Increasing the uptake of building-scale water sensitive urban design stormwater management options in Christchurch, New Zealand

A thesis submitted in fulfilment of the requirements for the Degree of Master of Water Resource Management at the University of Canterbury

Vicky Southworth, April 2019
Abstract

Christchurch Ōtautahi, New Zealand, is a city of myriad waterways and springs. Māori, the indigenous people of New Zealand, have water quality at the core of their cultural values. The city’s rivers include the Avon/Ōtākaro, central to the city centre’s aesthetic appeal since early settlement, and the Heathcote/Ōpāwaho. Both have been degraded with increasing urbanisation. The destructive earthquake sequence that occurred during 2010/11 presented an opportunity to rebuild significant areas of the city. Public consultation identified enthusiasm to rebuild a sustainable city.

A sustainable water sensitive city is one where development is constructed with the water environment in mind. Water sensitive urban design applies at all scales and is a holistic concept. In Christchurch larger-scale multi-value stormwater management solutions were incorporated into rapidly developed greenfield sites on the city’s outskirts and in satellite towns, as they had been pre-earthquake. Individual properties on greenfield sites and within the city, however, continued to be constructed without water sensitive features such as rainwater tanks or living roofs.

This research uses semi-structured interviews, policy analysis, and findings from local and international studies to investigate the benefits of building-scale WSUD and the barriers that have resulted in their absence. Although several inter-related barriers became apparent, cost, commonly cited as a barrier to sustainable development in general, was strongly represented. However, it is argued that the issue is one of mindset rather than cost. Solutions are proposed, based on international and national experience, that will demonstrate the benefits of adopting water sensitive urban design principles including at the building-scale, and thereby build public and political support. The research is timely - there is still much development to occur, and increasing pressures from urban densification, population growth and climate change to mitigate.
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Glossary

1 in 100 year storm: describes a design rainfall that could be expected to occur over a specified period of time at a given location based on statistics and rainfall data. For example, in Christchurch 38 mm total rainfall depth falling in a 2 hour period has a probability of 2% of occurring in any given year, equivalent to once every 50 years (1 in 50 year, 2 hour storm). This storm would have an intensity of 19 mm/hour. It is important to note that the frequency of occurrence is a statistical likelihood meaning two 1 in 50 year storms could occur in the same place in the same year and not be repeated for another 100 years.

At-source: Site design, materials choice and small-scale devices that reduce contaminant and runoff generation close to source to minimise the impact of development on the wider environment. Includes both building-scale and streetscape devices.

Baseflow: Water that seeps or flows into waterways from the groundwater table. A more consistent source of water than surface flows which only occur during a storm event. Particularly important during periods of dry weather to maintain a minimum flow.

Global stormwater consent: A time-limited consent with conditions granted by ECan to CCC to permit stormwater discharge from the stormwater network to the natural environment. The stormwater network receives multiple inputs from many land use types across the city.

Groundwater: Water flowing within the ground augmented by infiltrated rainwater.

Green infrastructure: Describes a broad concept of incorporating ecologically-supportive and people-friendly spaces into urban environments, often creating linkages for use as paths and cycleways. In the context of stormwater management the devices that include planting are particularly supportive of this concept, and therefore includes rain gardens and tree pits.

Kaitiaki: Guardian of the environment

Low Impact Development: Using recognised best practice techniques in urban development to promote the efficient use of natural and physical resources and to reduce environmental impacts. It includes freshwater, energy use and conservation values.

Māori: The collective term for New Zealand’s indigenous people used since colonisation.
Mahinga kai: All the natural resources and traditional techniques involved in providing food, fibres, medicines, fire-making, etc., including the land providing those resources.

Ngāi Tahu: The tribal group, or iwi, with authority in Canterbury and other areas of South Island.

Ngāi Tūāhuriri: The sub group, or hapū, with customary rights and responsibilities in Christchurch Ōtautahi.

On-site: At-source solutions applied within the boundary of a property (building and grounds) whereby maintenance responsibility lies with the property owner.

Rain planter: A planted container placed above ground that receives and treats roof runoff. Useful where space or groundwater levels restrict the use of a rain garden.

Regional scale: Large-scale WSUD devices at the end-of pipe or treatment train, typically retention or detention basins and/or wetlands, receiving stormwater from multiple subdivisions and public road networks.

Site scale: Larger-scale WSUD devices for a wider area than at-source, such as a collective system on a subdivision or within a road scheme. Typically maintenance responsibility is transferred to the local authority after completion of the development.

Stormwater: Water that collects and flows off urban surfaces during a rainfall event.

Streetscape: Devices installed in the street to capture runoff generated on the street and that flows from private property if building-scale devices are absent. Installations are carried out by the local authority, or by a developer as part of a subdivision development with maintenance responsibility transferring to the local authority. Usually bio-swales, grass swales or rain gardens in Christchurch currently.

Tree pit: A subset of a rain garden and therefore providing stormwater treatment and some storage but designed to contain a tree without risk of roots damaging infrastructure.

Water sensitive city: A city that treats all urban water resources respectfully and is designed to mimic the pre-development water cycle. Rainfall is treated as a resource that enhances the urban environment and is used for water supply to minimise imported and treated water
demand. Individuals’ awareness of and responsibility towards water is an important requirement since a water sensitive city relies in part on decentralised solutions.

**Acronyms**

CCC - Christchurch City Council  
ECan - Environment Canterbury  
LID - Low Impact Development  
LWRP - Canterbury Land and Water Regional Plan  
NIWA - New Zealand Institute of Water and Atmospheric Research  
NPS-FW - National Policy Statement for Freshwater  
NZIA - New Zealand Institute of Architects  
PPS - Permeable/porous paving systems  
RIBA - Royal Institute of British Architects  
RMA - Resource Management Act  
SuDS - Sustainable (Urban) Drainage System  
SWS - Surface Water Strategy  
USEPA - United States Environmental Protection Agency  
WERF - Water Environment Research Foundation  
WSS - Water Supply Strategy  
WSUD - Water Sensitive Urban Design
Chapter 1 – Introduction

Urban drainage history and impacts

Drainage networks have been developed to manage excess runoff, known as stormwater, within cities and towns for centuries. The proportion of impervious surfaces rapidly expanded through the twentieth century to accommodate a growing urban population and the car, resulting in larger volumes of runoff. The drainage network was also expanded to cope with this volume, moving rainwater rapidly away from where it falls to minimise ponding and localised flooding (Karvonen, 2011). The drainage network is a mixture of manmade and natural elements: connecting pipes; natural channels, although these may be straightened, contained or even buried; storage areas, buried and above ground; and larger waterways. In Christchurch, New Zealand (NZ), and other locations with a separate stormwater system, stormwater is discharged directly into a local waterbody.

The frequency and volume of runoff increases significantly as catchments become more urbanised. Runoff is generated even in small rainfall events, eroding riverbanks and contributing a regular source of contaminants. These frequent flows would not occur in a natural system and are detrimental to the ecological health of waterways since only the more tolerant species survive reducing diversity (Burns et al. 2012). The likelihood of flooding also increases due to the rapid delivery of water from impermeable surfaces via the stormwater network. Further, the extent of surface sealing has reduced infiltration which maintains the groundwater table and thereby provides a steady flow of water to the waterways, called baseflow. Baseflow supports flows even after surface runoff from a rainfall event has ceased and is particularly important during drier months to maintain minimum flows. This collection of impacts is known as urban stream syndrome (Paul & Meyer, 2001), and these problems are widespread globally (Booth, Roy, Smith, & Capps, 2016).

What is Water Sensitive Urban Design?

Water Sensitive Urban Design (WSUD) refers to a system that seeks to construct the urban environment in such as way as to mimic the natural hydrological cycle. To mimic the natural
system infiltration must be maintained to support baseflow, and a portion of rainfall must be used within the catchment to replicate evapotranspiration which is significantly reduced in an urban environment and reduce the reliance on imported treated water. Importantly rainwater is considered as a resource to be incorporated into the urban landscape in a visible way (Graham, 2017), rather than as a waste to be removed and rapidly piped away. To be effective WSUD has to be incorporated at all scales and requires a change in individual behaviour and thinking, as well as the use of technical devices (Graham, 2017). Unlike the current drained system which is predominantly developed and maintained by the local authority, WSUD places some responsibility back onto landowners, including developers temporarily involved through an initial development project, as well as longer term property owner/occupiers. Developers and property owners can improve the management of rainwater that falls on their site by paying attention to impervious surface materials and coverage, as well as incorporating devices to retain or detain water on site. Where water supply is limited systems that recycle wastewater are also incorporated into the built environment. Wastewater recycling systems are not considered in this research however since they are expensive and much cheaper and simpler rainwater harvesting systems are uncommon.

In addition to reducing contaminant transport and limiting flows other WSUD benefits include intangible or hard to measure benefits, such as reduced urban heat island effect, increased biodiversity, amenity and landscape improvements. WSUD also requires urban water supply and wastewater flows to be reduced, and therefore includes water efficiency measures, such as low flow taps, and systems that treat and reuse greywater and wastewater as fit-for-purpose.

WSUD is more easily applied to greenfield development than retrofitting into existing development. The site layout can be designed to retain and support features that naturally limit the generation of runoff, such as stands of trees or wetland areas. These features also enhance the landscape. Buildings can be designed to limit their effect on water quality and runoff by careful siting, minimising footprints and using non-polluting building materials. Residual runoff can be limited by using permeable surfaces to increase infiltration, and rainwater collection with reuse to simulate evapotranspiration losses. Larger areas needed for retention or detention during heavier storms should be designed for amenity and/or
biodiversity benefits since the storage function is only needed infrequently and for a limited period of time. Stormwater runoff from a site designed in this way would more closely mimic the pre-development hydrological pattern and rainfall becomes beneficial and valued. The Earthsong development in Ranui, Auckland, NZ, demonstrates this complete approach to site design (Figure 1.1), laid out and constructed to minimise the impact of the development on the water environment, including the use of devices that support infiltration and water reuse. The community is committed to ongoing maintenance and supporting their ecosystem.

Figure 1.1: Earthsong, Ranui, Auckland. A housing development demonstrating the complete WSUD approach including site layout, building design and water sensitive features and devices.

For the majority of sites in Christchurch, and urban catchments the world over, the opportunity to apply WSUD citywide is limited by pre-existing land development and ownership patterns. Even new subdivisions are constrained by the ongoing preference for patchworks of privately owned blocks of land, each developed in isolation connecting to publicly maintained infrastructure, rather than the community-styled development seen at Earthsong. Building-scale devices, described in the next section, can be applied to individual properties on greenfield and infill development sites, and retrofitted to existing property to
help reduce the impact of traditional urban development. Infill development is where areas of existing development are densified by the construction of properties on under-used land or through demolition and replacement with more units.

**Building-scale WSUD devices**

There are broadly four types of stormwater device that can be included with new buildings or retrofitted to existing properties to support the WSUD concept. These devices have been used successfully on and around buildings internationally and within New Zealand:

**Living roof** (also *green/brown/eco roofs*) - a roofing system with growing media and drainage layers placed over the waterproofing layer to support plants, providing habitat and reducing runoff by absorbing and storing rainwater which subsequently evapotranspires or, under higher rainfall intensity or prolonged rainfall, gradually drains via the gutters. The traditional ‘green’ roof has been replaced with a broader concept of design that accommodates the local climate, desired aesthetic, or habitat creation goals, hence the various names (Figure 1.2). For this thesis the term ‘living roof’ will be used.

**Figure 1.2:** Living roof on the Tait Technology Centre, Christchurch, seen from a foyer area.
Rain garden (bioretention) - an attractively planted shallow depression that provides an area for runoff to drain to and pond in temporarily (<48 hours) (Figure 1.3). Runoff infiltrates through the plants’ growing media to drainage layers and either enters the piped stormwater network via an underdrain, or infiltrates the underlying soils. An underdrained rain garden includes a drain which releases water gradually back to the stormwater network as it collects above an impermeable membrane laid at the base of the system to prevent infiltration. The water quality is improved primarily through filtration, adsorption and biodegradation of pollutants in the soil and through uptake by plants. If the rain garden is designed to allow infiltration then baseflow is augmented and total runoff volumes are reduced. Evapotranspiration from the plants also reduces the runoff volume and can enhance biodiversity. A similar concept is a tree pit - the principles are the same but the pit is deeper and designed to contain the roots.

The Terraces, central Christchurch
Public car park, Sumner, eastern suburb

Figure 1.3: Streetscape rain gardens in Christchurch

Permeable/porous paving systems (PPS) - A paving system that has a permeable upper layer (block paving with permeable gaps, plastic or concrete grids with grass, or porous asphalt or concrete) with storage under the surface. A block type permeable paving system is visible in Figure 1.1. An aggregate mix with a high void ratio is used as a sub-base to retain water while it percolates into underlying soils, or flows via an underdrain to the stormwater network. Runoff to waterways is slowed, and contaminants are reduced, primarily by filtration and adsorption, but also biodegradation in some systems. A standard PPS construction can effectively manage runoff directed from an area at least as large again, such

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1 These terms are sometimes used interchangeably, but US literature often distinguishes between them using the term rain garden for a smaller landscaped feature associated with a private home, whilst bioretention is reserved for a larger scale engineered system that might be used in a road or commercial car park.
as an area of roof or impervious driveway. Systems can be constructed with increased underground water storage, including setups for reuse.

**Rainwater harvesting** - typically above or below ground tanks are used to store runoff from roofs, but can be incorporated with a PPS. Rainwater harvesting tanks are installed so that at least some of the water is available for internal and/or external uses compatible with the quality of water collected, such as flushing toilets and irrigation, known as ‘fit for purpose’ (Figure 1.1). The potential for reducing demand for high quality potable water is governed by two key factors, the total annual rainfall and the distribution of rainfall throughout the year. By diverting runoff to beneficial uses the total volume of water released to the stormwater drains is reduced. A reduction in runoff volume also means a reduction in pollutant load in a city with a separate stormwater network, such as Christchurch. Rainwater tanks can be set up to balance the competing aims of water storage for use and available volume to temporarily capture excess runoff generated during a storm thereby supporting flood management aims (Melville-Shreeve, Ward, & Butler, 2017).

**WSUD in Christchurch**

Christchurch was selected for this study because it is undergoing significant redevelopment and change following a damaging earthquake sequence that occurred in 2010/11, providing an opportunity for the inclusion of WSUD. The city experienced a permanent removal of housing in ‘red zoned’ areas where land was deemed unsuitable for built development due to a high risk of damage from future earthquake events or flooding. In response, new housing subdivisions on the outskirts of the city were rapidly developed. These new suburbs have incorporated some water sensitive features at the street, site, and regional scales, in line with council guidelines (Christchurch City Council, 2012), including grassed or vegetated ditches, known as swales, planted retention basins and wetlands. However, building-scale WSUD devices that reduce runoff from individual properties, such as small rain gardens and permeable paving, or rainwater collection for reuse, have been largely absent. Similarly, in the central city whole blocks were demolished, with 1240 buildings demolished within the city’s Four Avenues between September 2010 and February 2015 (Gates, 2015). Some new commercial buildings have included rain gardens such as the Bus Interchange (a central
government anchor project) and King Edward Barracks (Ngāi Tahu Property development), but the majority do not appear to have done so.

Cost considerations are always important when approaching a construction or renovation project which will have budgetary constraints. Examples are published of WSUD providing a cost effective method of mitigating contaminant and flood issues, compared with traditional drainage infrastructure, but this is when applied to a whole subdivision or highway scheme (United States Environmental Protection Agency, 2007 cited in Roy et al., 2008). At the individual building-scale the cost to landowners compared with direct benefits is likely to be higher (Montalto et al., 2007). At present, in Christchurch, runoff is usually directed as rapidly as possible to the council’s stormwater network. Residents pay for water supply and stormwater management as a component of rates, and commercial volumetric charges when applied are low. Therefore direct benefits to the site owner/occupier for reducing and/or reusing runoff are limited. There are many potential benefits associated with building-scale WSUD devices, such as improved waterway health, reduced heat island effect, increased biodiversity, and reduced flooding, but these are often societal, cultural and environmental benefits which are difficult to value and subjective. There is limited motivation for individuals and businesses to mitigate the environmental externalities generated by stormwater leaving their sites, other than altruism.

Runoff management has been insufficient to achieve water quality suitable for contact recreation\(^2\), the gathering of mahinga kai\(^3\), and survival of more vulnerable macro invertebrate populations that support a diverse and healthy ecosystem (Christchurch City Council, 2009a).

(Christchurch City Council, 2009a). There is as an increasing focus on the cumulative effects of stormwater runoff in New Zealand, resulting in legislative requirements for local authorities to reduce the negative effects of stormwater contaminant inputs to waterways (Environment Canterbury, 2017; Ministry for the Environment, 2017). To reduce stormwater contaminant concentrations will incur a cost. Building-scale WSUD solutions seek to reduce the impact of contaminants and excess runoff volume from individual sites, thereby

\(^2\) Activities that bring people into contact with the water environment, such as swimming, where water could be accidentally inhaled or swallowed.

\(^3\) The term ‘mahinga kai’ encompasses all the natural resources and traditional techniques involved in providing food, fibres, medicines, fire-making, etc., including the land providing those resources.
internalising the cost of managing the social and environmental impacts generated by each site - the polluter pays principle. If landowners, residents and businesses take more responsibility for the runoff leaving their land rates increases for new public stormwater treatment devices, needed to achieve the increasingly stringent water quality targets, could be reduced. This could partially offset the cost of on-site installations and ongoing maintenance.

Future impacts

The urban strategy in place at the time of the earthquakes anticipated population growth and included a mix of greenfield and infill development, with intensified urban areas anticipated to absorb about two thirds of growth (Environment Canterbury, Christchurch City Council, Selwyn District Council, Waimakariri District Council, & Transit New Zealand, 2007). Following the earthquakes, rapid greenfield development occurred to provide housing for displaced residents. There is now a need to promote infill amongst existing developed areas to accommodate future population growth (Canterbury Regional Council, 2016), for example replacing a single villa with several units. Without mitigation the proportion of impervious surface coverage, and therefore runoff and contaminant transport, is likely to increase (Christchurch City Council, 2009a). Climate change predictions indicate a potential for increased rainfall intensity and therefore greater runoff peaks and volume. Building-scale WSUD devices offer an opportunity to mitigate these future pressures that will exacerbate the existing situation.

Thesis objectives

Objective 1: Identify the reasons for the lack of adoption of WSUD at the individual property level, with particular reference to Christchurch

The impacts of urban runoff were well understood by stormwater practitioners prior to the earthquakes, and goals for improvement were set out in the Surface Water Strategy 2009-2039 (SWS) (Christchurch City Council, 2009a). The opportunistic inclusion of streetscape rain gardens in public spaces and roadways during the city’s reconstruction, particularly through central Christchurch, is in keeping with the strategy (Figure 1.2).
However, building-scale devices, also included within the strategy, have not featured heavily as part of the rebuild. With this context, one aim of this research is to identify the barriers that have resulted in the rebuilding and renovation of the majority of buildings and their curtilage without the inclusion of WSUD devices to date.

**Objective 2: Discuss the cost-benefit of individual building-scale WSUD in both new build and retrofit projects**

The costs and benefits will be viewed differently by different stakeholders depending on their personal values, circumstances, knowledge and the timeframe decisions are based upon. For example a developer building a property to sell is likely to prioritise upfront costs compared with an investor building a property to lease long-term who may be interested in whole-of-life costs. Similarly in the context of a residential property, the considerations are likely be different for a homeowner with a long-term vested interest in the local community, compared with a landlord seeking to maximise profits. The cost-benefit considerations of installing and maintaining building-scale WSUD devices have been touched upon in the introduction. How these affect the barriers to and opportunities for increasing their uptake is considered in greater detail as part of this research.

**Objective 3: Make recommendations that, if implemented, would lead to an increase in the uptake of WSUD at the individual building-scale in Christchurch**

Christchurch is still undergoing rapid and extensive development. An important objective is to make recommendations that, if implemented, could increase the uptake of building-scale WSUD solutions in both new and existing buildings across the city. Recommendations will pay attention to variations that exist within the city including topography, geology, development density and land use types.

