environment (2011) *National Policy Statement on Freshwater Management*. New Zealand Government. http://www.mfe.govt.nz/rma/central/nps/freshwater-management.html

Ministry for the Environment (2013a) *Freshwater reform 2013and beyond*. New Zealand Government. http://www.mfe.govt.nz/publications/water/freshwater-reform-2013/

Ministry for the Environment (2013b) Proposed amendments to the National Policy Statement for Freshwater Management 2011: A discussion document, New Zealand Government, Wellington.

Morison, P.J. and Brown, R.R. (2011) Understanding the nature of publics and local policy commitment to Water Sensitive Urban Design. *Landscape and Urban Planning*, 99(2): 83-92. http://dx.doi.org/10.1016/j.landurbplan.2010.08.019

Nagels, J.W., James, T., Davies-Colley, R.J., Fenemor, A., Merrilees, R., Burton, A., Stuart, B. and Parshotam, A. (2012) The Sherry River - a success story. *. In: Advanced Nutrient Management: Gains from the Past - Goals for the Future. (Eds L.D. Currie and C L. Christensen). Occasional Report No. 25. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand.*, http://flrc.massey.ac.nz/publications.html

New Zealand Government (1991) Resource Management Act (RMA) http://www.legislation.govt.nz/

Scholes, L., Revitt, D.M. and Ellis, J.B. (2008) A systematic approach for the comparative assessment of stormwater pollutant removal potentials. *Journal of Environmental Management*, 88: 467-478.

Semadeni-Davies, A. (2011) Urban Planning that Sustains Waterbodies: Review of Spatial Decision Support Systems for Urban Water Management., Prepared under contract C01X0908 funded by the Ministry of Science and Innovation, NIWA Client Report No:AKL2011-003.

Semadeni-Davies, A., Moores, J. and Altenberger, A. (2010) C-CALM development and application of a planning tool for stormwater management in New Zealand *17th Congress of the Asia and Pacific Division of the International Association of Hydraulic Engineering and Research incorporating the 7th International Urban Watershed Management Conference*, Auckland, New Zealand, 22-24 February, 2010.

Semadeni-Davies, A., Shankar, U. and Elliott, S. (2009) Using CLUES to Identify Impact Catchments – Waikato River Catchment Pilot Study, Prepared for AgResearch, NIWA client report: HAM2009-101.

Shoemaker, L., J., R., Alvi, K., Zhen, J.X., Paul, S. and Rafi, T. (2009) SUSTAIN – a framework for placement of best management practices in urban watersheds to protect water quality, EPA/600/R-09/095, US EPA.

Storey, R.G., Neale, M.W., Rowe, D.K., Collier, K.J., Hatton, C., Joy, M.K., Maxted, J.R., Moore, S., Parkyn, S.M., Phillips, N. and Quinn, J.M. (2011) Stream Ecological Valuation (SEV): a method for assessing the ecological functions of Auckland streams, Auckland Council Technical Report 2011/009.

Taylor, A.C. and Fletcher, T.D. (2005) Triple-bottom-line assessment of urban stormwater projects. *10th International Conference on Urban Drainage* Copenhagen, Denmark, 21-26 August 2005.

Timperley, M., Skeen, M. and Jayaratne, J. (2010) Development of the Contaminant Load Model. Auckland Regional Council Technical Report 2010/004.,

Voinov, A. and Brown Gaddis, E.J. (2008) Lessons for successful participatory watershed modelling: a perspective from modelling practitioners. *Ecological Modelling*, 216: 197-207.

Walker, W.E., Harremoës, P., Rotmans, J., van der Sluijs, J.P., van Asselt, M.B.A., Janssen, P. and Krayer von Krauss, M.P. (2003) Defining uncertainty. A conceptual basis for uncertainty management in model based decision support. . *Integrated Assessment*, 4: 5-17.