**Summary**

A literature review covering the potential for building-scale WSUD devices to improve water quality and reduce peak flows both on an individual basis and at a catchment scale is addressed in Chapter 2. There is an assumption behind this research that building-scale devices would be a positive addition to Christchurch and Chapter 2 assesses the evidence for

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4 Combination of upfront costs, operation and maintenance, and end-of-life costs.
supporting measures to increase the uptake of such devices. A review of barriers to uptake that have been identified elsewhere in New Zealand and internationally is presented in Chapter 3 together with solutions that could be considered to overcome these barriers. Chapter 4 provides the Christchurch context including presenting details on waterway health; a review of relevant national, regional and local policy; anticipated impacts from infill development and climate change, current plans to accommodate it and their likelihood of success. The methodology in Chapter 5 describes how the barriers relevant to Christchurch were identified. Findings and conclusions follow in Chapters 6, 7 and 8, addressing the thesis objectives. Chapter 6 discusses the barriers to the uptake of building-scale WSUD solutions and addresses objective 1. Chapter 7 sets out recommendations to increase the uptake with a Christchurch focus, addressing objective 3, but also reflects on the cost-benefit of some stormwater management occurring on site using WSUD solutions, addressing objective 2.
Chapter 2 - General principles of WSUD

Introduction

In Chapter 1 the four main building-scale WSUD devices for on-site stormwater management were introduced. This chapter will assess the benefits that each device can deliver, both in terms of environmental benefits and direct benefits to the site owner/occupier. In addition their relative cost will be considered, again from the perspective of a site owner. Research based in New Zealand has been prioritised, where it exists, albeit that studies based in Auckland come from a wetter, larger and more densely developed city than Christchurch. Internationally, research from northern Europe, northern United States (US) and Melbourne, Australia, has been included since their climates are not too dissimilar from Christchurch, at least compared with studies located in the tropics or arid areas for example. The research from these areas augments the New Zealand work as it is more abundant and governmental support for WSUD at multiple levels has been in place for longer and more extensively. To determine whether encouraging or requiring building-scale devices is justified the potential cumulative improvement on catchment hydrology and water quality will be assessed.

Individual building-scale devices

The impact of draining impervious surfaces directly to waterways is well known. Walsh, Fletcher and Burns (2012) reviewed the actions required to reinstate ecologically healthy waterways in urban catchments. For a waterway to be in good ecological condition contaminants should only be present in low concentrations and fluctuations in water temperature caused by runoff warming as it passes over man-made surfaces should be limited. Algal and invertebrate assemblages should be comparable with those in an undisturbed catchment in the same region. To achieve this ecological aspiration they concluded that almost all runoff from impervious surfaces needs to be intercepted and treated. Critically, to mimic pre-development hydrology they state that a proportion of runoff must be captured and retained within the catchment to counter the loss in evapotranspiration from vegetation clearance, and a proportion should be infiltrated to augment groundwater levels. Table 2.1 presents a summary of the processes that the four
key devices suitable for use at the building-scale enable in order to support water quality improvements and flood reduction. Some of the additional benefits and a ballpark cost guide are also included as these are relevant to decision-making if considering installing a device. Volume reduction is important for both reducing contaminant load transported to the receiving water environment and supporting flood management (Sage, Berthier, & Gromaire, 2015), and hence it is included twice.

Table 2.1 - Comparison of the four main building-scale WSUD devices. (Adapted from Digman et al., 2012; Woods Ballard et al., 2015)

<table>
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<th>Flood management</th>
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<th>Other benefits</th>
<th>Cost</th>
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<td></td>
<td>Effectiveness</td>
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<td>Biodegradation</td>
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<td>Uptake by plants</td>
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<td>Aesthetics</td>
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<td>Reduced land take</td>
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<td>Reduced heat island effect</td>
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<td>Runoff cooled before release</td>
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<td></td>
<td>Retrofit?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rain water harvesting</td>
<td>Low*</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Pervious pavement</td>
<td>High</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Living roof</td>
<td>Medium/high</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Rain garden/bioretention</td>
<td>High</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

P - possible
U - unlikely

* Dependent on design - balance between storage for reuse and space for flood management, and volume of demand compared with rainfall yield.
** Dependent on design - can be underdrained and directed to storm drains with no infiltration

Each type of device has a variety of advantages (Table 2.1). PPS and living roofs provide stormwater management benefits whilst avoiding taking up land that can be used for other purposes, such as parking, and are therefore easier to fit into densely built up urban areas. These solutions are particularly attractive to developers seeking to maximise building footprint and parking spaces on a constrained site. Rain gardens and living roofs enhance biodiversity and reduce the temperature of runoff. Whilst living roofs provide many benefits, retrofit opportunities may be limited due to structural requirements (S. Wilkinson, Proverbs, & Lamond, 2017) and they are much more expensive than the other building-scale WSUD devices. Advantages of living roofs such as reduced energy bills through insulation and cooling can be achieved with cheaper insulation options (Lamond, Wilkinson, & Rose, 2014).
Conversely, rainwater harvesting is relatively cheap and easily retrofitted, but if used only as a source of water for irrigation it has a very limited effect on runoff peaks and volume during winter in temperate climates. A rainwater harvesting system connected for regular non-potable internal uses, such as laundry and toilet flushing, will provide a greater flood management capability (DeBusk, Hunt, & Wright, 2013) but is more complex to install retrospectively. For this reason installing rainwater harvesting with new build construction or during refurbishment is important to gradually achieve a proliferation of these systems. In areas with volumetrically charged water supply and wastewater services the payback for investing in rainwater harvesting is around five years. Without both fees the payback period can be decades (BRANZ, 2018). PPS can be relatively easily retrofitted, particularly when a driveway is being replaced.

Beyond considering the immediate benefits and improvements a device can offer, it is also important to consider the long term maintenance costs as this will provide the complete lifecycle cost of a device. Lifecycle cost more accurately reflects the true financial impact of installing a particular WSUD solution rather than just comparing upfront costs. Good design will minimise and simplify maintenance (Berwick, 2017). Interest in lifecycle costs will depend on the installer however. If a developer installs a device and maintenance is transferred to a new owner, then upfront cost carries greater significance in the decision-making process. Devices located on public land or buildings will fall to the local authority to maintain, while devices on private property are the responsibility of the property owner. Chui, Liu & Zhan (2016) found PPS to be most cost effective for reducing peak flows, including rain gardens for comparison in their analysis.

Living roofs extend the lifespan of the waterproof membrane that would usually be exposed to damaging ultraviolet light (UV) on a standard flat roof construction. A living roof lifespan can be 40 to 55 years, which is around double that of a conventional roof (Bianchini & Hewage, 2012). Ongoing maintenance is greater, however, with weeding and occasional fertilising required. Irrigation may be needed depending on the climate and soil depth. Rain gardens similarly need attention given to the planting. They can be susceptible to clogging, which reduces infiltration rates, particularly in areas with a high sediment load in the runoff. PPS is also susceptible to clogging, and weed growth in paving block systems. A four-year study of three different PPS types found significant declines in infiltration rates occurred,
Despite maintenance (Kumar et al., 2016). These devices need to be wet vacuumed to remove fines and maintain high infiltration rates. The filler in a block-type PPS may then need replacing. However, even with clogging the infiltration rates were substantial and a different maintenance regime may help to reduce the clogging rate (Kumar et al., 2016). Rainwater harvesting tanks on the other hand are easily maintained, particularly if filters are installed to avoid leaves entering the tank.

Flood management

The impacts on urban hydrology caused by the expansion of sealed surfaces has long been well understood (Leopold, 1968). Impervious surfaces result in an increased runoff peak and total volume. The piped network conveys this volume to the end of the system which discharges into a receiving waterbody. During large rainfall events the piped network becomes overwhelmed when its design capacity is exceeded and excess water concentrates into overland flow paths. In the case of discharge to a waterway, the enhanced speed of rainwater transfer through the catchment results in a rapid rise and increased peak in flow compared with the pre-development hydrological response. The size of the peak determines whether flow remains within a river’s banks or overtops and spreads across the floodplain, potentially causing damage to property. Smaller scale more localised flooding that generally causes inconvenience or nuisance, rather than property damage, results from ponding of water and overland flow when the piped network is overwhelmed.

A conventional technique for reducing flood impacts is to construct water storage areas within the landscape or underground with restricted discharge rates to slow the delivery of runoff to the waterway. Delivery times from different sub-catchments can be offset by introducing lags to reduce effect of peaks from different areas arriving together and increasing the total peak (McCuen, 1979 cited in Jarden, Jefferson, & Grieser, 2016). Traditionally retention or detention basins were designed purely to achieve flood reduction, but knowledge and design has improved to include additional benefits such as landscaping and water quality treatment. The availability of suitable land to create new large scale storage areas reduces as urban areas become more developed, a particular problem for intensifying areas with infill development. Where larger scale stormwater retention systems are feasible, whilst recognising that they can provide multiple-benefits, they also restrict
land use opportunities diminishing land available for other uses, including construction for example. Building-scale devices, such as PPS or rain gardens, can complement these systems by providing temporary storage with restricted outflow rates and/or infiltration to help reduce the runoff peak and total volume. They are also viable for inclusion in all areas and can be retrofitted into densely built up urban areas. They can also reduce the size of site or regional-scale devices, providing greater flexibility for land use planning (Bastien, Arthur, Wallis, & Scholz, 2010; Melville-Shreeve et al., 2017).

Rain gardens receive runoff from a much larger area than that which they occupy. The area will depend on the purpose and available space, so a rain garden installed to primarily capture pollutants from frequent rainfall events will be smaller than one designed to detain and infiltrate storm volumes. A rain garden in a large private garden receiving roof runoff may be sized at 10% or more of the contributing roof area (Bannerman & Considine, 2003), while a rain garden in a road or car park may be sized at nearer 3% of the contributing area (Christchurch City Council, 2016b). Rain gardens are designed to retain and evaporate water at the surface, designed to pond at a maximum depth of between 150 mm to 300 mm. The plant media provides some capacity for water retention within the soil pores. Excess stored water drains through the growing media to an underdrain or infiltrates into underlying soils within 24 to 48 hours to free up space for another storm and to avoid becoming a breeding ground for mosquitoes (Hinmann, 2013). In larger storms excess runoff will bypass directly to the stormwater network.

Rain gardens designed to infiltrate into in situ soils, rather than draining to the conventional stormwater network, will generally provide a greater benefit in terms of peak flow reduction, volume reduction and extended lag time to peak flow (Jarden et al., 2016). It is important to note however, that under some ground conditions infiltration can exacerbate flooding by raising the groundwater table locally (Locatelli et al., 2017) and can introduce or mobilise contaminants. Additional storage in the underground layers can be included to improve performance where low permeability soils are present (Auckland Council, 2017). Underdrained rain gardens will still create a lag in the delivery of peak flow. A direct connection to the stormwater network is included in all systems to prevent overflows in a large rainfall event, except when built in an area that can safely discharge to adjacent land.
PPS is designed to store water in the basecourse and sub-base materials which are specified to provide 30% void space (i.e. a 5 m by 3 m parking space with a 0.30 m thick underlying basecourse will provide 1.3m$^3$ of storage). Permeable paving constructed in this way can receive runoff from an impermeable surface of equal area without needing to increase the storage volume. Permeable paving can be underdrained, or designed to infiltrate into the natural soils and includes a connected overflow, just as with a rain garden. The design parameters are set to ensure the stored volume is drained gradually and storage is made available for subsequent rainfall events. An experiment on four types of PPS found that after six years of use almost no runoff was generated during fifteen analysed rainfall events totalling 570 mm of rainfall with a maximum intensity of 7.4 mm/h (Brattebo & Booth, 2003). As with rain gardens, the greatest environmental and flood reduction benefits are achieved with an infiltrating system if the site conditions are suitable (Lashford, Charlesworth, Warwick, & Blackett, 2014; S. Wilkinson et al., 2017). Again, as with rain gardens, PPS will create a lag in the time to peak flow (Lashford et al., 2014).

Debusk et al. (2013) monitored four rainwater harvesting systems in North Carolina, an area of the US with plentiful winter rainfall, and showed that systems used for irrigation purposes overflowed frequently during winter when there was no need to draw the water. Consistent year round water uses, such as for toilet flushing and laundry, ensures water is taken regularly, freeing up space and improving stormwater management benefits (DeBusk et al., 2013). Alternatively temporary storage can be added to the rainwater harvesting tank to support flood reduction.

In the UK the British Standard 8515 for rainwater harvesting systems includes a method for designing a dual-purpose tank with storage for reuse, and temporary storage with a slow release orifice for runoff capture during a storm event (BSI 2013 in Melville-Shreeve et al., 2017). Rainwater harvesting is difficult to justify on the basis of water supply alone in regions with plentiful water and therefore needs to be designed to be multi-purpose, such as providing stormwater management (DeBusk et al., 2013). Figure 2.1 shows this conceptually.

The Environment Agency in the UK estimated 75% of commercial and industrial sites are suitable for retrofitting rainwater tanks for internal water use, and 50% of public buildings such as schools and hospitals (Gordon-Walker, Harle, & Naismith, 2007). These sites may be
sufficiently spacious to include dual purpose rainwater harvesting tanks to support flood management.

![Figure 2.1](https://docs.google.com/document/d/1RobScioOB-ZVGOHPRD_8h11YwFUHDOJBjcgd6ObQLEA/edit#)

**Figure 2.1**: Rainwater tank design for single and dual purposes. (Adapted from Melville-Shreeve et al., 2017).

Modelling shows that it is feasible to use rainwater harvesting tanks to reduce flood impacts, even for large storms, but the size of tank required could be substantial and therefore less easily retrofitted to existing residential properties. An example based on a UK housing development shows an additional 1500 L of temporary storage and discharge rate limited to 0.5 L/s is sufficient to mitigate roof runoff for the most significant 1 in 100 year return high intensity short duration storm; however, the roof area of each home was only 50 m² (Melville-Shreeve et al., 2017). The average floor area of New Zealand homes built in 2010 was 205 m² (QV, 2011) and is often of single storey construction. This New Zealand home would need around 6000 L of storage for a similar design storm. Rainwater collection for garden use alone can be easily retrofitted: the Environment Agency in the UK estimates that 90% of semi-detached and detached homes could install one, but these have very limited benefit in terms of flood reduction (Gordon-Walker et al., 2007).

Living roofs are typically formed by placing growing media and drainage layers over a standard shallow pitched waterproofed roof construction (Figure 2.2). The plant layer on a living roof intercepts rainfall which moves through the plants to the growing media and

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5 Style of house where two properties are built together sharing a central dividing wall.
6 A house built separately from others with no shared walls.
Evapotranspiration is an important process for removing stored water and freeing up capacity for future rainfall events (Gregoire & Clausen, 2011). The retention capacity depends on several factors, including the type of vegetation used, the thickness of the growing media, the rainfall intensity and the preceding dry period. Living roofs generally reduce runoff peak and volume, and delay the time to peak runoff (S. Wilkinson et al., 2017). Fassman-Beck and Simcock (2013) report that a well designed roof with adequate permeability and underlying drainage will always mitigate peak flows, even for large storms, albeit less effectively than for the smaller events. In an Auckland study median peak flow reductions from four living roofs ranged from 62% to 90%, compared with a conventional roof, monitored over periods of 8 to 28 months (Fassman-Beck & Simcock, 2013). Intensive systems (growing media >150 mm thick) have a greater rainwater retention capacity compared with an extensive system (<150 mm thick), but are more often developed for recreational access which can reduce the proportion of the roof covered with living roof layers (S. Wilkinson et al., 2017).

**Figure 2.2:** Typical living roof construction layers. Adapted from Czemieli Berndtsson (2010).

**Quality treatment**

The concentration of contaminants in stormwater runoff varies significantly depending on various factors, such as the surface types the rainwater makes contact with, the distance travelled from where it falls to where it enters the stormwater network, and the intensity
and duration of a storm. Roads and car parks give rise to multiple contaminants including zinc from rubber tyres, copper and other metals from brake pads, sediment, oils and greases. A rapid rate of build up of contaminants is associated with heavily used roads and industrial areas where heavy-vehicle traffic is present (Revitt et al., 2014, cited in Lundy, 2016). Metal roofs can contribute significant concentrations of metals to stormwater, particularly if poorly maintained or uncoated (F. J. Charters, Cochrane, & O’Sullivan, 2016).

Establishing the effectiveness of individual devices in reducing contaminant concentrations in stormwater runoff is a common theme in research literature. A summary of findings collating multiple international studies that included PPS and rain gardens showed that significant reductions in contaminant concentrations can be achieved by both devices (Liu, Ahiablame, Bralts, & Engel, 2015). This is unsurprising given the range of physical, chemical and biological processes that occur within these devices (see Table 2.1 above). However, there is also a large variation in the reported efficiencies across the multiple studies for both device types.

Contaminant reduction efficiency is used to describe the effectiveness of a device at removing contaminants from stormwater. To calculate this, samples of stormwater flowing into and out of a device are taken at regular intervals throughout a rainfall event. The average concentration for each contaminant at the outflow is compared with the inflow and the difference is presented as a percentage change (Lundy, 2016). A positive change represents a reduction in contaminant concentration. The change in concentration is not only related to the device type, but also to the initial concentration of contaminants which can result in a wide variation in calculated efficiencies even for the same device (Liu et al., 2015). For example, copper reduction in rain gardens is reported between 37% and 98%, and between 13% and 67% for PPS. However, a large percentage reduction in concentration may still be insufficient to achieve water quality targets, and hence this method of comparison has been criticised (Fassman, 2012). Sometimes, and clearly undesirably, a device can become a contributor of contaminants, for example by washing out copper in fungicides used in compost mixes, or in the case of block-type PSS poor installation can result in sand loss from joints (Fassman & Blackbourn, 2008; Trowsdale & Simcock, 2011). To date percentage reduction is still commonly reported and used for comparing devices.
An Auckland study investigating the treatment efficiency of a rain garden located in a heavily trafficked road found that total suspended sediments (TSS) and total and dissolved zinc were effectively reduced, but copper reduction varied and was even remobilised in some events (Trowsdale & Simcock, 2011). A study investigating a rain garden treating runoff from a multi-storey car park at Monash University, Melbourne, Australia found TSS and heavy metals, including copper, were consistently reduced (Hatt, Fletcher, & Deletic, 2009). Well designed, constructed and maintained rain gardens have been demonstrated to effectively manage contaminants that are commonly found in stormwater runoff from road surfaces and metal roofs, although dilution by a receiving waterbody is still frequently required to meet ecological trigger values for copper and zinc (Fassman, 2012).

An Auckland study monitoring a 200 m$^2$ area of PPS (block type) installed in a stretch of road found pollutant control to be ‘substantial’ for the contaminants of local concern which were TSS, zinc and copper. Runoff volumes were also effectively managed, with rain events up to 7 mm depth generating no measurable runoff, despite very low permeability soils underlying the site and a high slope angle of around 6.5% (Fassman & Blackbourn, 2010). As described previously, runoff frequency reduction and retention of stormwater volumes is critical for improving waterway ecology (Walsh et al., 2012). Volume reduction is very varied both with different devices and for the same device type. Runoff volume reduction is reported to vary between 0.4% to 93% for rain gardens, and 50% to 93% for PPS (Liu et al., 2015).

Living roofs reduce contaminants present in atmospheric dust that settles on the roof surface, such as zinc (Gregoire & Clausen, 2011). The use of a living roof also removes the potential for future increases in contaminants that result from poor maintenance of metal roofing surfaces long term. It is important to note however, that living roofs can also contribute contaminants depending on the use of fertilisers and other additives that may be present in the growing media (Gregoire & Clausen, 2011; Trowsdale & Simcock, 2011).

Reduction in the frequency and magnitude of runoff during small rainfall events is probably the most significant benefit to in-stream health provided by living roofs. One study reporting 88% of runoff retained for rainfall events of less than 25 mm (Carter & Rasmussen, 2006, in Czmiel Berndtsson, 2010). A study measuring runoff from four living roofs in Auckland found that all retained the majority of rainfall for events of up to 25 mm depth (Fassman-Beck & Simcock, 2013), very effectively reducing the small frequent flows. A
German study found that intensive living roofs reduced the total annual runoff volume by between 65% and 85% (Mentens et al., 2006, in Czemiel Berndtsson, 2010).

Rainwater harvesting reduces the volume of runoff directed to the stormwater network and thereby any associated contaminants. Runoff is diverted to the wastewater system if used for toilet flushing or laundry, or to land if used for irrigation. Environmental benefits are also achieved through the retention of small rainfall volumes in a frequently used harvesting system (DeBusk et al., 2013). The contaminant load reduction will vary with the volume of water removed through reuse, and the concentration of contaminants in the runoff. Contaminants will vary with the roofing material, coatings and condition, and build up of atmospheric dust (Ward, Memon, & Butler, 2010). The reduction in contaminants entering waterways through the use of rainwater harvesting is not often recognised as a benefit. Much of the research into WSUD devices is based in locations with combined stormwater and wastewater systems and stormwater therefore already passes through a treatment process before being discharged to a waterbody, unless an overflow occurs.

Some rainwater harvesting guides recommend removing the ‘first flush’ of rain water to avoid exceedance of drinking water standards for some determinands, such as metals and pathogens (Ward et al., 2010). Ideally a first flush would be diverted to a rain garden or other treatment system to avoid the contaminants entering the stormwater network instead. If the water is for non-potable uses it doesn’t need to be drinking water standard although quality standards should be set to ensure safety if used for showering or watering a vegetable garden for example.

**Catchment scale impact of building-scale devices**

The previous sections summarise the benefits that can be expected individually from the four most common building-scale devices. To have a measurable effect at the catchment scale devices need to be installed at multiple locations. This section will describe the effects that could be expected from wide scale implementation of building-scale WSUD devices. The predicted effects are based on modelling studies for the most part as very few catchment-scale field experiments have been carried out (Walsh, Fletcher, Bos, & Imberger, 2015).
Flood management

Fry and Maxwell (2017) modelled the effect of variably distributing residential rain gardens and streetscape rain gardens in a suburban upper catchment under a range of rainfall events, including 1 in 100 year return storms. Through a combination of modelling scenarios it was shown that rain gardens placed in critical flow paths to capture runoff during both small and large rainfall events were most effective in reducing peak flows and total runoff volume. Converting berms to streetscape rain gardens (representing 7% of the total catchment area) reduced the 2 year return storm peak flow by 25%, and 100 year return storm peak by 9%. Adding rain gardens to front gardens in streets with streetscape rain gardens only yielded a small benefit. This was because excess roof runoff that had not infiltrated via the lawn was already intercepted by the streetscape rain gardens in the absence of a storm drain network.

A model developed to calculate the effectiveness of different WSUD devices in reducing peak flows for a proposed housing development in Coventry, UK, found PPS to be very effective (Lashford et al., 2014). PPS was used on every driveway (7 m² each). Peak flow reductions of 19% for the 30 minute, 1 in 100 year return storm event, and 41% for a longer but less intense 6-hour storm were calculated. The scale of runoff reduction compared with the small PPS surface area was enabled by the diversion of runoff from adjacent road and garden surfaces as topography allowed. The PPS was modelled as non-infiltrating due to risks from previous land uses i.e. the model was based on an underdrained design. It was considered likely that the PPS would have been even more effective if infiltration had been viable.

A catchment-scale study investigating the effect of applying extensive sedum roofs across a densely developed urban area in Villette, near Paris, France, found that peak flows were reduced for smaller rainfall events, but the reduction was very dependent on the initial saturation of the growing media. If previously dry the peak reduction was 30% for a 10-year return interval storm of 26 mm depth over 2.5 hours, but only 5% for the same storm if the media was 50% saturated at the outset of the storm (Versini, Gires, Tchinguirinskaia, & Schertzer, 2016). Another catchment study, this time using 400 mm thick intensive roofs, also found that peak reductions were severely reduced if the growing media was saturated at the start of a rainfall event, varying from 33% reduction to a very a slight increase in peak
Masseroni and Cislaghi, modelling a large catchment, recommended that policies should aim to increase living roofs where the highest proportion of roof area exists within the catchment. Versini et al. (2016), however, modelling a much smaller urban catchment, warned that an additive effect can occur if only roofs close to the stormwater network outfall are adapted since a reduced but also delayed peak can combine with peaks from more distant areas to generate a larger peak at the outfall. This effect can also result from other WSUD types that create a lag in peak flow. Versini et al. (2016) recommend focusing living roof adaptation in upstream areas of a catchment to avoid this effect.

Sharma, Pezzaniti, Myers, Cook and Tjandraatmadja (2016) modelled the effect of installing rainwater harvesting tanks using 100 L of water per day to see if this could counteract the effect of a 20% increase in directly connected impervious surface created by infill housing in a catchment in Adelaide, Australia. The model demonstrated almost no reduction in peak flows even for relatively small rainfall events (1 year return) with 5000 L rainwater harvesting tanks or detention tanks connected to 38% of all houses in the catchment. A detention tank slowly releases water to ensure available volume at the start of the next storm and limit flows during a storm. The effect of infill was only mitigated when 100% of houses had tanks installed or rain gardens were incorporated into the street (Myers et al., 2014 cited in Sharma et al., 2016). The scale of mitigation required to reduce peak runoff rates generated by the additional impermeable surfaces due to infill development is important to acknowledge.

Larger rainwater tanks on commercial sites (40,000 L compared with 18,000 L) made little difference to modelled annual runoff reduction (Wright, Liu, Carroll, Ahiablame, & Engel, 2016) but if the authors had also investigated peak flows they may have found the extra volume beneficial in terms of flood management. A dual purpose rainwater harvesting system can support peak flow reduction in conjunction with other water retention devices (Melville-Shreeve et al., 2017), but requires a much larger tank which can be problematic in terms of space. Sharma et al. (2016) observed that a study using 10,000 L tanks for 200 m²
roofs had demonstrated peak flow reductions, but they thought that tanks of this size were unrealistic for use in a residential area in Adelaide. They also recognised that capturing roof water only is limited in effect because other impervious surfaces remain unintercepted.

There are very few studies monitoring the effect of retrofitting building-scale WSUD devices within real-world catchments but Jarden et al. (2016) carried out a catchment-scale experiment in a residential suburb in Parma, Ohio. Rain barrels and rain gardens were retrofitted to 13% of private properties on Klusner Avenue, together with multiple streetscape rain gardens. The installations reduced peak runoff by 25% for the larger storms and 40% for smaller storms that occurred during the monitoring period. Fifty-eight percent of total catchment imperviousness was due to streets, roads and driveways, and the researchers attributed the vast majority of peak flow reduction to the streetscape rain gardens, and particularly those designed to infiltrate, since they intercepted runoff from the dominant impervious surface types. The private property installations only disconnected a very small proportion (3.7%) of the total impervious area.

Quality

A reduction in annual runoff volume means the delivery of contaminants and the frequency of flows, both of which negatively impact on waterways, are reduced. If runoff reduction is by way of infiltration then groundwater levels and baseflows are supported, assuming connectivity naturally exists between groundwater and surface water features. Reducing the frequency of flows and enhancing baseflow are considered necessary to address ecological degradation in urban waterways (Ladson, Walsh, & Fletcher, 2006). A series of models were developed to investigate the reduction in annual runoff achieved by retrofitting a single WSUD device type as widely as possible into residential, commercial and central city areas in Lafayette, Indiana, US. It was found that annual runoff volume reduction was directly related to the proportion of the catchment covered by surfaces intercepted by each device type (Wright et al., 2016). This varies by land use.

Where living roofs were applied in a built up central city catchment to commercial and industrial roofs only annual runoff volume was reduced by 40%. In an out of town commercial area where roof surfaces were a lower proportion of the impervious surface total, a reduction of only 13% was calculated. PPS was more effective for the out of town
commercial area, reducing annual runoff by 51%, since paving areas that met the PPS retrofit criteria formed a large proportion of the impervious surface area. Rain gardens were most effective in all modelled catchments in the Lafayette study, reducing annual runoff by between 72% and 74% because bioretention was applied to all suitable impervious surfaces as well as open spaces i.e. the device could be applied extensively throughout all the modelled catchments (Wright et al., 2016).

Rainwater harvesting had a relatively limited impact on annual runoff volume in all catchments in the Lafayette study, with reductions ranging from 7% to 15% (Wright et al., 2016). It was not clear from the paper whether the model assumed cisterns were connected for irrigation only or for internal uses. For harvesting tanks to capture flows consistently they need to be connected for internal water use (DeBusk et al., 2013). The Adelaide rainwater harvesting model, with daily use of 100 L/property, applied to 38% of houses in the catchment reduced the annual runoff volume by 10 ML/year. Unfortunately the runoff reduction as a proportion of the total was not reported.

A field experiment in Shepherd’s Creek catchment, Ohio, was designed to see whether ecological improvements could result from WSUD installations on private residential property. Of 350 eligible residential properties in the catchment, 30% accepted installations resulting in 186 rain barrels (total storage 52,800 L) and 83 rain gardens (332,000 L total storage). Rain barrels were for irrigation only, and overflows were diverted back to the stormwater drain. Small changes in hydrology were only observable close to the most densely distributed installations (Mayer et al., 2012). The relatively large runoff contribution from roads compared with roofs and driveways was considered to limit the benefit of distributed management on private properties. Ecological improvements were limited, but the authors considered three years post-installation too short a period for a greater diversity of aquatic species to re-establish.

In 2009 a long-term retrofit experiment investigating ecological outcomes was set up in the Little Stringybark Creek (LSC) catchment, Melbourne, Australia (Walsh et al., 2015). A reverse auction was used to determine the best value options offered by residents. In a reverse auction interested residents submit bids to install WSUD devices on their property stating what works they will include and how much they need to be paid for the installation, which could be less or more than the total installation cost. The most cost-effective proposals are
then funded by the project team. A cap is set above which installations on public land are more cost-effective. After three rounds 237 installations were placed on 231 private properties. Of these, 235 installations were rainwater tanks with the majority connected for internal non-potable water uses. The researchers encouraged residents to consider connecting tanks to a rain garden, infiltration system, or trickle irrigation to further reduce runoff. The local council also installed rain gardens and tanks. The majority of installations were complete by October 2013, and resulted in 18 hectares of impervious surface being disconnected from the stormwater network; 7 hectares from private property, and 11 hectares from public land. The total catchment area is not given and it is therefore not known what proportion of the catchment this represents. There have been some improvements in water quality based on some of the monitored ecological indicators, but again, the monitoring period was too limited at the time of publication to be certain of any benefits generated by the installations (Walsh et al., 2015). An important observation was that during the installation period (2009 to 2013) the impervious surface area, through new connections, increased by 2 hectares counteracting some of disconnection.

At-source devices are those that capture and treat stormwater close to where it is generated, which includes both building-scale and streetscape devices. A series of WSUD devices that includes source-control solutions is known as a treatment train. A treatment train enhances water quality outcomes throughout the catchment (Bastien et al., 2010; Liu et al., 2015) and reduces maintenance requirements for larger scale devices (Berwick, 2017). The ecological performance of site and regional scale devices, particularly wetlands, is also improved as the build up of sediments and metals, a source of contaminants longer-term, is reduced (Graham, 2017; Newman & Coupe, 2017). Modelling of a residential suburb in Glasgow, UK, showed that using at-source devices could enable regional devices (a stormwater basin) to be reduced in size (less land take) thereby offering the developer alternative site layout options. Combining PPS with a regional pond in a proposed housing development enabled the regional pond to reduce in area from 2200 m$^2$ to 1600 m$^2$, whilst still meeting water quality requirements. Since PPS is installed in roads and driveways the pond area reduction increases the area of land available for other uses (Bastien et al., 2010).
**Retrofit potential**

Models are based on an idealised situation with devices installed where suitable surfaces are present, both on private and public land. Real-life limitations reduce the potential modelled benefits (Zellner, Massey, Minor, & Gonzalez-Meler, 2016). For example, the Lafayette catchment models assumed that all industrial and commercial roofs were suitable for living roofs (Wright et al., 2016) but a study assessing potential living roof retrofits in Melbourne’s Central Business District found only 15% of roofs to be suitable. This was based on a range of criteria including structure types, shadowing, orientation, roof pitch and equipment already located on the roof (S. Wilkinson et al., 2017). Factors such as buried infrastructure, slope, or the need to retain parking spaces limits the ideal placement of rain gardens on both private and public property too (Jarden et al., 2016; Mayer et al., 2012). There are also limitations to the installation of PPS, but there is wide scope to implement these systems. It has been estimated that at least 50% of off-road paved surfaces in the UK would be suitable for permeable paving (Gordon-Walker et al., 2007). A Melbourne study considered 40% of total central city road surfaces to be suitable for a PPS retrofit (S. Wilkinson et al., 2017).

Rainwater barrels or cisterns for irrigation purposes only can be easily retrofitted to most detached or semi-detached homes (Gordon-Walker et al., 2007).

**Summary**

Research shows it is likely that all four building-scale devices considered in this chapter can be effective in reducing urban runoff if installed widely throughout a catchment. Rain gardens and PPS are particularly effective at reducing contaminant concentrations, annual runoff volume, and peak flows. An appropriately sized dual purpose rainwater harvesting tank can reduce runoff peaks, even from large storms, and reduce small environmentally damaging frequent flows if connected for internal uses. The size of tank required may be impractical or undesirable however (Sharma et al., 2016). Living roofs reduce total runoff from smaller storms but are less effective at reducing peaks for a 5 or 10 year annual return period or larger, particularly if already saturated (Masseroni & Cislaghi, 2016; Versini et al., 2016). At the catchment scale, it is important to consider lags introduced by decentralised
installations to avoid additive effects increasing peak flows. For this reason initially targeting installations in upper catchment areas may be preferable.

For maximum effect, intercepting devices should be placed in critical flow paths to capture runoff during both small and large storms. Infiltrating devices are more effective in reducing runoff and enhance baseflow (Jarden et al., 2016), but ground conditions must be suitable. Where infiltration rates are low designs can be adapted to provide temporary storage for slow infiltration, or in the case of PPS storage for reuse (Auckland Council, 2017). Improvements in water quality generated by at-source devices used in a treatment train can reduce maintenance (Berwick, 2017) and enhance the ecological value of larger scale devices, particularly wetlands (Graham, 2017).

Reducing annual runoff volumes should bring ecological benefits but this has not been demonstrated through field experiments as yet. Models demonstrate that devices that capture runoff from the dominant impervious surfaces within a catchment have most impact (Jarden et al., 2016; Mayer et al., 2012). In a suburban residential area capturing driveway, footpath and road runoff is critical, but in commercial/industrial or central city areas runoff from roofs and large off-street parking can be significant (Versini et al., 2016; Wright et al., 2016) i.e. all four main building-scale devices have their place and can contribute to an overall reduction in stormwater impacts.

Models represent an idealised situation, but building-scale devices are not as easily applied in the real world. Very few field experiments integrating building-scale WSUD devices throughout a catchment have been carried out, and those that have focused on rainwater barrels or tanks and rain gardens in suburban residential catchments (Jarden et al., 2016; Mayer et al., 2012; Walsh et al., 2015). The effect of these installations has been limited, but only 13% to 30% of eligible private properties installed devices. Streetscape rain gardens have been most effective in these field studies, supporting modelled findings (Jarden et al., 2016). No field experiments have investigated the benefit of wide-scale installation of PPS, although modelled findings and data from individual sites are very encouraging.

To conclude, widespread uptake of building-scale WSUD devices is most likely to improve the ecological health of waterways throughout the entire network of ditches, creeks and rivers. Building scale devices will be most effective in conjunction with streetscape and larger scale
devices as part of a treatment train and are not intended to replace other components of the WSUD system although they may enable subsequent devices in the train to be reduced in size. Building-scale devices will support flood management and can reduce nuisance flooding, but will not significantly reduce large floods. An additional advantage provided by building-scale devices, and at-source solutions more generally, is the wider benefits such as planted areas for biodiversity and urban landscape enhancement, decentralised water supply and a reduction in the urban heat island effect.
Chapter 3: Barriers to the uptake of building-scale WSUD and potential solutions

Introduction

The negative impacts of urban stormwater are recognised in many towns and cities of the world, but whilst engineers, ecologists and planners have developed devices and plans to address water quality and quantity issues with decentralised devices, wide-scale implementation of WSUD has not occurred (R. R. Brown & Farrelly, 2009; Roy et al., 2008). The previous chapter demonstrated that the inclusion of building-scale WSUD devices within a catchment should improve the ecological status of local waterways, as well as delivering a non-potable water supply, biodiversity benefits, urban heat island reduction and more. The impact of building-scale WSUD depends on the number of devices that are installed, albeit that the effectiveness of an individual installation will vary with device type, design and location within the catchment. In this chapter barriers that have prevented greater uptake of WSUD, with a particular focus on building-scale devices, will be investigated and methods that have been applied elsewhere to overcome these barriers will be discussed. Motivations that have led some cities to adopt WSUD more rapidly will also be highlighted.

Internationally recognised barriers

In Melbourne, the WSUD approach to stormwater management was initially investigated by academics and public institutions responsible for water management, such as Melbourne Water, because of concern about the detrimental effect of stormwater on water quality in Port Phillip Bay (R. Brown & Clarke, 2007). Similarly some areas in the US have experimented for some time with decentralised alternatives to ‘grey’ infrastructure upgrades to address issues of urban water pollution, particularly from combined sewer overflows. Chesapeake Bay, located on the east coast of the US, was found to contain a large deoxygenated zone caused by polluted runoff from many land uses, including urban stormwater. States within the Chesapeake Bay catchment signed up to the Chesapeake Bay Program in 1983 to collaboratively reduce contaminant flows into the bay. Maryland was a signatory and
became an early adopter of WSUD design and policy to address urban runoff (Roy et al., 2008).

Researchers have investigated the barriers to the mainstreaming of WSUD in general (Rebekah R. Brown, 2005; Roy et al., 2008), or focused on specific devices such as rainwater harvesting or permeable paving (Bint & Jaques, 2017; Cote & Wolfe, 2014). Brown and Farrelly (2009) analysed 53 studies to identify the key socio-institutional barriers to WSUD. They condensed their findings into a list of 12 in order of importance, based on the proportion of studies in which the barrier was identified. The barriers are strongly linked. For example, poor collaboration and coordination between the institutions that influence water or land use decision-making was most frequently listed, but a poor regulatory framework, insufficient human and financial resources, lack of commitment, and poor engagement with citizens to achieve a transition, also on the list, are likely to arise from institutions that aren’t working well together to increase WSUD. Lack of political and public will is cited as the 12th barrier, only cited in 9% of studies. Arguably other outcomes that are specified more frequently can be caused by poor public and political will, and it is worth highlighting this potential root cause.

Dodge Data and Analytics (2016) surveyed individuals associated with the construction industry, including architects, builders and developers, to understand trends in ‘green’ building. Although not exclusively considering the adoption of building-scale WSUD devices, green building certification schemes will likely consider impacts on the water environment. Compiling the findings from 13 countries, they found the top three obstacles to increasing green buildings were:

1. Higher perceived upfront costs
2. Lack of public awareness and
3. Lack of political support or incentives

The most common barriers identified within academic literature are discussed individually below, but it is important to recognise that the barriers are related to one another. Case studies where WSUD has been implemented in the field are used to demonstrate these barriers in action. Possible solutions to overcome the barriers are considered alongside each
barrier although, as with barriers, the solutions are also interdependent. Addressing one barrier only is unlikely to be effective.

Cost

Perception of higher upfront cost was selected as a top three barrier to the construction of sustainable buildings in 11 out of the 13 countries reported by Dodge Data Analytics (2016). The cost of voluntarily installing WSUD devices is particularly difficult to justify as a private property owner/developer. This is because, ‘Private property owners may marginally benefit from onsite [WSUD]...but usually bear the brunt of installation and maintenance costs.’ (Montalto et al., 2007). Understanding the costs and spread of benefits across private and public stakeholders is very important in understanding the motivations of building owners (Lamond et al., 2014) and the likelihood of on-site stormwater management installations (Mistry, Gabe, & Trowsdale, 2010; Wright et al., 2016). Participants in an Australian retrofit project observed that installing a rain garden was of no tangible benefit to them (H. L. Brown, Bos, Walsh, Fletcher, & RossRakesh, 2016). Devices that primarily offer a wider community or environmental benefit will be of lower priority than those that offer the building owner or occupier a direct benefit (Lamond et al., 2014).

Developers are an important group of stakeholders since they make decisions about the features that are included in residential, commercial and industrial properties that are available to future owners and tenants. Often developers build to sell on to a new owner. Features included in a new property need to be paid for by the new owner in order for the developer to make a profit. For a developer, upfront costs are very important. If reducing runoff from a property isn’t a requirement through the planning process and WSUD devices aren’t a positive sales feature, a developer will be unlikely to recoup installation costs.

New buildings are usually constructed to have a lifespan of many decades. Decisions made about a development today will therefore have a long-term impact. Options available to encourage a developer to adopt features that provide a public good without a significant cost to the local authority include:

- An expedited planning consent process and/or reduced permit fees
- Density bonus for developers who incorporate WSUD
- Green building certification schemes

A density bonus, in the form of increased floor area or height allowance, can be offered to developers in return for including building-scale WSUD devices, such as including a defined minimum living roof area. Schemes can target areas that have most need for runoff reduction, or particular building types, such as commercial buildings which can generate a relatively large proportion of catchment runoff. A scheme in Chicago, Illinois, US offers bonuses for living roofs that cover more than 50% of the total roof surface area, or a minimum total area of 186m$^2$ (Water Environment Research Foundation, 2009). As an example a 370m$^2$ living roof area gained the developer 1115m$^2$ of extra floor generating an additional $2M US of saleable property. This recognises the public good provided by improved on-site stormwater management, enhanced biodiversity and urban heat island reduction (S. J. Wilkinson & Dixon, 2016). The Green Factor, in Seattle, Washington, requires sites in designated neighbourhood commercial zones to either have 30% landscaped or to include WSUD devices such that the site operates as if 30% of the site soft landscaped. The program prioritises areas visible to the public so environmental standards and urban aesthetics are improved together (Water Environment Research Foundation, 2009). The Green Factor, although mandatory, offers more flexibility to the developer than a scheme that targets living roofs only, and includes lower cost options (Bracey, Scott, & Simcock, 2008; Montalto et al., 2007).

Sustainable building certification schemes, such as Homestar, Green Star or Leadership in Energy and Environmental Design (LEED), can also motivate and direct developers and homeowners to incorporate techniques and devices that limit environmental impact. Water management is often, although not always, a component of these schemes. Such schemes argue that they bring economic benefits to the building owner by increasing the value of the building and rental returns (Burger, 2018). Additionally the motivation of ‘doing the right thing’ is recognised as a driver for sustainable building (Dodge Data & Analytics, 2016). These schemes offer developers the freedom to select solutions that fit their needs best whilst meeting the environmental standards for certification. In Seattle, developers aiming for silver LEED standards or higher are also eligible for density bonuses (Water Environment Research Foundation, 2009).
Once a technique becomes visible it can motivate others to follow suit. In parts of London, UK, living roofs were required to provide habitat for a rare bird species, but following these installations the popularity of living roofs increased across central London and some developers now include them as standard (S. J. Wilkinson & Dixon, 2016). It has been suggested that in Sydney’s Central Business District (CBD) living roofs are are a mark of prestige (Irga et al., 2017). Some owners or tenants are willing to pay for prestige. Conversely this can also be a significant barrier. A perception that green building is only for high-end projects is reported as the fourth most common barrier by Dodge Data Analytics, and was identified by 42% of Australian respondents (Dodge Data & Analytics, 2016). In Melbourne, roof landscaping to provide a pleasant view for hotel guests and accessible roof space has been cited as an incentive for building owners, albeit the environmental benefits may then be compromised (Rajagopalan & Fuller, 2010). Options that generate a demand will be included by developers if they have confidence in the market. Market demand is the third most frequently cited reason for developments being constructed with green features, after client demand and environmental regulation (Dodge Data & Analytics, 2016).

Another important group of stakeholders are existing property owners. Cities include large expanses of existing development that generates runoff. The retrofit of WSUD devices on private property can usually only be achieved through voluntary actions by the property owners. The catchment-scale modelling demonstrated that in residential areas streetscape rain gardens, or potentially permeable paving systems (PPS), used to capture runoff from roofs, driveways and roads are most cost-effective, but installations in the road may not always be feasible. In commercial areas, or built up city centres the dominant contributing surfaces may be roofs or parking areas on site. Field studies that aim to understand property owners’ priorities, and programs that have been developed to influence property owners to retrofit measures to reduce runoff from their sites, are discussed below.

A survey carried out in a residential suburb in Kitchener, Ontario, Canada, investigated the potential for retrofitting driveways with permeable paving. They found that a majority of residents (70%) would pay more for a driveway surface that was beneficial to waterway health, but most capped the increase in spending to no more than 15% extra compared with a standard driveway surface (Cote & Wolfe, 2014). Another survey found that 79% of residents would be prepared to use PPS if it cost no more than standard paving (Montalto et
al., 2007). The uplift in cost for PPS quoted for Auckland was 33% (David Kettle, Mayhew, Irvine, & Young, 2013); only 5% of residents in the Kitchener study would be willing to adopt PPS at this level of additional cost. Ongoing maintenance costs are comparable with traditional paving (Crossland, Girvan, & Kettle, 2016) and so there is no long term saving to offset the higher upfront cost. Financial incentives or subsidies can be used to motivate owners of existing property to reduce runoff from their site voluntarily (Parikh, Taylor, Hoagland, Thurston, & Shuster, 2005).

If environmental or flood reduction benefits can be generated at less cost and/or less disruption on private land then subsidies to support WSUD installation on private property could be justifiable, as long as the right safeguards are in place to ensure ongoing functionality (Fletcher et al., 2011; Montalto et al., 2007; United States Environmental Protection Agency, 2009a). In the case of the residents in Kitchener subsidies could be used to reduce the cost of PPS to a level that could begin to see some uptake when driveways are renewed. Over 50% of applicants in a WSUD implementation study in the Little Stringybark Creek (LSC) catchment had previously considered installing rainwater tanks but had not done so due to cost; subsidies provided through the project overcame that barrier for them (H. L. Brown et al., 2016). Nevertheless financial impacts on fiscally conservative authorities may restrict the viability of direct financial incentives (Brudermann & Sangkakool, 2017, as cited in Irga et al., 2017).

Where water supply is measured and charged accordingly, users (businesses or residents) can be motivated to investigate lower cost methods of meeting their water needs, including the use of rainwater harvesting tanks (Wright et al., 2016). Stormwater fees can also be charged based on the runoff volume leaving a site since it is related to the proportion and type of impermeable surface cover. Again, charging a fee that is related to volume provides a direct benefit to property owners who reduce their bills by reducing impermeable surfaces and/or using devices that infiltrate or store and reuse stormwater. A disadvantage is that it is a labour-intensive data set to create and monitor (Roy et al., 2008) and therefore expensive to instigate.

Fees may generate a payback but if the payback period if too long it is an ineffective motivator. Wright et al. (2016) showed that water supply and stormwater fees in Lafayette, Indiana, resulted in payback periods that were extended at best and non-existent at worst.
Bioretention systems in commercial car parks would take 15 to 19 years to pay back, and up to 39 years in residential areas. PPS had a minimum payback period of 42 years for commercial areas, with no payback in residential or mixed development inner city areas. Rainwater harvesting generated a more rapid payback because it also reduced water supply costs (Wright et al., 2016). Payback needs to be within three to five years for New Zealand businesses to consider investing and the only place where this rate of payback is achieved for rainwater harvesting is in Auckland where both drinking water and wastewater charges are applied (BRANZ, 2018).

In Germany local authorities have been able to charge stormwater fees since 1985 following a change in national law. Local authorities implemented charges during the 1990s and now around three quarters of cities with a population over 100,000 charge stormwater fees (Wikipedia contributors, 2018). The fees are sufficiently high to motivate change at around US$2.6 per square metre of impervious surface per year, equating to around US$550 per year for a 200 m$^2$ roof and 10 m$^2$ driveway. Germany installed 60,000 tanks per year around 2010, the largest number in Europe. In 2009 44% of new family homes were constructed with rainwater tanks (Ziegler, n.d.). Rainwater tanks become a desirable feature in a new home when they reduce bills. It is important to recognise the potential impact of fees of this scale on low income groups (Dhakal & Chevalier, 2017), but measures can be put in place to ensure low income families have access to water services.

Fees can be politically sensitive. In Elgin, Illinois, US, for example, a Stormwater Utility Tax was proposed for introduction in 2014, but was rejected by councillors after local election results made it clear the proposal was unpopular with local residents. All references to the fees were also removed from the council’s five year strategy (Ferrarin, 2013). Anti ‘rain tax’ publicity reported annual costs were likely to be between US$36 and US$101 per year for residents, depending on property size, which is much lower than the German fees (Wikipedia contributors, 2018). An Elgin councillor commented on the poor communication with the public about the importance of stormwater management and the need to fund it (Ferrarin, 2013). In the United States funds raised from stormwater fees must be used to support activities that will reduce stormwater pollution thereby providing a mechanism to fund change programmes or incentives.
Buehler et al. (2011) summarise lessons learnt in Germany’s transition to a more sustainable economy. They emphasise the importance of starting small and implementing policies gradually. Incentives used to initiate change are followed by mandating policies. Stormwater fees were initially opposed in Berlin but public participation was used as a way to build community knowledge of the connection between stormwater runoff from their own properties and the degradation of local lakes and rivers during the data collection process for determining individual fees (Buehler et al., 2011). By creating a fee structure that is clearly linked to impervious surfaces property owners are motivated to make changes to reduce their impact and become more willing to accept fees as they are seen to be fair and environmentally beneficial.

Rates rebates for including WSUD measures that reduce runoff may be more acceptable than fees to property owners, and therefore also more politically acceptable. A scheme run in Portland, Oregon, called ‘Clean River Rewards’ reduces the stormwater component of rates by up to 35% if stormwater is retained on site. The scheme encourages both commercial and residential property owners to reduce runoff (The City of Portland, 2018). Residential properties are only required to manage runoff from roofs to qualify, while commercial sites also need to attend to paved areas. The scheme is supported by advisors, and encourages simple solutions as well as the use of more expensive options. The scheme reduces rates revenue for the council, but also reduces the council’s maintenance costs by transferring the responsibility for some stormwater back to the property owner. Property owners continue to pay their portion of the public stormwater network rates, making up the remaining 65%.

Portland’s council has been running schemes to reduce runoff from private property for many years. They have promoted low cost solutions. One scheme offered practical support and a small incentive of US$53 for disconnecting gutters from the stormwater network and redirecting the runoff to lawns, landscaped areas or rain gardens where the soils and topography were suitable. The Disconnect a Gutter Programme resulted in 56,000 disconnections and a reduction in stormwater runoff of 5 million cubic metres per year (Schofield, 2012). Bracy, Scott and Simcock (2008) also noted the benefit of simple solutions identifying vegetated and mulched landscaping instead of grass as most cost effective at Talbot Park, Auckland, along with rainwater tanks. An example of a mulched garden in
Christchurch is shown in Figure 3.1. Portland has also incentivised the planting of larger trees as a valid method to reduce runoff from private property which attracts a rates reduction.

![Mulched and landscaped garden in St Marns, Christchurch](image)

Ensure simple and timely access to a rebate or financial incentive is important. In the LSC WSUD retrofit project successful bidders were required to pay full installation costs before claiming the agreed subsidy. Some residents were unable to pay the full costs up front and therefore didn’t submit a bid (H. L. Brown et al., 2016). For these residents a subsidy paid directly to the contractor or a low cost loan with a long payback period would have reduced this hurdle.

Interest-free or low cost loans can help reduce the cost hurdle for property owners and has less financial impact on local authorities. Repayments can be added onto the rates for an extended period and if the property is subsequently sold the repayments will transfer to the new owner.

An important finding that is apparent from the catchment-scale field studies is how hard it is to motivate the uptake of WSUD devices on private property, even when the full cost of installation is covered. The Shepherds Creek study, which resulted in 30% of eligible properties installing a device, offered full installation cost, a small additional financial incentive and three years maintenance. The LSC project received bids for installations from only 13% of eligible households. The scheme ultimately paid 85% of installation costs but issues associated with the timing of payments and complexity of submissions created a
barrier to entry (Fletcher et al., 2011). Jarden et al. (2016) commented on the ‘massive effort’ required to recruit homeowners in the Parma, Ohio study which offered free installation.

There is an opportunity cost to property owners giving up land for on-site stormwater management (Parikh et al. 2005) and it seems that even with substantial financial support the majority of householders are not motivated to install WSUD devices. Assessing the uptake rates of different device types, there are clear preferences. Rainwater tanks are adopted much more frequently than rain gardens, perhaps because rainwater tanks offer a direct benefit to the homeowner in the form of water supply and security. Montalto et al. (2007) reported from survey data that almost 80% of respondents would include either living roofs or PPS if these were no more expensive than traditional options. No studies have offered free or heavily subsidised PPS or living roofs to test this. An advantage of both living roofs and PPS is that they avoid land take, unlike rain tanks and rain gardens.

Socio-institutional barriers

A case study from a residential development in Cross Plains, Wisconsin, US, demonstrates several of the barriers included in Brown and Farrelly’s list of socio-institutional barriers (R. R. Brown & Farrelly, 2009). The proposed development was situated within the Black Earth Creek catchment which had experienced negative impacts from previous developments. Local residents were concerned about the potential impact of further development. To address these concerns the St Francis subdivision was designed to include individual rain gardens on each plot as part of the site’s stormwater management system (Morzaria-Luna, Schaepe, Cutforth, & Veltman, 2004), supported by the local Department of Natural Resources (DNR). There was an assumption on the part of the developer and the DNR that because the design reduced potential impacts on waterway health the consent process would be straightforward. Instead it became lengthy and challenging. Despite the regulator, planning authority and local residents wanting water quality improvements, the existing rules and governance structure did not support innovation. New technologies had to be installed in addition to traditional infrastructure. The developer chose to retain a requirement to install rain gardens on each section using a covenant, but they did not form
part of the stormwater management system for the purpose of gaining the subdivision’s planning consent.

The consenting delays, substantial design alterations, and doubling-up of traditional and new technologies will have added to the developer’s and site end users’ costs. The difficulty of working within policies and rules set up for conventional stormwater management, even with the support of the local regulator, can be a significant barrier (Morzaria-Luna et al., 2004) and provide a discouraging example to developers considering innovative stormwater solutions (Farrelly & Brown, 2011). In Cross Plains a particular concern for the planning authority was uncertainty associated with maintenance of devices on private property, which is discussed in the next section on technological concerns. The remainder of this section will cover motivation for transition to WSUD and the potential impact of policies and guidance at different levels of governance.

The effectiveness of legislation and guidance can be difficult to measure as it may cover a variety of land use types, policy objectives or scales of development for example. Also, legislation and guidance is often accompanied by other supportive activities, such as workshops to enhance professional capacity, public awareness campaigns, or incentive schemes. However, a study comparing the uptake of living roofs on suitable roof spaces in five cities in five countries found that the much higher uptake in Basel, Switzerland and Stuttgart, Germany, at 25% and 22% respectively, was due to public sector strategy and policy implemented in stages over an extended period of time (Mees et al., 2013, cited in (S. J. Wilkinson & Dixon, 2016). Both cities mandated living roofs on new buildings, and introduced subsidies for a period of time to encourage retrofitting. Stormwater fees introduce a financial benefit for building owners following installation. In comparison living roofs were installed on less than 1% of available flat roofs in Chicago, US, London, UK, and Rotterdam, Netherlands. In Chicago living roofs have been encouraged through education and financial incentives, and can be used to meet planning requirements for stormwater, landscape and energy efficiency, but are not mandated. In London living roofs have simply been encouraged where feasible.

It may be no coincidence that installation costs in Basel and Stuttgart are substantially lower than in Chicago, London or Rotterdam with a more mature market increasing competition. Talbot Park, Auckland, New Zealand provided a demonstration site for the retrofit of rain
gardens, PPS and rain water harvesting tanks. At the time, in 2006, the range of suitable products and experienced installers was described as limited and the cost of PPS prohibitive, but the authors considered both suppliers and installers to be increasing in number (Bracey et al., 2008). Policies that support the development of a competitive market for new technologies could help to reduce the cost barrier identified previously.

Irga et al. (2017) found, when investigating the effect of policy on the prevalence of green roofs and walls in Australia, that the average number of green roof or wall projects per council area within the same city was much higher when guidance or policy, either specific or general, was present. The City of Sydney (local authority) had the highest number of projects at 123, and was the only council in Australia to have a dedicated green roof/wall policy supported by environmental performance grants. The policy was approved by the City of Sydney on account of multiple benefits, including reducing the urban heat island effect, slowing and cleansing stormwater, biodiversity enhancement and improving solar panel efficiency (City of Sydney, 2014). Brisbane had the highest number of projects per 100,000 population. In Brisbane green roofs are encouraged through more generalised environmental policies and sustainability grants. Investigations into WSUD uptake in South Australia concluded that strong policy is needed if developers are to adopt WSUD systems (Sharma et al., 2016). A review of policies from international cities concluded the same (Irga et al., 2017). Dodge Data Analytics (2016) report environmental regulations to be the second most frequently identified trigger for building a certified sustainable property, after client demand (Dodge Data & Analytics, 2016).

As demonstrated by the earlier example of stormwater fees in Elgin, Illinois, public objections can prevent policy change. Political support from communities is needed for local authorities to develop programmes and policies that drive changes to stormwater management (Roy et al., 2008). If direct policy relating to stormwater management specifically is not viable support through compatible policy areas, such as climate change mitigation and adaptation, energy use reduction or biodiversity enhancement may be acceptable instead (Irga et al., 2017). Living roof policies in Stuttgart were connected to air quality goals, while Basel linked them to biodiversity. Different issues have motivated cities at the forefront of WSUD transition and connecting WSUD policies and incentives with wider strategic goals has been successful in gaining wider support (Buehler et al., 2011).
Whitehouse (2017) explains that green infrastructure, which includes rain gardens and living roofs, has a different value depending on the context. For example, planted options will be more highly valued in a built-up urban environment where green spaces and biodiversity is limited, compared with a residential suburb with private gardens. Similarly options that reduce the urban heat island effect will be more highly valued in hotter climates.

Understanding the multiple benefits offered by WSUD in the local context and focusing on aspects that have a particular local relevance, beyond stormwater management, could help to build wider support for WSUD. Conversely, in drought prone areas the need to irrigate a living roof could be both politically and environmentally undesirable (Irga et al., 2017). Local government policies and guidance can address local concerns and design issues accounting for climate and other physical variations.

Wilkinson and Dixon (2016) considered the ‘green political climate and culture’ in Basel and Stuttgart to have been a key factor in enabling long-term public sector support for living roofs. Buehler et al. (2011) state that sustainability has long been a part of German culture because of the challenges of a large population and limited natural resources. Gradual change and the use of communication and public participation improves understanding of the purpose of policies and builds cross-party support to minimise issues of partisan politics (Buehler et al., 2011).

Source-control solutions to stormwater impacts, such as building-scale WSUD devices, have only been implemented in Australia and the US where there is support at the community level (Roy et al., 2008). Portney and Berry (2016), comparing 50 cities across the US in terms of environmental programs and policies, found that local environmental organisations advocating for sustainable development was a key factor in determining which local authorities became sustainability leaders. Seattle, used as a case study by Portney and Berry to demonstrate the impact of effective local advocacy groups, has a target to reduce urban runoff by 700 million gallons (2.6 million cubic metres) by 2025. There are programs to support the voluntary retrofit of building-scale WSUD, particularly rain barrels and rain gardens, and policies applicable to new builds to increase WSUD (Seattle Public Utilities & King County Department of Natural Resources and Parks, n.d.).

Policies and programs that focus on improving an identified impact on downstream ecosystems may be more easily implemented than an opportunistic scattergun approach.
across a wider urban area (Roy et al., 2008). Identifying solutions to address local scale issues provides the opportunity to build local community support (DeFries et al., 2012); this can address the lack of public awareness and build political support, discussed in the next section. In addition incentives or policy measures could target areas where runoff reduction can be achieved more cost-effectively (Parikh et al., 2005), such as areas with high permeability soils where runoff infiltrates easily and supports baseflow.

In Auckland, policy has been developed to protect the city’s most ecologically valuable waterways. Runoff limits have been set that relate to the pre-development hydrology with the aim of reducing the more frequent runoff events to protect the ecological values still present (David Kettle et al., 2013). Guidance outlines how lower runoff volumes and flow rates can be achieved practically using a variety of WSUD solutions, together with indicative costs (Auckland Council, 2017). The targets are challenging enough that developments and redevelopments incorporate building-scale WSUD devices as well as streetscape rain gardens and larger scale measures. For the highest quality streams 100% of impervious surface area has to be mitigated (David Kettle et al., 2013). Although the policy has only been applied to higher quality waterways, it could be applied more widely to instigate a gradual improvement in waterway health across the city.

In Melbourne, the initial driver for funding research and the implementation of WSUD was water quality but the focus turned towards water efficiency because of an extended drought. Extreme events can trigger a shift from traditional practices (Keath & Brown, 2009). Buehler et al. (2011) cite the reunification of east and west Germany as a stimulus for transforming old infrastructure. In Melbourne, however, the drought entrenched the traditional approach to water management. Rather than ongoing attention to the whole urban water cycle, promoted by a WSUD approach, the focus turned to water supply with a multibillion dollar investment in desalination, appeasing public and political pressure (Keath & Brown, 2009). Nevertheless, rainwater tanks have become more popular in Melbourne as a way to overcome water restrictions as individual’s priorities have changed. Policy or incentives could support the inclusion of tank storage for flood management or the diversion of overflows to rain gardens to achieve more than just water supply goals and build resilience to a wider range of risks.
Policy at multiple levels of government, including national, is identified as a key factor in driving stormwater management improvements (Buehler et al., 2011; Dhakal & Chevalier, 2017). The absence of national policy in New Zealand has been recognised as a ‘major gap’ hindering the uptake of WSUD (Chang, Lu, Chui, & Hartshorn, 2018). In the US although the Clean Water Act (1972) gave the United States Environmental Protection Agency (USEPA) power to regulate discharges to water, approaches to managing stormwater impacts have varied across the country. Only some proactive local authorities have implemented WSUD (Roy et al., 2008). WSUD can provide a cost-effective solution for reducing combined stormwater and wastewater system overflows (Montalto et al., 2007) which attract sizable government fines and this has been a driver for the use of WSUD in Seattle for example (Department of Ecology State of Washington, 2018). Policies at the local government level can be very effective but cannot be developed and applied in isolation, needing wider public and political support.

In the UK extreme events in the form of major urban floods in 2007 triggered increased interest in Sustainable Drainage Systems (SuDS), the stormwater management component of WSUD. The Pitt Review, investigating the floods, identified the need for a more coordinated approach to catchment management (Pitt, 2008). SuDS were seen to have advantages for both water quantity and quality management. The Flood and Water Management Act (2010) that followed required key public sector organisations involved in catchment management to collaborate, and included provisions requiring the use of SuDS in new developments. However, in England the use of SuDS was limited to ‘where reasonably practicable’, unlike in Scotland. It is too early to tell how effective the national policy will be but Warwick (2016) is critical of the English approach which delegates decision-making on planning and maintenance to the local authority, rather than the national environmental regulator, which risks inconsistent standards despite a national approach, as seen in the US. National policy may support a more consistent approach, but to achieve consistency policy must set clear expectations for local authorities, regulators and developers, and be difficult to avoid or dilute.

Development policies usually only apply to new build or major refurbishment projects and are therefore effective for greenfield or infill sites but their impact on existing development is gradual. To achieve a more rapid transition to WSUD in developed areas measures that
stimulate voluntary change are essential, as discussed in the previous section. Fees can create change, if high enough, but if they are not politically acceptable will not be adopted. This emphasises the need for communication and education about the problems caused by urban runoff and a clear vision of the benefits of addressing the issues so that community support for change increases.

Technological concerns and awareness raising

For building-scale WSUD uptake to increase it needs to be a viable solution to a recognised problem and it needs to be advantageous compared with other options (R. Brown & Clarke, 2007). In existing developed areas property owners need to recognise and appreciate the benefits of installing devices. Survey findings from the Kitchener study in Canada found that only 12% of participants were aware of the full range of activities that negatively impacted on waterway health, although 70% did know that stormwater had a detrimental effect on surface water quality (Cote & Wolfe, 2014). Of the 18 residents interviewed in detail as part of the LSC project, only one considered stormwater to be a concern, and that related to flooding rather than quality (H. L. Brown et al., 2016). Five residents erroneously thought stormwater runoff supported flows in the creek and was therefore positive. Amongst the wider group of LSC participants 17% were unaware there was even a creek in their neighbourhood. Clearly a lack of knowledge relating to stormwater and its impact on waterway health will limit the likelihood of property owners making a change to reduce their property’s impact.

The successful Downspout Disconnection Programme, mentioned previously and run in Portland for 16 years, was supported by outreach programmes with trained staff and information brochures explaining why and how to disconnect gutters (Schofield, 2012). The LSC project measured changes in community awareness as a result of their programme to retrofit rainwater tanks and rain gardens within the catchment. They found significant differences in knowledge between the control catchment and the LSC catchment. Following the project 48% of landowners in the LSC catchment acknowledged they had a role to play in improving stream health compared with just 19% in the control catchment (H. L. Brown et al., 2016). Recognition that individual behaviour can make a difference to the environment is an important motivator for changing behaviour (Chawla, 2008, and Jordaan & Stevens, 2007
in (Cote & Wolfe, 2014). In the Kitchener study 44% of residents were aware of PPS prior to the study, but following the study 78% considered PPS could make a difference on their property and 70% were prepared to investigate PPS (Cote & Wolfe, 2014), indicating that once householders are aware of both an environmental problem and a potential solution they will consider options for their own property. Education and communication is a fundamental part of shifting some responsibility for stormwater impacts back to private property owners.

Once a problem is recognised a proposed solution needs to be feasible and advantageous, but private individuals express concern about WSUD technologies. Respondents to Kitchener’s PPS survey asked about lifespan, suitability for sloping sites or lower permeability soils, aesthetics and impact on property values (Cote & Wolfe, 2014). Space and ugly aesthetics have been reported in several studies as barriers to rainwater harvesting (Bint & Jaques, 2017; H. L. Brown et al., 2016; Mistry et al., 2010). Rain gardens raise even more concerns with residents, citing loss of space, potential property damage, ponding and mosquitoes (H. L. Brown et al., 2016; Morzaria-Luna et al., 2004). A North Shore, Auckland study found residents required to include rain tanks in new developments to be apprehensive due to their lack of experience with the technology (Mistry et al., 2010). Conversely residents in the LSC study who had prior experience of a technology or an educational background that supported their understanding of the device function were supportive of adopting new devices on their property when given the opportunity (H. L. Brown et al., 2016). Again, communication and education is key to building recognition that WSUD devices, such as rain gardens or rainwater tanks, can reduce stormwater impacts as well as provide an advantage to property owners. Regardless of environmental benefits, willingness or ability to pay remains a barrier. Stormwater fees to create ongoing benefits from reduced runoff could help increase uptake, as could financial incentives or subsidised installations, although a sense of ‘doing the right thing’ will motivate some (Dodge Data & Analytics, 2016). Environmental education may invoke a greater sense of wanting to do the right thing, particularly if a connection with the local environment is developed and the link between actions and local outcomes is recognised.

Technological concerns are also evident amongst professionals involved in stormwater management. The long term infiltration performance of rain gardens dependent on
maintenance by private individuals was a primary concern to the Wisconsin planning authority in the St Francis subdivision case study (Morzaria-Luna et al., 2004). A proposal by the Urban Land Corporation in Melbourne to use stormwater management based on WSUD principles on the Lynbrook Estate, backed by Melbourne Water (local water authority) and local research organisations, was also rejected by the planning authority. They had concerns about the design functioning as expected and potential non-compliance with stormwater regulations (R. Brown & Clarke, 2007). Clearly creating a transition from mainstream technologies to WSUD solutions will be extremely difficult if the alternative solutions are not supported by lead organisations due to technological and maintenance concerns.

Throughout this section cities that are leading on WSUD have been led by local government, albeit that local communities have influenced the new direction.

Farrelly and Brown (2011) highlight that an important part of transition is ‘learning-by-doing and doing-by-learning’. Irga et al. (2017) state that a lack of research into living roofs and walls in hot dry climates raises concerns about the risk of implementing new and unproven technology. Demonstration projects provide an opportunity to test and adjust new technologies to the local environment. Early installations may not be optimal, but they provide important information, if properly monitored, that can be used to adjust future designs (Keath & Brown, 2009). It is also helpful for potential adopters of new technology if it can be seen first-hand. A key concept that supported Germany’s transition to a global leading ‘green’ economy was starting small scale, either in scope or geographically with well managed pilot projects, before gradually expanding policies supporting or mandating WSUD solutions (Buehler et al., 2011).

In Australia the fear of failure and costs are some of the factors that have inhibited experimental projects (Farrelly & Brown, 2011). Early adoption of new technologies can be led by innovative private developers, such as the 7000 m² living roof installed as part of a shopping mall redevelopment in Paris (S. J. Wilkinson & Dixon, 2016). Pre and post-construction monitoring of the St Francis development provided data that was used to develop new rules for stormwater management that included rain gardens and PPS. Further, a handbook on rain garden design and maintenance was published for use by local residents (Morzaria-Luna et al., 2004). Often the public sector is important for constructing demonstration projects providing ‘patient capital’ (Roberts, 2017). In 2009 President Obama
signed an Executive Order that required the USEPA to lead by example with regards to on-site stormwater management on their own properties (United States Environmental Protection Agency, 2009b). A lack of confidence in technologies will perpetuate if there is not sufficient funding to develop demonstration projects that can progress knowledge.

WSUD guidance provides supporting information to assist in the implementation of new technologies. The UK national guidance on SuDS, known as the SuDS manual, comprises almost 1000 pages of expert knowledge whilst allowing for locally specific design, providing a cost-effective way for local authorities to access good practice. The SuDS provisions requiring inclusion of SuDS in new development were nevertheless delayed by five years due to technical concerns (Warwick, 2016). There was clearly some apprehension and resistance to change in the UK which the original manual did not overcome. Time will tell if the combination of guidance and policy, together with further research contributing to technological improvements is sufficient to shift the traditional stormwater management paradigm in the UK.

Summary

As demonstrated by catchment scale studies, achieving widespread uptake of building-scale devices on private property is a major challenge (Jarden et al., 2016). Significant universal barriers to WSUD uptake include cost, institutional resistance, technological concern, and lack of public awareness (R. R. Brown & Farrelly, 2009; Dodge Data & Analytics, 2016). Potential solutions to overcome each of these barriers have been considered barrier by barrier, but they also overlap. The barriers are interrelated, as are the solutions. Public awareness can drive political will needed to drive policy changes and allocation of budgets to support demonstration projects and subsidies. These actions can help overcome the cost and technological barriers. Problematically, public awareness is influenced by education, but if local and national support for WSUD is limited budgets for education will be limited. The process of achieving change seems to be an iterative one and takes time. Nowhere has WSUD been fully implemented at all scales.

Where policies and financial incentives have supported the uptake of building-scale WSUD they have been effective, particularly if continued over decades, as demonstrated in Basel
and Stuttgart. Community organisations can be instrumental in unlocking local authority resistance to policy measures by advocating for policy changes (Portney & Berry, 2016). Policy change needs to be implemented gradually however to give time to build up public support and avoid or minimise objections. Solutions need to be adapted to suit both the physical characteristics and financial circumstances of a city. Effective regulation mandating stormwater management on site will increase the uptake of building-scale devices in new builds, but voluntary change is required in areas of existing development. Cheap simple building-scale solutions, such as disconnecting gutters, tree planting and mulched landscaping rather than lawns, supported by education programmes and small incentives, can be effective. Water supply and stormwater fees can help to generate a payback for property owners who invest in building-scale WSUD devices, providing an incentive. Catchment-scale projects show that even when devices are supplied for free or heavily subsidised those that provide a tangible benefit to the site owner/occupier are preferred, such as rainwater harvesting tanks.

Policies or programs that demonstrate a local benefit, protecting a locally important waterway for example, may improve community support. Stressors, such as drought or floods, can provide an opportunity for change but can also lead to entrenchment of the traditional system if it provides a quick fix. Adapting to foreseeable risks such as climate change, or working towards broader urban strategies such as improved air quality or biodiversity with well supported policy, incentives and communication may provide the impetus needed to encourage change with political and public support.
Chapter 4 - The Christchurch Context

Introduction

Chapter 2 presented the potential multiple benefits that can be achieved through the installation of building-scale WSUD. Chapter 3 discussed the barriers to WSUD identified internationally with a focus, where possible, on building-scale WSUD solutions. This chapter will explore the local context for WSUD in Christchurch, examining its rivers and the stormwater network; pre and post-earthquake development impacts; current legislation, policies and guidance that directs or influences on-site stormwater management; future stressors on the system; and opportunities that building-scale WSUD could bring.

Christchurch’s rivers and the effects of development

Christchurch has three main rivers which flow eastwards to the coast - the Heathcote/Ōpāwaho, Avon/Ōtākaro and Styx/Pūharakekenui Rivers (Figure 4.1). All three are spring-fed and receiving runoff from urban areas. Around 50 springs have been mapped across the city. Many rise from permeable river gravels that have been confined by overlying deposits. The gravel aquifers are supplied by rain falling on the gravels exposed to the west of the city centre, and by flows from the Alps-fed Waimakariri River which loses water through its bed as it approaches the coast to the north of the city. Barr (2016) monitored several springs contributing flows to Christchurch’s rivers over summer 2015/16 and found that the groundwater levels supporting baseflows to the Avon/Ōtākaro and Heathcote/Ōpāwaho rivers were particularly sensitive to low winter rainfall and identified rainfall as the dominant recharge mechanism in this part of the aquifer. Springs to the north associated with the Ōtukaikino and Styx/Pūharakekenui were maintained by the Waimakariri River and were less affected by dry winters (Barr, 2016). Springs also rise at the foot of the Port Hills at the southern edge of the city.
Figure 4.1: Map of Christchurch rivers and streams, showing the Avon-Ōtākaro red zone.
The development of Christchurch was planned ahead of the arrival of the early European settlers in 1850. The town centre was situated on a dry slightly raised grassy gravel lobe with wetlands to the north, east and south (Lucas, 2014). The low lying areas flooded regularly during the winter and became stagnant during summer. Historically the Waimakariri would overtop into the Avon/Ōtākaro; this is now prevented by stopbanks. The City Council, established in 1862, constructed stormwater drains and levelled streets to help free drainage of water (McKinnon, Bradley, & Kirkpatrick, 1997).

Edward Ward, an early European migrant, described the Avon/Ōtākaro in 1850 as ‘cool and clear as crystal - most delicious to taste’ (Ward, 1850 cited in Strongman, 1999). By the 1870s the city had gained a reputation of being the most unhealthy in New Zealand (McKinnon et al., 1997). Household waste was deposited onto the land and into the rivers. Epidemic outbreaks became a concern. The Christchurch Drainage Board was created in 1875 to address these issues with drainage improvements and building sewers (Watts, 2011). As the city developed many springs were sealed and streams and rivers were gradually straightened, deepened, boxed, piped or buried underground to drain more land for development and protect the population from waterborne diseases and flooding. These natural and altered water features form a large part of the city’s stormwater network today (Watts, 2011). The network is extensive comprising over seventy kilometres of river and hundreds of kilometres of stormwater pipes, streams and tributaries (Christchurch City Council, 2009a). Wastewater is excluded from the stormwater system, except where wastewater connections have been misconnected. Stormwater, for the most part, continues to drain directly to the rivers without treatment whilst wastewater is passed through a treatment system at Bromley before being discharged three kilometres off the coast (Christchurch City Council, n.d.).

The Greater Christchurch Urban Development Strategy (UDS), published in 2007 and since updated to reflect changes caused by the earthquake (Canterbury Regional Council, 2016), identified suburban greenfield areas and intensification zones within the city to accommodate development for predicted population growth. Following the 2010/11 earthquakes 8000 red-zoned homes that had to be replaced were predominantly located in greenfield sites. The proportion of new housing provided by intensification fell from around 50% prior to 2011 to 30% following the earthquakes. The updated UDS plans for 55% of new
housing to be provided through infill development between 2022 and 2028. Densifying urban environments through property alterations such as extensions, driveways and infill development whereby a single property is replaced by two or more, typically increases runoff peaks and volumes. An increase in the proportion of impermeable surfaces has been accounted for in catchment management plans for many years (Canterbury Regional Council & Christchurch City Council, 1998). Intensification will require further management but also offers an opportunity for improvement if on-site stormwater management solutions are included in the new developments.

As described in Chapter 2 frequent flushes of runoff which transfer a regular input of contaminants, including warmer water, and erosive flows are a key issue impacting on the ecological diversity of urban rivers (Burns, Fletcher, Walsh, Ladson, & Hatt, 2012; Ladson et al., 2006). The number of days of rainfall may slightly increase due to climate change, and average temperatures are set to rise, both of which are likely to impact negatively on the city’s waterways. As development increases and densifies the proportion of surfaces contributing contaminants to runoff such as roofs and roads also increases. Without mitigation the city’s rivers are likely to be increasingly impacted.

Metal roofs are common in New Zealand, being well suited to earthquake-resilient construction as well as low cost. But poorly maintained galvanised steel roofs are the key contributor of zinc in runoff in Christchurch (Golder Associates (NZ) Limited, 2018). Roofs contribute 81% of the annual zinc load in the Okeover catchment, a tributary of the Avon/Ōtākaro (F. J. Charters et al., 2016). Copper roofing and spouting has increased in popularity in the Christchurch rebuild (Christchurch City Council, 2015; Stylianou, 2016) but contributes a disproportionate quantity of copper. In the Okeover catchment copper roofing formed just 0.4% of impervious surface areas, but contributed 8% of the copper load. Metals from roofs can be difficult to remove from stormwater because of the high proportion in dissolved form (Christchurch City Council, 2015). Copper and zinc are two priority contaminants identified in the city council’s Surface Water Strategy (2009a).

Stormwater samples collected from modern subdivisions (post 2000) between 2005 and 2011 were found to have lower zinc concentrations than those from older subdivisions. It was hypothesised that the reduction was due to the use of factory-coated zinalume roofing materials in the new subdivisions (Brough, Brunton, England, & Eastman, 2012). This is
borne out by more recent catchment modelling (Golder Associates (NZ) Limited, 2018).

Urban atmospheric dust is an ongoing source of zinc and copper contamination produced by wear on tyres and brake-pads. Atmospheric dust settles on hard surfaces and washes into storm drains after each rainfall event.Particles are fine and difficult to remove from runoff once entrained (Christchurch City Council, 2015).

A ribbon of industrial and commercial land use runs east west through Christchurch, concentrated along the railway line to the south of the CBD and Hagley Park (Figure 4.1). These areas predominantly drain to the Heathcote/Ōpāwaho, although the Addington Brook and Riccarton Stream drain to the Avon/Ōtākaro. Point source discharges are now treated and land use activities are better managed but stormwater draining from industrial areas is still associated with Christchurch’s most polluted streams. This is both an enforcement issue and one of businesses not taking responsibility for their environmental impacts. Stormwater runoff from these areas contains elevated concentrations of copper, zinc, ammonia and dissolved phosphorus (D. Harris, 2018). In part this is due to the large zinc-coated roofs commonly used on industrial buildings (F. J. Charters et al., 2016; Christchurch City Council, 2015). In addition transport and associated infrastructure contributes a wide range of contaminants to stormwater, the more so where traffic is heavier. Without changing preferred modes of transport its impact on stormwater quality is likely to increase as the population increases.

The Styx/Pūharakekenui and Ōtukaikino river catchments are mixed residential, horticultural and rural, with small and occasional areas of commercial/industrial land use. These rivers have higher quality water to date compared with the Heathcote/Ōpāwaho and Avon/Ōtākaro.

Water quality in the Heathcote/Ōpāwaho is also significantly impacted by sediment. The river closely follows the northern limit of the Port Hills which are coated with loess, a highly erodible fine windblown silt deposit. Construction activity on the hills exposes the soils and generates silt-laden runoff which is very difficult to settle out before it enters the waterway. Housing development post-quake together with fires in 2017 have exposed soils and increased sediment loads in the catchment. Following storm events the Heathcote/Ōpāwaho runs brown and murky and requires dredging to maintain its capacity. Sediment concentrations can exceed levels that are tolerated by fish (Christchurch City Council,
Environment Canterbury (ECan) is working with contractors and landowners to reduce these effects. At present channel erosion releasing silt is of much less significance than the contribution from land (McMurtrie, 2017). Climate change may increase annual sediment loads from both land and channel erosion as rainfall events of a given magnitude increase in frequency. When runoff from land is better managed the contribution from channel erosion is likely to become more apparent, just as the effects of stormwater contamination became more visible once industrial point source discharges were controlled. Reducing channel erosion requires frequent flushes and stormwater volume to be controlled as well as peak flows.

Low flows also impact a river’s ecological health. Local media reports highlighted community concerns relating to low flows in the city’s rivers in summer 2015/16 and suggested it was caused by excessive pumping of groundwater lowering the shallow aquifer and reducing baseflow (Salmons, 2016). Barr (2016) however found low winter rainfall in 2015 to be the significant factor. Baseflow is also likely to have reduced as impermeable surface cover has increased with urban development as the city has expanded (Barquin & Scarsbrook, 2008 cited in Barr, 2016). Climate change predictions anticipate an increase in winter mean rainfall. This may reduce the frequency of dry winters and low summer baseflow, however greater evapotranspiration and increased water demand due to predicted warmer average temperatures and more hot days per year may offset the benefit.

Flooding has been an ongoing problem in the lowest lying areas around the Heathcote/Ōpāwaho and Avon/Ōtākaro rivers (Watts, 2011) and has been exacerbated by increasing development and earthquake-induced changes to land levels. Following the 2010/11 earthquake sequence ground levels were found to have changed by up to 500 mm in parts of the city. Areas around the lower Heathcote/Ōpāwaho close to the Port Hills rose while land further north around the Avon/Ōtākaro was lowered (Christchurch City Council, 2018). The topographical changes resulted in more homes being at risk of flooding in both catchments and several flood events have affected residents since 2011 (Law, 2015). A large area of land close to the Avon/Ōtākaro was red zoned due to both liquefaction and flood risks. The stormwater network was extensively damaged by the earthquakes and a major programme of pipe replacement is ongoing as part of the city’s rebuild. Longer duration storms cause most flooding in the mid and upper river catchments (Canterbury Regional
Council & Christchurch City Council, 1998; Christchurch City Council, 2015). The lower catchments are also affected by tidal flooding.

As a coastal city Christchurch will be affected by sea level rise. Flood models developed in the early 1990s assumed 100mm of rise over a 50 year period (Oliver & Peters, 1993 cited in (Canterbury Regional Council & Christchurch City Council, 1998). A more recent flood model for the Avon/Ōtākaro assumed 0.5m of sea level rise by 2050 which increases flood impacts in the lower reaches (Christchurch City Council, 2015). Rainfall intensity and the number of wet days is also expected to increase due to climate change. By 2055 rainfall intensity and depths are predicted to rise between 6% to 10% for storm frequencies greater than 1 in 10 year return (“Our Future Climate New Zealand,” n.d.). Climate change is expected to increase the effects of flooding throughout the city’s river reaches without mitigation (Christchurch City Council, 2015).

It is clear that urban development in Christchurch has had a significant and detrimental effect on the ecological health of the city’s rivers. Flooding has been an ongoing issue since early settlement. Increasing densification of the city and climate change will only serve to worsen these effects, unless mitigated. As argued in Chapter 2, the use of building-scale WSUD devices could provide part of the solution.

**WSUD in Christchurch**

In the 1980s ecological and recreational values provided by the city’s waterways began to be recognised. The Woolston Cut, a significant flood management project on the Heathcote/Ōpāwaho completed in 1986, negatively impacted the aesthetic and ecological quality of a stretch of the Heathcote/Ōpāwaho causing anger amongst the local community. The issues were caused by sea water moving further inland with the tide following construction, resulting in slumped river banks and tree dieback. A tidal barrage was constructed in 1994 to mitigate these effects (Watts, 2011). Within the city council a transition occurred, shifting from hard engineering solutions focused on drainage only to a more balanced approach that sought to enhance multiple values and work more sympathetically with nature and local communities, including river restoration with planting of natives, or even removal of pipes to daylight streams (Christchurch City Council, 2003a).
Since the 1990s greenfield developments have incorporated larger scale WSUD features, such as swales and wetlands, to treat stormwater prior to discharge and provide amenity (Watts, 2011). Whilst treatment in basins and wetlands form part of WSUD they are still an end-of-pipe solution if at-source solutions are not also included.

In 2003 the Council published its Waterways, Wetlands and Drainage Guide (WWDG) setting out plans to improve the city’s waterways and wetlands over the next forty years (Christchurch City Council, 2003). The council adopted a six-values approach for assessing potential projects, balancing ecology, landscape, recreation, heritage, culture and drainage benefits. The guide outlines the problems caused by urban development in Christchurch and describes how stormwater management can work with natural processes to reduce impacts and provide environmental and amenity enhancements. The WWDG is still in use and influences the decisions made by developers. Chapter 6 of the guide provides guidance on the selection and design of stormwater management systems but no building-scale WSUD devices are included even though it was updated in 2012. In contrast, rainwater harvesting and living roofs have been supported in Auckland since at least 2003 (Auckland Regional Council, 2003).

The WWDG strongly encourages stormwater management in community systems on public land because ongoing maintenance by the council is assured. The only building-scale solution included in the guide is roof water soakage to ground which is permitted for commercial buildings in approved areas because roof water is considered to be ‘relatively clean’. This contradicts details provided earlier which highlight the extent of dissolved metal contamination sourced from such roofs. The advantages of infiltrating stormwater to reduce runoff and augment groundwater levels are recognised in the WWDG as long as safeguards are in place to avoid the migration of contaminants to groundwater. This is achieved by defining approved areas where soakage on private sites is permitted after treatment. South and west Christchurch have suitable soils for infiltration but opportunities are more limited in central and eastern areas due to lower permeability soils and a high water table. Devices can be designed for shallower water tables and low permeability soils (Auckland Council, 2017) although care is needed to avoid raising groundwater levels in areas susceptible to groundwater flooding. Residential properties are only encouraged to use a soakage system for roof water where there is no approved stormwater pipe to connect to i.e. the majority of
new residential developments are expected to connect to the traditional piped-network regardless of a site’s suitability for infiltration options.

The Surface Water Strategy 2009-2039 (SWS) (Christchurch City Council, 2009) directs council decisions and influences policy. There are nine goals in the SWS. Eight of these relate to improving surface water quality, reducing impacts of flooding, and supporting and protecting activities and values associated with surface water features. The ninth recognises the negative impact of stormwater contaminants on the city’s waterways and the need, therefore, to manage stormwater appropriately. An implementation programme is also included with actions identified to enable the goals to be achieved, but they are dependent on funding. The Long Term Plan (LTP) process identifies, through consultation with residents and elected representatives, how, when and whether to fund these actions.

Section seven of the SWS specifically covers stormwater management policies for different development areas and types. The potential role of building-scale devices is considered, with reported advantages being treatment before stormwater enters the council’s collective system and installation and maintenance is carried out by the developer and subsequent property owners. However, it is concluded that the collective system should be prioritised over on-site management, as it has been since 1875. The reasons given are efficiency, cost-effectiveness and ease of maintenance. Nevertheless it is acknowledged that in some areas, such as residential urban intensification areas and industrial and business areas, on-site stormwater management is more cost-effective and will be pursued because public land suitable for stormwater management devices is limited and the drainage network is reaching capacity. On-site multi-value options identified by the strategy include rain gardens and porous paving. The implementation programme identifies the need to develop a process to ensure ongoing maintenance of devices on private property as well as education to avoid the risk of poor maintenance resulting in flood or contaminant risks. A review of the potential for the use of rainwater tanks is also identified as a necessary action, as it is in the Water Supply Strategy (WSS) which is discussed later in this section (Christchurch City Council, 2009b).

Preferred options for different land-use areas are ranked in the SWS using a multi-criteria analysis that incorporates environmental, social and cultural, and economic values (Christchurch City Council, 2009a, Appendix 7). Building scale devices considered in this
thesis are ranked as shown in Table 4.1. In all areas riparian planting and buffer zones rank first, but these are only applicable to sites adjacent to waterways.

Table 4.1: Building-scale WSUD ranking by land use types in the SWS. Adapted from: (Christchurch City Council, 2009a, Appendix 7)

<table>
<thead>
<tr>
<th>Technique</th>
<th>Residential urban intensification</th>
<th>Greenfield</th>
<th>Existing suburb</th>
<th>Industrial and business areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain garden</td>
<td>2nd</td>
<td>3rd</td>
<td>2nd</td>
<td>2nd</td>
</tr>
<tr>
<td>Green (living) roof</td>
<td>3rd</td>
<td>6th</td>
<td>-</td>
<td>4th</td>
</tr>
<tr>
<td>Porous paving</td>
<td>4th</td>
<td>5th</td>
<td>4th</td>
<td>-</td>
</tr>
<tr>
<td>Rainwater tank</td>
<td>10th</td>
<td>8th</td>
<td>9th</td>
<td>11th</td>
</tr>
</tbody>
</table>

Development rules are set out in the District Plan (Christchurch City Council, 2017). Requirements for stormwater management on site have been limited to date. The most recent District Plan, adopted in 2017, now includes a requirement for commercial property to incorporate water reuse and water efficiency measures as part of a policy on Low Impact Development (LID). LID can also be construed to include sustainable stormwater management which is a broader concept than water reuse and efficiency. Industrial development is simply encouraged to use a multi-value approach to stormwater management and places the emphasis on larger scale devices such as swales and wetlands. Similarly there is only policy encouraging the use of sustainable technologies in housing.

As seen in Chapter 2 streetscape rain gardens are a cost-effective means of reducing the concentration of contaminants in runoff. A recent model of the Avon/Ōtākaro catchment, developed using Auckland Regional Council’s contamination load model (C-CLM v.2.0), applies an additional 35% reduction in total suspended solids (TSS), 45% reduction in zinc and 49% reduction in copper from roof runoff at the discharge point when a rain garden is included in a treatment train before a basin and wetland. The effect on runoff from paved or road surfaces is less pronounced but still significant with a TSS improvement of 16%, zinc 28% and copper 23% (Golder Associates (NZ) Limited, 2018). The Ōtākaro Avon River Stormwater Management Plan assesses retrofit options, including one installing 4357 rain gardens and 13 detention basins or wetlands to reduce contaminants and flooding. The rain

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7 Defined by CCC as using recognised best practice techniques in urban development to promote the efficient use of natural and physical resources and to reduce environmental impacts. It includes freshwater, energy use and conservation values. (Christchurch District Plan, 2017)
gardens provide sufficient additional storage to mitigate the effect of future infill development on flood levels for shorter period storms (4.5 hour), but would be less effective for the critical storms of 24 hours or longer (Christchurch City Council, 2015). Runoff from 47% of hard surfaces in the catchment would pass through a treatment device, but runoff from the remaining 53% of developed land remains untreated. The quality of runoff is improved but not sufficiently to meet in-river zinc and copper minimum standards set by the Canterbury Land and Water Regional Plan (LWRP) (Environment Canterbury, 2017). The timescales for installing public devices is not rapid. A more recent report covering all Christchurch’s main river catchments assumes 35 years for the retrofit of all modelled devices and changes to less contaminative roofing materials to occur (Golder Associates (NZ) Limited, 2018). This highlights the challenge for CCC. The aspirations for Christchurch’s environment seemingly cannot be achieved with council delivered installations only. The gap could be closed with the use of building scale-devices on private land, based on the findings presented in Chapter 2, but would require support and direction from CCC to implement.

The concept of a treatment trains is described in the WWDG but at-source devices are excluded, instead beginning with a macro-pollutant trap for litter and a swale for conveyance to a basin and possible wetland. The more recently published Rain Garden Design, Construction and Maintenance Manual (Christchurch City Council, 2016b) reiterates that basins and wetlands are the council’s preference in larger brown and greenfield developments, which implies an either-or approach, rather than a treatment train. Golder’s recently published assessment of future contaminant loads from stormwater continues to avoid the inclusion of building-scale WSUD devices, although it does highlight the importance of reducing unpainted galvanised roofs (Golder Associates (NZ) Limited, 2018).
Figure 4.2: Soils' drainage classification and indicative depth to groundwater

Legend:
- Approximately 1m to groundwater
- Groundwater protection zone
- Well drained
- Imperfectly drained
- Poorly drained
- Very poorly drained

Note: 1m depth to groundwater adopted from average depth to groundwater contour data.
The rain garden manual provides a detailed specification for an installation designed to treat road and car park runoff with high concentrations of TSS and metals. These rain gardens are recommended to use underdrains unless infiltration rates in the underlying soils are high exceeding 50 mm/h which implies very sandy and/or gravelly soils (Christchurch City Council, 2016b). These soil types are limited in Christchurch (Figure 4.2). Infiltrating rain gardens can be designed with less permeable soils, as demonstrated in the Auckland manual (Auckland Council, 2017). Infiltration reduces stormwater volume. Guidance for less stringently engineered rain gardens suitable for receiving less polluted roof or driveway runoff are also not included. In the US simple to follow Do-It-Yourself guides for rain gardens that can be installed by residents, community groups or schools have been published by states that are embracing WSUD at all scales to tackle stormwater issues (Hinmann, 2013).

Some cities and states, such as Washington DC’s River Smart Homes programme or the Montgomery County RainScapes Rewards, have allocated financial incentives to encourage stormwater devices on private property in areas where runoff reduction is particularly desirable (United States Environmental Protection Agency, 2009a).

WSUD considers the whole urban water cycle. Rainwater harvesting reduces the demand for high quality potable water supply, as well as having the potential to reduce small frequent flushes of runoff. Christchurch’s water abstraction cap will be exceeded by 2050, based on the predicted population and no change in water use per capita (Christchurch City Council, 2009b). The WSS aims to reduce water use with a particular focus on summer garden irrigation - the peak abstraction rate in summer is double that of winter. In the future with climate change Christchurch’s summer mean temperature is predicted to rise by 0.5°C to 1°C, coupled with five to ten additional hot days. This will likely result in higher water use for irrigating gardens and an increased urban heat island effect. The WSS includes a recommendation to investigate a potential subsidy or rebate to encourage the use of rainwater tanks to augment mains supply and this was supported by stakeholder consultation feedback. Despite this, the SWS places rainwater tanks low on the preferred solution list and describes rainwater tanks for be a single benefit solution. The strategic goals of the SWS and WSS could be better aligned in this regard.

Christchurch is well suited to rainwater harvesting with a relatively consistent rainfall year round (Figure 4.3) (National Institute of Water and Atmospheric Research, n.d.). A relatively
small 1500 L tank collecting from a 180 m² roof connected for internal non-potable water use could provide around 25% of the annual water demand for a four-person household in Christchurch (D. Kettle, 2018). A particular benefit of a decentralised water supply in Christchurch is resilience in the event of another earthquake. Climate change may slightly increase the mean summer rainfall total by up to 5% which would benefit rainwater collection.

New infill properties in the Port Hills are required to include a minimum 9000 L stormwater tank with restricted outflow to detain runoff from the roof, driveway and other hardstanding areas to reduce flood impacts downstream, but there is no requirement to reuse the water. A diagram on a single side of A4 last updated in 2004 is provided on the council’s website illustrating rainwater collection connected for toilet flushing. The detail is extremely limited but the environmental benefit of reducing runoff is stated (Christchurch City Council, 2004). Tank installations connected for internal water use are most easily and cheaply achieved in new builds. Anecdotally not all builders are familiar with connecting rainwater tanks for internal water uses and are therefore discouraging new build developers from internal use installation (Superhome owner, 2018). As described in Chapter 2, retention capacity can be effectively combined with rainwater harvesting to support flood management.

![Average monthly rainfall data](image)

**Figure 4.3:** Mean monthly rainfall and rainy days in Christchurch 1981 to 2010. Adapted from: (National Institute of Water and Atmospheric Research, n.d.)

A bylaw requiring rainwater harvesting tanks to be installed in new developments in Akaroa, a town within CCC’s area, was passed in 2014 (Christchurch City Council, 2014). During the
consultation process several submissions, including from the Christchurch West Melton Zone Committee, Environment Canterbury, three community boards and the Canterbury District Health Board proposed the bylaw should extend to cover Christchurch City as well. Staff at CCC dismissed these submissions stating that there was no reason to require rainwater harvesting in Christchurch, as water supply in Akaroa is much more limited (Christchurch City Council, 18-19 September 2014). No reference was made to the WSS. The Port Hills in particular, where tanks are already required for managing flow rates, could have been used as a pilot scheme for requiring or encouraging reuse. More recently, as mentioned, a District Plan policy now requires rainwater reuse in commercial properties, if practicable.

Finally, there are no design guides for living roofs or permeable paving (PPS) provided by CCC despite support in the SWS with living roofs ranking third in residential urban intensification areas, and PPS fourth in these areas and existing suburbs and fifth in greenfield developments (Table 4.1). Rain events up to 25 mm in depth have been reported as generating almost no runoff from living roofs (Carter & Rasmussen, 2006, in Czemiel Berndtsson, 2010). In Christchurch this would capture around 78% of the annual rainfall (Christchurch City Council, 2012) providing an effective technique for reducing frequent flushes, albeit the scope for widespread use of living roofs is limited compared with the other devices. PPS has a greater scope for use in both new build and retrofit projects and is also very effective at limiting flows and reducing runoff volumes from smaller rainfall events. PPS can also be effective at removing metals from runoff, priority contaminants in Christchurch, particularly those systems with a concrete block component which has been shown to raise the pH and reactions immobilise some metals (Murphy, Cochrane, & O’Sullivan, 2015). Figure 4.4 presents the construction profile of a standard rain garden in Christchurch, one underdrained and one infiltrating (Christchurch City Council, 2016b), and the PPS profile for a block system based on Auckland Council’s guidance (Auckland Council, 2017). PPS is compatible with a slightly higher water table and requires less excavation depth, although would need to cover a wider area to treat the same volume of runoff as a rain garden. A shallow water table is a constraint for infiltrating rain gardens across parts of Christchurch (Figure 4.2). Both PPS and living roofs would reduce the negative effects of stormwater runoff on the natural environment but are unsupported locally. Design manuals are important because they give designers confidence that if they adhere to the manual
their design will be approved by the council and avoid delaying the consent process (Watts, 2011). Delays to planning consent have a financial impact on developers and act as a barrier, as identified in Chapter 3. Support for the full selection of building-scale WSUD devices specified to suit a wider variety of sites and development types would encourage installations and support the SWS goals. As reported previously, implementation is critical for achieving the strategic goals set out in the SWS.

Figure 4.4: Rain garden and block permeable paving system standard construction profiles. Adapted from: (Auckland Council, 2017; Christchurch City Council, 2016b).
It is clear that regulatory requirements and guidance could support the uptake of on-site stormwater management in new developments more effectively. Regardless, mandatory requirements for new build development has a limited reach since existing development is not affected. Voluntary changes to on-site stormwater management is also critical if water quality targets are to be achieved within the foreseeable future. There is a severe lack of motivators or support for voluntary change, based on the drivers that have been effective internationally. Water supply and stormwater management is charged in rates rather than volumetrically. Despite the relatively low total rainfall the city’s aquifer provides cheap reliable high quality water year round (Christchurch City Council, 2009b) - even during long hot dry periods hosepipe bans are rare. The quality of water in the Avon has no impact on the quality of drinking water supply. Summer flows in the Avon have been low and of concern to local residents but no clear message is provided to residents in the western suburbs about how they could augment water table levels with infiltration measures on their properties. Frequent combined sewer overflows, caused by excess stormwater combined with sewage in a single system, are a key driver for change internationally. These effects are not present to the same extent in Christchurch with the separate stormwater network.

Earthquake challenges and opportunities

Major events can trigger a transition to a different regime or lead to entrenchment (Keath & Brown, 2009). The 2010/11 earthquakes offered such a transitional opportunity. Immediately following the February 2011 earthquake water supply was cut off. Access to mains supply was returned to 70% of the city within a week of the 22 February 2011 earthquake (“Long wait for some without power, water,” 2011). Virtually all properties were back on mains supply after four weeks (Henderson, 2011). The stormwater network was significantly disrupted and flooding became a more frequent occurrence in some parts of the Heathcote and Avon catchments.

The disruption to water supply following the earthquakes could have motivated individuals and/or businesses to increase their resilience to a future event, but there has not been a widespread uptake of rainwater tanks during the rebuild. A single 7-star Homestar property with rainwater tank connected for internal non-potable uses was built and promoted in 2012 by a group builder, Stonewood Homes, in Lincoln, near Christchurch (Wood, 2012). A study
investigating small and medium sized businesses’ responses to a significant water supply contamination event that affected almost 40% of the town’s population in Havelock North, New Zealand, found that very little adaptation followed the crisis (Teen, 2018).

The rapid greenfield development that occurred following the earthquakes incorporated the larger-scale WSUD features. Some developments also included rain gardens and planted swales, but their extent varies between developments. These features were already familiar in new subdivisions and supported by CCC strategy, development policies and rules and guidance prior to the earthquakes.

Public consultation following the earthquakes revealed a desire to rebuild a more sustainable city (Lucas, 2014). CCC proposed a planning rule requiring all new homes to be built to a 6-star Homestar minimum standard. Homestar is a sustainable building certification scheme based on points for measures that create a more sustainable home, such as insulation, solar panels and rainwater harvesting. The Government opposed the proposal because it set standards above the national Building Code requirements, despite the government committing to better urban design, including high standards of construction and reducing environmental impacts via the New Zealand Urban Design Protocol (Ministry for the Environment, 2005). The New Zealand Institute of Architects (NZIA) also opposed the proposal citing the cost of installing more insulation (Cairns, 2014; NZIA, 2014). In comparison the Royal Institute of British Architects (RIBA) took a different approach when responding to a national consultation in the UK on planning and future housing stating, ‘Clearly no developer is going to build something that is unprofitable, but there is a negotiation to be had which is in the interests of the public and the Local Authority.....If affordable housing provision and quality of new development are consistently compromised by an opaque argument for financially viable, we will not be able to adequately respond to the challenge ahead of solving the housing crisis.’ (Beagle, Fox, Parkinson, & Plotka, 2014).

Improving knowledge of the link between activities and impacts on waterways and demonstrating practical solutions is an important part of creating behaviour change. A small temporary ‘Gap Filler’ project called SWASH demonstrated a mockup of a living roof and a permeable paving area with signage, located on a vacant site in the central city (F. Charters, 2018). The demonstration was intended to motivate developers and homeowners to use WSUD solutions to mitigate the generation of runoff on their properties and adapt to more
water-sensitive behaviours. A much more substantial demonstration of sustainable building technologies was to have been developed through the Breathe design competition which ran in 2012/13. The competition was led by a partnership of government, CCC and Ngāi Tahu. Consideration of the effects of the development on the downstream environment was included in the earliest brief for the project, together with an explicit requirement for stormwater treatment to be addressed in the design (Breathe Competition Information Pack, 2012). Despite a high level of interest a lack of financial support from the government prevented the winning design becoming a reality (Roberts, 2017). Whilst the primary purpose of the project was to revitalise the city centre, it was also intended to showcase sustainable technologies. A more recent innovation has been the creation of the Superhome movement in Christchurch, launched mid 2015, which provides the opportunity for those interested to visit homes of early adopters who have incorporated sustainable technologies, including rainwater harvesting and grey water recycling. These homes are categorised using the Homestar rating tool. Tours are held several days a year and the attendance of these events has risen from around 3500 in 2016 to 9500 in 2018 (Superhome movement, 2019). These offer a great opportunity for knowledge sharing and inspiration but there is also a risk that these ‘Super’ homes are seen as ‘high end’ which can be a barrier in itself (Dodge Data & Analytics, 2016).

Prior to the earthquakes South Library and Riccarton Library used rainwater to flush toilets and small notices informed library visitors. The rainwater collection systems are no longer functional and toilet flushing is now on the mains water supply. Post-quake CCC developments, such as Turanga, the new central library, or the new swimming pool and gym complex at QEII have not visibly included rainwater harvesting. Of 41,000 non-residential buildings in New Zealand it is estimated that only 370 collect and reuse rainwater, most of which are rural schools (BRANZ, 2018).

Changes to the layout of the CBD to establish a more compact core of inner city commercial and residential development alongside an increased area of central city green space (Canterbury Earthquake Recovery Authority, 2012) has provided an opportunity for rain gardens to be more widely installed, continuing a process of opportunistic rain garden installations in public spaces that began in the 2000s. However, information boards to explain the presence and purpose of rain gardens to passers by are largely absent, and in
that regard they do not provide the education or demonstration benefit that they could. In some cases they are used as an ashtray. Signage could help to reduce this practice and provide motivation to developers or others in a position to incorporate a rain garden into a project.

A few commercial properties are incorporating building-scale WSUD features. A Ngāi Tahu Property central city office development, on the site of the old King Edward Barracks, includes rain gardens with native planting and eel sculptures representing the link back to the river. The Bus Exchange, a government anchor project, also includes a rain garden. The University of Canterbury has installed several rain gardens that are both functional, reducing the effects of runoff from the Campus on the Okeover, and used for research purposes. The Tait Technology Centre on the western edge of the city has a small area of intensive green roof planted with native grasses visible from entertainment areas of the conference centre, although not accessible (Figure 1.2). Two small areas of native planting have been included on an accessible roof terrace at Turanga which shows the potential amenity benefit of a living roof, although their impact on stormwater management will be very limited.

Figure 4.5: Collett’s Corner, Lyttelton. Living roof concept with rooftop gardens and entertainment area. Source: (Young, 2018)

A proposed development in Lyttelton has been promoted with an intensive rooftop garden, demonstrating the advantages a living roof can bring for amenity and/or biodiversity as well
as stormwater improvements (Figure 4.5). There is some evidence that living roofs could also
enhance earthquake damping in structures (Matta & De Stefano, 2009; Omenzetter, Clifton,
& Fassman, 2009). Higher density terraced housing and apartment blocks are forming part of
the new mixed development in the densified CBD. This increases the proportion of
impervious cover on private sites compared with public streets. These intensifying areas
would seem ideal for the use of living roofs and permeable paving, as advocated in the SWS,
and may provide an opportunity to demonstrate WSUD in its entirety, as seen at Earthsong
(Figure 1.1).

At odds with the densifying city, around 600 hectares of previously developed red-zoned
residential land adjacent to the Avon/Ōtākaro has been cleared of housing and
infrastructure and will form a ‘green-spine’ from the CBD to the coastal suburb of New
Brighton. Proposals for the area include extensive wetlands for stormwater treatment and
flood management, as well as providing biodiversity and amenity benefits, and are well
supported by the public (Guildford, 2018). Wetlands provide a cleansing function but the
inclusion of building-scale and streetscape WSUD devices in a treatment train will enhance
the ecological value, improve the final water quality released to the Avon/Ōtākaro (Graham,
2017; Newman & Coupe, 2017) and slow the buildup of metals, reducing maintenance
requirements (Berwick, 2017). As such, the opportunity for development of new wetlands
supports the argument for on-site stormwater management and the creation of a treatment
train. The application of WSUD at all scales across the city could improve amenity and
ecological value to the city’s springs, creeks, wetlands and main rivers, supporting goals in
the Biodiversity Strategy (Christchurch City Council, 2008) and the Public Open Space
Strategy (Christchurch City Council, 2010b) as well as the SWS.

New Zealand and water - national, community and indigenous views

Environmental concern amongst the New Zealand public grew throughout the 1970s as a
series of large-scale government and private sector developments were constructed with
significant environmental effects and limited consideration for local opinion. In 1980 the
Organisation for Economic Co-operation and Development (OECD) recommended changes to
the country’s environmental institutions, laws and policies. In 1991 the Resource
Management Act (RMA) was adopted setting out how natural and physical resources are
managed based on the principles of sustainable management. Sustainable management is
defined in the Act as managing the use, development and protection of natural resources in
a way that enables people and communities to provide for their social, economic and
cultural well-being while: sustaining the potential of those resources to meet the needs of
future generations; safeguarding the life-supporting capacity of the essential components of
the environment, including water; and avoiding or mitigating any adverse effects of activities
on the environment. The Act was supported across the political spectrum. Unfortunately, the
level of environmental protection it was expected to afford has not materialised. One
criticism is that the Act focuses on effects. Development is permitted as long as it avoids
adverse effects but in practice this allows for minor effects from each new development
which cumulatively results in detrimental environmental effects (Knight, 2018). Small
stormwater contributions from private properties added together impact on the ecological
functioning of a watercourse, although each individual contribution has a minimal effect in
itself.

The RMA in Section 5 recognises four components of sustainability: culture, society,
environment and economics. In theory these four aspects are balanced to achieve a
sustainable outcome, but in practice it is easy for the economic aspects to be prioritised over
the others (Wheen, 1997). Interpretations of the RMA in Environment Court judgements
until 2014 generally applied such a balance with the matters set out in subsequent sections
of the RMA, such as the maintenance and enhancement of amenity values; intrinsic values
of ecosystems; and maintenance and enhancement of the quality of the environment, being
considerations but not objectives in their own right (Knight, 2018). Cost-benefit analysis
involves assessing the financial costs and benefits of a proposed development but as
highlighted in Chapter 1 intangible benefits are difficult to put a dollar value to and are
therefore easily undervalued. Further, as highlighted in Chapter 3 short-term direct benefits
will be prioritised by developers or property owners (Lamond et al., 2014).

It was expected that national policy statements would follow the enactment of the RMA
providing more detail on aspects of national significance giving more direction to councils on
decisions relating to development and the environment (Knight, 2018). The first National
Policy Statement for Freshwater Management (NPS-FM) (Ministry for the Environment, 2017) was published in 2011, 20 years after the RMA. By 2011 concerns about the quality of groundwater and surface water, and over abstraction were already significant in Canterbury. The Canterbury Water Management Strategy (CWMS) (Canterbury Water, 2009) created a collaborative process for addressing water conflicts in the region. Whilst the NPS-FM and CWMS mention urban water issues the focus of both is rural water problems. The NPS-FM includes minimum water quality standards for a limited suite of rural contaminants to be achieved within a defined timeframe, but no bottom lines are provided for urban contaminants such as heavy metals or hydrocarbons.

The NPS-FM directs Canterbury’s regional council (Environment Canterbury) to set water quality standards for freshwater bodies. Limits for urban spring-fed watercourses, such as the Avon/Ōtākaro, are defined in the Canterbury Land and Water Regional Plan (LWRP) (Environment Canterbury, 2017 Table SSB, p.367), based on the freshwater trigger values for a highly disturbed stream defined in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000). They are applied to the water quality in the watercourse (both physical and chemical) after a defined mixing zone downstream from any stormwater discharge point and are selected to give confidence that 90% of aquatic organisms will be protected if the trigger concentration is not exceeded. Whilst this approach recognises the urban context it does not acknowledge the community aspirations or cultural needs. The Australian and New Zealand Guidelines recommend selecting site-specific guideline values (previously trigger values) which involves a ten-step process including consultation with the local community and developing a management plan (Water Quality Australia, n.d.). To date this approach to selecting in-river water quality standards has not been taken by ECan. A recent update to the generic guideline values which takes into account additional research including New Zealand native aquatic species has reduced the maximum zinc concentration to achieve 90% protection by more than half from 15 μg/L to 6 μg/L. Conversely the copper guideline concentration has slightly risen from 1.8 μg/L to 2.1 μg/L (NIWA, 2017).

CCC is required to improve the quality of stormwater runoff to ensure the city’s rivers are compliant with LWRP standards by 1 January 2025 (Environment Canterbury, 2017). CCC is in the process of renewing its global discharge consent (a single consent that permits and sets standards for most discharges in the city). The council is responsible for all discharges it
receives, including from private properties. Stormwater management plans form part of the consenting process and set out how each catchment is to be managed to achieve the LWRP targets. However, the council has limited scope to force alterations on private property to improve the quality of runoff discharging to the stormwater network. The RMA affects new development decisions, but provides limited opportunities to wind back effects, other than for time-limited consents that are reviewed periodically. In general consents associated with residential stormwater discharges are only reviewed if a change of land use is proposed.

A further purpose of policy is to elicit behaviour change (Brown, Peart and Wright, 2016 in Knight, 2018). Behaviour change can address the limitations of regulation that only applies to new development. Stormwater fees were cited in Chapter 3 as one method for encouraging the uptake of WSUD solutions on private property but economic instruments have rarely been used in New Zealand (Knight, 2018).

Education is another key part of creating behaviour change. Water-interest groups across the city have recognised the detrimental effect of stormwater contamination on the city’s rivers. The local media has published articles highlighting the poor water quality in the city’s rivers (D. Harris, 2018; Stylianou, 2016). The Christchurch West Melton Zone Committee has developed the ‘Stormwater Superhero’ project, which, via news articles and roadshows, informs individuals about day-to-day changes they can make to improve stormwater quality. The advice focuses on small individual actions, such as washing cars on grassy areas and selecting copper-free brake-pads. CWMS funding is limited and does not stretch to a high profile citywide campaign.

CCC’s Innovation and Sustainability Fund can be accessed for stormwater-related projects and sustainable education activities. The Avon-Ōtākaro Network was created to advocate for the creation of a publicly owned reserve with high ecological and recreational value on the cleared red zoned land. They applied to CCC for funds to build a small demonstration rain garden and rain barrel at Avebury House in the suburb of Richmond, Christchurch. It was installed in 2018 with prominent educational signage as part of the Matariki in the Park celebrations (Figure 4.7). The design is based on a US-style DIY rain garden rather than the more complex design specified by CCC’s rain garden manual. The purpose is to promote simple changes that residents can make to their own property to reduce their environmental
impact. The location of the demonstration was important, being sited close to the Avon/Ōtākaro to highlight the connection between runoff and the river.

![Signage board](image1.png) ![Rain tank connecting to the rain garden](image2.png)

**Figure 4.7**: Avebury rainwater tank and garden demonstration site

Local community action and advocacy can be very influential (Portney & Berry, 2016). Christchurch has a history of resident groups advocating for its waterways, albeit coming from a range of perspectives. The Christchurch Beautifying Association was founded in 1897 with a focus on aesthetics. More recently local groups have instigated projects to support healthy native ecosystems within their local waterways. The Cashmere Stream Care Group was set up in 2006, with support from ECan, to improve the quality of water and ecological diversity through the catchment. The Styx Living Laboratory Trust has a focus on education and research. The Working Waters Trust has focused on vulnerable native fish species and education projects, including an urban eel project with two Christchurch schools. The Ōpāwaho Heathcote River Network was formed in 2015 to connect several individual groups and pursue a whole of catchment vision for an ecologically healthy, readily accessible river with an engaged community. The Avon-Heathcote Ihutai Estuary Trust, set up in 2002, recognises the impact of stormwater inputs to the rivers on the estuary. As well as championing projects and rallying volunteers, these interest groups also make submissions on plans, policies and development applications (Avon Heathcote Estuary Ihutai Trust, 2013; Avon Otakaro Network, 2018).

CCC staff involved in stormwater management are encouraging a collaborative approach to surface water management, called the Community Water Partnership, by further developing
connections between CCC staff, ECan, Department of Conservation, Ngāi Tahu, water-interest groups, and other interested residents and businesses. The long term goal is to improve individual knowledge about waterway health, promote actions that could be taken individually to reduce contamination and encourage citizens to engage with their local waterways. A total of $1 million per year was sought for a 20 year period (Avon Otakaro Network, 2018) via the most recent LTP (Christchurch City Council, 2018). International experience shows an extended period of time is crucial to build support for and embed behaviour change. The benefit for the council is a long-term reduction in spending on the management of contaminants, compliance with the LWRP water quality standards and progress towards goals set out in the SWS. The benefit for individuals would be an ecologically-rich catchment and waterways suitable for a wider range of activities than at present. The proposal was not supported for funding because of competing demands for funds and rates rises which were already substantial (Dominic Harris, Law, & Ineson, 2018).

Flooding is a politically sensitive issue that attracts funding (Law, 2015, 2017b). CCC has been focused on reducing flood risk back to pre-earthquake levels. The council pursues ecological and water quality benefits through flood mitigation schemes using the six-values approach. These schemes also offer an opportunity for the council to work towards achieving the LWRP targets. Recently, for example, an urban forest and wetland was planted on former school playing fields within the Heathcote/Ōpāwaho catchment as part of a flood management scheme (Law, 2017a). The council acknowledges the need to spend more on stormwater quality treatment to meet the LWRP targets (Christchurch City Council, 2018) but, with the exception of recent changes to commercial development planning policy (, only encourage solutions that can be retrofitted or included in new build development by individuals or businesses.

Māori cultures place a high value on maintaining the quality of resources for current and future generations, with a particular emphasis on water (wai). For Māori mahinga kai is a fundamental need. A tribe’s prestige or ‘mana’ is linked to their ability to provide good quality food for their own families and visitors. Their belief system emphasises the interconnectedness of humans and the environment and places a duty of care for the environment on tribe members on behalf of all future generations, guided by traditions passed on by ancestors. Ngāi Tūāhuriri, the local sub-tribe or hapū, has customary rights and
responsibilities for the Christchurch Ōtautahi area. The nested sustainability model in which the environment is prioritised because societal and cultural wellbeing and the economy are dependent on a healthy functioning environment (Figure 4.7) represents more accurately the Māori prioritisation of values. It does not mean the economy isn’t important but recognises that the environment has a finite capacity and current generations must maintain healthy ecosystems if the planet is to continue to provide for future generations (Willard, 2010).

![Three nested dependencies sustainability model](https://docs.google.com/document/d/1RobScioOB-ZVGOHPRD_8h11YwFUHDOJBjcgd6ObQLEA/edit#)

**Figure 4.7:** Three nested dependencies sustainability model (Adapted from Doppelt in Willard, 2010)

It was recognised that the rebuild of Christchurch provided an opportunity for urban development to reflect and embed their culture and values. Matapore, a charitable trust, was set up to represent Ngāi Tūāhuriri with respect to post-earthquake regeneration, including the government’s anchor projects. Cultural narratives produced by Matapore to guide designers identify mahinga kai as a principle value for consideration. They make reference to the ongoing degradation of the waterways. Design features that improve stormwater management and therefore support rehabilitation of ecosystems and aspirations
for re-establishing mahinga kai sites are highlighted, with rainwater harvesting included as an example (Tau, 2016). The ability to act as guardians (kaitiaki) to their environment through these developments is a key component when applying a Māori worldview to the four principles of sustainability (environmental, social, cultural and economic). Further, the concept of rangatiratanga is also referenced with respect to empowering communities, achieved in part through the transfer of both knowledge and responsibility, which on-site stormwater management with the inclusion of building-scale WSUD features supports.

At a national and local level water is a political priority. The poor state of waterways was a key issue during the 2017 government elections (Morton, 2017). At present 80% of New Zealanders want tighter rules to protect rivers and lakes from pollution (Gudsell, 2019). However, rural contamination caused by farming practices continues to dominate the debate. Matapōrē presents the potential for a bicultural approach to addressing Christchurch’s waterway pollution by motivating residents to appreciate the rivers through an appreciation for gardens and landscape and the increasing interest in building urban food resilience since the earthquakes (Tau, 2016). This approach seeks to reconnect individuals with their environment and recognise their potential to have a positive influence on it.

Summary

The ecological, cultural and recreational values in the many waterways that pass through urban Christchurch are impacted by contaminants and an urbanised hydrological pattern caused by stormwater runoff from impervious surfaces and limited recharge to groundwater. Contamination and flooding in particular has been an issue for the city since its early development. Since the 1980s a more holistic approach to waterway management by the city council has replaced the traditional drainage-only approach. This has led to new subdivisions incorporating larger-scale WSUD features, and a retrofit of rain gardens, basins and wetlands, where feasible, into the public spaces across the city. Post-earthquake redevelopment has increased these features. However, very little changed in the rebuilding of individual properties with regards to on-site stormwater management by developers, residents or businesses.
Contaminant inputs from stormwater have to reduce to achieve the LWRP in-river water quality standards and modelling predicts this cannot be achieved with installations on public land and changes to roofing materials only. Densification and climate change may cause poorer water quality, worsening flooding and extended drying reaches during the summer, together with increased demand for water supply, unless addressed through development policies and/or behaviour change. Building-scale WSUD has been recognised as necessary to achieve improvements in existing built up areas since 2009 when the SWS was published, but supporting policies are still almost entirely absent from the District Plan which sets out what new development has to include. A Community Water Partnership to engage with community groups and other key organisations to address individual’s impacts on the water environment was proposed for funding at CCC’s last LTP process but was unsuccessful in attracting funding.

Evidence presented in Chapter 2 demonstrated that water quality improves when WSUD is installed in a treatment train. At source management of contaminants, including the use of building scale devices, protects the ecological health and reduces maintenance of larger scale devices such as wetlands. Streetscape rain gardens are a cost-effective at source treatment, but cannot be installed in all areas. Consideration of all types of building-scale WSUD device provides an opportunity to incorporate at source treatment more widely. CCC has encouraged the use of WSUD devices within public spaces, including land within subdivisions that transfers to the council for maintenance. It is not clear why there is not the same support for the uptake of building-scale devices to complete the treatment train. Chapter 5 sets out the methodology for investigating the barriers to the uptake of building-scale devices in Christchurch.
Chapter 5 - Methodology

Introduction

Chapter 4 demonstrates that building-scale WSUD devices could be beneficial, particularly to enhance the ecological and cultural value of Christchurch’s rivers if incorporated widely. At present WSUD features, almost exclusively in the form of rain gardens, are predominantly located in the street or other public areas. Key barriers identified in the literature that have limited the uptake of building-scale WSUD were summarised in Chapter 3. The physical and cultural context and current legislation and policies influencing WSUD in Christchurch are described in Chapter 4. This chapter describes the methodology used to investigate the three research objectives: to identify the barriers to uptake of building-scale WSUD in Christchurch (Objective 1); to understand the financial implications and benefits afforded to the individual property owner that chooses to install WSUD devices on their property (Objective 2); and to identify measures that could be taken to increase the use of building-scale WSUD solutions (Objective 3). The chapter begins with my motivation for pursuing this research topic and the experience I bring to the research.

Positionality

I visited New Zealand in 2002. I returned home to the UK and described tramping in the beautiful expansive forests, mountains, lakes and rivers, but also observed that it was only ‘clean and green’ because of the small population, not because the environment was well cared for. Returning as a resident 16 months after the most destructive 22 February 2011 earthquake I was shocked by the devastation apparent across the city but was also enthused by discussions about a sustainable rebuild. Over the next few years it seemed that although flagship projects gave a nod to sustainability the majority of construction continued with standard pre-earthquake construction and sustainable features were absent. I also had the impression that a majority of New Zealanders took their environment for granted and were generally unaware of their impact on it. The expanse of concrete driveways poured was particularly noticeable to me. News articles about flooding and the poor quality of water in
Christchurch’s rivers and an article about architects objecting to raising building standards in the city created my thesis topic.

I trained and worked in the UK as an engineering geologist in consultancy before a career change to strategic planning in the public sector. This experience has given me an understanding of the technical considerations relating to water management and the importance of good planning. Planning can minimise the negative effects of development on and increase beneficial outcomes for the environment and communities, whilst enabling economic activity. I am also acutely aware of the political realities council staff and city councillors have to work with.

From a personal perspective, I believe in taking responsibility for my environmental impact, and that we should pass a better world on to our children. I believe knowledge of and exposure to the natural world is essential if we are to value it - therefore environmental education is critical. Through this research I have tapped into others’ professional knowledge and personal perspectives and am grateful for all my interviewees’ time and openness. I hope this work can stimulate debate and help move the urban environment closer to one that embraces and supports our natural world rather than works against it.

To answer the research objectives I recognised the need to collect first-hand information from people already involved in stormwater management and construction. Although there are many research papers on barriers to WSUD internationally there is limited research on this in New Zealand. The importance of understanding the local drivers and local politics in devising solutions to overcome hurdles was evident from the international research.

**Interviews, posters and field trips**

Interviews are considered to be the most effective way of gathering knowledge, experience, motivations and opinions from a diverse range of stakeholders. Interviewing also provides an opportunity for findings to be fed back iteratively into subsequent interviews so that topics that arise more commonly can be explored more deeply (Dunn, 2005). In addition the interviewer can be flexible with the location, date and length of interview to accommodate interviewees, as well as providing anonymity. A disadvantage is that interviews are time consuming for both the researcher and the participants. My interviews were designed to be
completed within 40 minutes to 1 hour but fitting in with participants timetables and venue choices, and my part-time day, meant two interviews was the most achieved in a single day. Typing transcripts was also time consuming but would be less so for a more proficient typist. Dunn (2005) estimates at least four hours per hour of interview for creating transcripts. A researcher more familiar with using interview data could more confidently decide which information was most relevant to record and create abridged transcripts (Cameron, 2005).

Questionnaires were not the preferred form of information gathering because they are constrained by the need to keep them short and simple and therefore are limited in the depth of information they can collect. However, since the time commitment is so much less than for interviews they can relatively rapidly gather information from a larger number of stakeholders and may therefore access a more diverse group (McGuirk & O’Neill, 2005). Questions can be designed to provide quantitative data which can highlight dominant viewpoints from a sample population effectively. Research for this thesis coincided with a CCC survey on residents’ attitudes to water. The survey is outlined in more detail later in this chapter.

In Chapter 3 key barriers to the uptake of WSUD identified in international research were synthesized. They included: limited policy, higher upfront cost, lack of public awareness and technological concerns. To achieve widespread adoption of building-scale WSUD devices installations are needed in both new builds and existing properties. Measures that could positively influence the use of WSUD, particularly at the building-scale, were presented barrier by barrier, and included: changes to policy, educational programmes, subsidies, demonstration projects and local research. These solutions require key stakeholder groups to act to influence change. Stakeholders in a position of influence through their professions from both the public and private sectors were included on a list of potential participants, including developers, researchers, architects, planners and stormwater practitioners. Representation by the community sector was also important since community advocacy has been shown to be a significant factor in creating cities with strong sustainability policies and outcomes (Portney & Berry, 2016). Table 5.1 below shows stakeholders grouped by job type and business sector. Examples of targeted organisations are listed, although not all of these organisations were represented by interview participants.
Table 5.1: Summary of interviewed stakeholders

<table>
<thead>
<tr>
<th>Sector</th>
<th>Public sector</th>
<th>Private sector</th>
<th>Community groups</th>
<th>Māori</th>
<th>Personal building project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineer/planner/project manager/sustainability assessor</td>
<td>MfE, CCC, ECan, Otakaro Ltd 5</td>
<td>Consultants and contractors 7</td>
<td>2</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Governance</td>
<td>CCC, ECan 1</td>
<td></td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Researcher/Academic - engineering, science, ecology</td>
<td>Crown institutes, universities 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Architect/landscape architect</td>
<td>CCC, Matapore 0</td>
<td>Private practices, building firms, student 3</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Developer</td>
<td>Housing New Zealand 0</td>
<td>Group builders, corporate developers, small-scale subdividing 2</td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Subdivision property sales</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplier/installer/maintenance</td>
<td></td>
<td></td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insurance representative</td>
<td>EQC 0</td>
<td>Insurance companies, consultants 0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>16</td>
<td>3</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>

The Māori perspective on stormwater and their position of influence on the rebuild was described in the previous chapter. Māori interviewees were identified who were also within
the stakeholder groups listed above. They were able to respond to questions about WSUD but include a Māori perspective.

At the outset of this project I assumed the insurance industry would be a significant stakeholder, given the large source of funding contributed to the rebuild of Christchurch through insurance policies and the industry’s interest in reducing flood risk (Insurance Council of New Zealand, 2014). Through interviews with experienced WSUD practitioners and the process of writing the literature review on building-scale devices, presented in Chapter 2, I concluded that although flood peaks for smaller storms are reduced with building-scale devices, they have limited impact on the major floods that cause property damage. The perceived advantage to the insurance industry of advocating for installing more expensive building-scale WSUD devices in rebuild projects was therefore less than I’d initially thought. Nevertheless, two potential interviewees involved in the insurance industry were emailed to see whether there could be an advantage to the insurance industry in rebuilding for resilience rather than replacing like-with-like, but neither responded.

In addition individuals who considered or installed building-scale WSUD with their own rebuild property were also likely to provide insights into the barriers encountered in Christchurch. The extent of rebuilding in Christchurch meant that whilst only one interviewee was selected specifically because of their rebuild experience, an additional five interviewees were able to comment on their personal experience of rebuilding or renovating.

The number of individuals who could realistically be interviewed within each stakeholder group within the time available was limited. It was considered more important to gain a breadth of views rather than focusing on gathering information from a greater number of representatives within a smaller range of stakeholder groups. Building up a picture of the motivations, difficulties and concerns of these diverse stakeholders was considered the most effective way to identify barriers to building-scale WSUD in Christchurch (Objective 1). Stakeholders were also asked about preferred WSUD solutions, including considerations of cost effectiveness and maintenance, and ideas for increasing the uptake of WSUD on site (Objectives 2 and 3).
Potential individuals from each of the listed stakeholder groups were identified through internet searches, word of mouth, the author’s own network, contacts made through events and recommendations from participants (known as snowballing). A total of 111 potential interviewees were identified. From this list 57 were prioritised to gain a spread of stakeholder types with a focus on those with Christchurch experience. In some cases organisations were contacted to identify a potential interview participant, but where possible individuals were contacted directly. Invitations to participate were generally sent via email, although first contact was made via LinkedIn if a direct email address was unavailable. Each email was bespoke and explained the relevance of the research to the potential interviewee. This was considered important to increase the likelihood of gaining a positive response, particularly from those not already involved in the stormwater debate.

Although I was able to interview a wide range of stakeholder types, engineers and planners dominated. In part this was a result of snowballing, whereby a potential participant is recommended by an existing interviewee, which can introduce some bias (Babbie, 2007). Also, those with an interest in stormwater issues are more likely respond positively to an invitation to participate in stormwater research. Key groups contacted but poorly represented or absent from the interviews were developers, architects, resource consent planners, local politicians and Ministry for the Environment. The city councillors contacted were known to be interested in sustainable development but are very pressured for time. All of the developers and architects who responded were found to have an interest in sustainable/environmentally sensitive development. Anecdotal information about non-interested developers and their perspectives was provided by interviewees who have worked with mainstream developers.

Positive initial responses were received from several stakeholders whose participation would have resulted in representation in all stakeholder groups identified in Table 5.1 or expanded groups with limited numbers of participants. Unfortunately despite follow up emails final interview arrangements were not confirmed. To achieve a more balanced range of interviewees, if I were to conduct the research again, I would plan the invites to cover broad ranges of stakeholder types in each batch of emails, rather than sending to batches of similar stakeholder type. I could then have recognised the gaps earlier and worked harder to find additional interviewees from those professions. Nevertheless, having a large group of
stakeholders with some commonality provided a data analysis opportunity which culminated in Table 6.1.

A total of 28 interviews were pre-arranged. A 29th was added spontaneously when an interviewee brought in a relevant colleague. Table 5.1 above shows a total of 30 interviewees because one interviewee represented two groups. Of the interviewees eight or nine also participated in one of the three of the workshops described in a section below. Of the remaining interviewees twelve were new to discussions on stormwater management and brought new perspectives and experiences to the research. The personalised emails and being flexible about the time and place of interview is likely to have contributed to successfully engaging with this broader group.

It is important that research does not expose those who participate in it to harm (Dowling, 2005). The University of Canterbury requires all research involving human participants to be reviewed by the Human Ethics Committee (HEC). All the potential interviewees identified for this research were adults and the research questions were non-personal. However, investigating opinions relating to work themes could risk an individual’s standing in their professional community or with their employer. Based on criteria established by the HEC the research proposed was suitable to follow a low risk application process. Before approval was given to contact potential interviewees HEC reviewed a list of potential stakeholder types; topics for discussion during the interviews; and the methods to be employed to ensure confidentiality of the participants.

An information sheet for prospective participants was developed providing enough details of the research that they could make an informed choice before participating, including the anticipated length of time required for the interview (Appendix A). McGuirk and O’Neill (2005) state, referring to gathering questionnaire data, ‘We are beholden as researchers to ensure that we have sufficient reason to call on the time and energy of the targeted research subjects.’ It is particularly important that interviewees are well informed before participation since the time contribution asked of interviewees is even greater. Interviewees are also advised that they can leave the study at any time and remove their interview information if they wish. The HEC advised emails to be used as the first method of contact to avoid invitees
feeling pressured to participate. Participants completed a consent form ahead of their interview.

To protect anonymity names were replaced with codes on interview transcripts and the codes were separated from names and other identifying details, both on paper and in digital storage. Participants were advised that they would be anonymous and quotes would not be attributed to them directly without their prior agreement. Any quotes to be attributed to an organisation required approval by senior management in the organisation without revealing the interviewee’s details. Including quotes is important for evidencing and building confidence in the reported findings, as well as providing interest in the analysis. Although a process was available for attributing quotes with consent, on writing up it did not seem necessary to identify individuals and quotes have all been reported anonymously using broad brush details of sector or profession and a code only.

In addition to interviews a poster was used to present the project at three events: Stormwater 2017, an annual conference held in May for public and private sector stormwater professionals, researchers and equipment suppliers; the Waterways Centre for Freshwater Management student conference, November 2017, attended by local consultants, researchers and students; and at an Intergovernmental Panel on Climate Change (IPCC) event held in Christchurch, 28 March 2018, where the poster was part of a public pop-up poster display. Attendees were asked to use Post-it Notes to leave questions or observations on the poster (Figure 5.1). Each event gathered a few comments. This method of collecting opinions, observations or questions was opportunistic but an easy way to gain some additional feedback.

The majority of responses left on the posters related to themes expressed during the interviews, such as cost or lack of awareness. In addition, an architecture student offered to be interviewed. I had not thought to include an architecture student, but realised it would be beneficial to know whether there is likely to be a growing cohort of architects with an education in sustainable design. Another message asked about protection measures to ensure constructed wetlands remain healthy, the writer having observed that Pegasus Lake, a man-made lake to the north of Christchurch that receives stormwater inputs, has suffered
from toxic algal blooms. This query had particular relevance to the proposed Avon-Ōtākaro red-zone wetlands.

Figure 5.1: Poster with Post-it Notes collected at an event

A standard set of questions was developed to understand the local context, including which issues caused by existing stormwater management were of most concern; which devices were considered to be most beneficial or problematic; and what barriers to including building scale WSUD had been experienced. Questions were written with an awareness of potential issues and barriers already identified through the literature review. I also included questions that investigated participants thoughts on how to address the issues they identified.

As the interviewer it was important for me to be aware of my positionality and avoid influencing responses. By developing questions in advance I was able to check that the questions were open ended and non-leading. The first two interviews were used to assess whether the pre-prepared questions were understandable, gathered relevant information and could completed in a reasonable period of time. Some questions were edited to make them shorter and clearer.

Questions were ordered such that a common set were asked of all participants followed by additional questions written specifically for different stakeholder types, such as engineers and planners or those able to share their Māori perspective. This was to gain access to aspects of technology or policy or cultural perspectives relevant to the research questions and likely to be particularly well understood by them. In four cases interviewees were asked
an abbreviated list of questions to make best use of limited interview me. One of these was with a property manager for commercial buildings, brought in by an interviewee to answer questions specifically relating to maintenance. Although interview questions were prepared in advance, spontaneous questions were asked at times to gain further knowledge or understanding in relation to the response.

I was confident of being able to engage positively with my interviewees as I shared a similar level of education and had worked alongside colleagues from different but related professional backgrounds previously. I was less confident asking questions about Māori perspectives having had little exposure to Māori culture having grown up in the UK. Nevertheless, in my experience people are usually keen to talk about their own culture and way of thinking when given the opportunity if the questioner is genuinely interested.

A voice recorder was used with permission to record each interview. This gave me the capacity to engage fully in the interview knowing I could create an accurate transcript with confidence later on. Participants in my research were discussing non-personal information. They universally agreed to interviews being recorded. During interviews a very occasional comment was made that had the potential to be sensitive if shared and the interviewee paused. In these cases I confirmed the confidentiality of responses and the participant continued to elaborate on a theme. I am therefore confident that the presence of the recorder did not inhibit responses.

Human error resulted in two incomplete interview recordings and instead responses were written down immediately after the interview from memory and the interviewees were asked to review the transcripts to check for accuracy. The original intention was for all interviewees to review and approve their transcripts. The interviews were typically about an hour long and occasionally almost two. They were typed up from an audio recording and carefully checked for accuracy during that process. As such I decided it was unnecessary to ask interviewees to contribute more time to check them. All interviewees were keen to receive a summary of the findings at the end of the research and this request will be respected.

Some interviews were extended in length and departed from the main focus of the research, but usually these provided additional insights and a richness to the interviews that wouldn’t
have been captured by sticking rigidly to the scripted questions – this is an advantage of a semi-structured interview.

Detailed transcripts of every interview were typed out at length although not verbatim. Prior to conducting interviews I researched software for automatic transcription and transcript services but concluded the financial costs were relatively high, but more importantly that transcribing can be a useful part of analysis. It is recommended to convert interviews to a typed transcript soon after an interview (Dunn, 2005). I was confident of the quality of my audio recordings, other than the two previously mentioned, and instead wrote up all interviews in a block after most interviews had been completed. I found this provided me with an opportunity to refresh my memory of the interviews and start to process common themes after a gap in research caused by the school summer holidays and associated childcare commitments.

The software package NVivo was considered for collating the interview transcripts and processing the data. I attended a brief training course and used the software to search for words relating to ‘cost\(^8\)’ which quickly became apparent as a key theme during early interviews. I also used tables to record some aspects, for example a table of positive and negative comments associated with each of the four building-scale devices considered in this thesis - living roof, PPS, rain garden and rainwater harvesting. However, as a novice to processing interview data, and taking advice from my experienced supervisor, I felt that using more traditional methods for extracting themes and making connections by using highlighter pens, scissors and glue to amalgamate themes and create mind maps was likely to be most successful for me.

The transcripts were initially separated into groups as seen in the header of Table 5.1 (public sector, private sector, etc), and then separated further by professional grouping. The responses to questions were reviewed within each group and compared between groups to gain an understanding of similarities and differences. As more interviews were analysed possible themes emerged. The process of analysing the data was iterative, so as themes became apparent earlier interviews were reviewed again to ensure the theme was fully explored.

\(^8\) Fees, subsidy, money, finance, financial, dollars, expense.
It is important to reflect on information as it is gathered and revise plans if necessary. The original premise set out in my research proposal was that if flood damage and contaminants could be reduced using building-scale WSUD devices a financial mechanism could distribute the reduced damage costs to motivate their use. A simple mathematical model would be developed to estimate the reduction in runoff, using a plausible distribution of building-scale WSUD devices to estimate the reduced flood-level, and therefore damage. The reduction in total runoff through infiltration and reuse would also provide a basic proxy for contaminant load reduction. Insurance companies and CCC could benefit from reduced flood risk, set to rise with climate change, and develop mechanisms to reallocate financial savings, via rates reductions or reduced home insurance premiums for example. The literature review in Chapter 2, however, strongly indicated that building-scale devices would only provide a reduction in nuisance flooding which would not generate a sufficient financial benefit to set against the cost of building-scale WSUD installations. It became clear that there is no current motivation for the insurance industry or the local authority to redistribute funds to motivate the installation of building-scale devices on private property. This caused me to reassess my approach. I adjusted Objective 2 from calculating costs and benefits to discussing costs and benefits with respect to the different barriers and possible solutions.

Additional first-hand information was sought to augment the interviews, either seeking clarifying opinions from experts, such as establishing whether living roofs are suitable for an earthquake-prone location, or more opportunistically, for example asking questions of residents during a Superhome tour in Christchurch. I took up an offer to visit several sites with building-scale WSUD devices in Auckland which took place on 11 and 12 April 2018. I was able to talk to site owners and ask questions, for example asking a site manager why they’d chosen PPS and whether they were happy with the choice with hindsight.

I also took opportunities as they arose to build my knowledge of the natural and urban water systems operating in Christchurch by attending field trips run by the Christchurch West Melton Zone Committee and the Stormwater Superhero organisers. Of particular interest to my as a British researcher was the opportunity to listen to Māori presenters describing their cultural connection to the waterways.
Policy analysis

Understanding the local policy context is important with regards to both barriers and opportunities to create change. Chapter 3 makes clear the influence national and local policy can have on the uptake of sustainable development solutions at the property-scale, such as WSUD devices. Interviewees’ comments referred to legislation, policy and guidance documents at the national, regional and local level. The advantage of national policy and guidance was highlighted in Chapter 3, but the increasing use of WSUD seen first-hand in Auckland, including building-scale, indicated that local solutions can be effective. Enacting change at the national level usually requires consensus building across local government, regions and national government and is therefore slow. I have therefore focused on local and regional policy and guidance, rather than the Resource Management Act, national policy statements or the Building Code.

CCC Waterways Survey and local workshops

A CCC survey investigating residents’ attitudes towards urban and rural waterways in their local area, and people’s behaviours in relation to those waterways was carried out between mid-November to mid-December 2017 using a questionnaire. It was sent to 5000 randomly selected residents, of whom just over 10% responded. It was also publicized to individuals with a known interest in waterway health and open to the general public via CCC’s website. I completed the survey via CCC’s website. There were 51 questions and the survey is reported to have taken most people around ten minutes to complete (Global Research Ltd, 2018b). Completing it seemed more time consuming and tedious to me however. The purpose of the survey was to inform the development of a programme of behaviour change in anticipation of the proposed Community Water Partnership gaining funding. The findings from the survey are published (Global Research Ltd, 2018b). Only the randomly selected respondents’ views were reported as they were considered a more accurate representation of typical Christchurch residents, although there was only a slightly more environmental response from those recruited through connections with relevant interest groups. This finding reinforces the possibility, as acknowledge by Global Research, that the 10% of self-selected
respondents from the random sample group were also more environmentally interested (Global Research Ltd, 2018b).

The survey was carried out completely independently from my research but some of the findings are relevant and are discussed in the next chapter. For example, some questions explored public levels of knowledge relating to stormwater as it has implications for motivations for change and a lack of public awareness of stormwater issues has been a barrier to improved management in other cities (Ferrarin, 2013). The CCC survey findings are compared with similar investigations from international research presented in Chapter 3.

Workshops, like one-to-one interviews, can be used to gather more in-depth information from a range of stakeholders. During my research I attended three workshops held in Christchurch relating to WSUD or waterways’ issues. An advantage of extended part-time study is the opportunity to connect with others’ research activities. A workshop was held on 12 December 2017, one of two workshops held to begin a two-year government-funded National Science Challenge, ‘Activating water sensitive urban design for healthy resilient communities’. The second was a follow up to CCC’s waterways survey, held on 1 March 2018. The third explored the Stormwater Superhero programme and was held on 19 October 2018. At the workshops there were opportunities to express opinions, but more critical or sensitive opinions may have been withheld because of the group setting.

There was an overlap of attendees at all three events. The Stormwater Superhero project was successful in attracting a representative from a local school interested in environmental education, although she was only able to stay for the first hour. The CCC event was intended to build on the waterways survey work. All 425 respondents to the survey were invited to one of three planned events, together with those with a known interest, but two events were cancelled because of lack of interest. The single event was held after work hours to attract a wider group of people, but when asked most attendees were already associated with a waterway project or related research.

I contacted the Activating WSUD researchers prior to the December workshop and discussed my early research findings. The project commenced with a national survey comprising five questions about WSUD experiences which was completed by 70 stakeholders. Of these two identified as an architect or landscape architect and none were developers, evidencing
further the difficulty of engaging with these key stakeholders. The Activating WSUD workshop in Christchurch attracted 24 attendees including me. The project considers WSUD as whole, rather than focusing on a part such as building-scale only. However, although part of the workshop involved reflecting on where Christchurch fits on the transition to a water cycle city the focus of attention was on stormwater management rather than the urban water cycle. This may have been because stormwater practitioners were well represented amongst the attendees. Additionally, the site visit focused almost exclusively on rain gardens in the public domain, likely for practical purposes since they were accessible on foot from the workshop venue. A summary report of findings from the Activating WSUD events has been published, including a reference to my work (Moores, Batstone, Simcock, & Ira, 2018). Where findings from the workshop augment my research findings they have been included.

I did not choose to carry out my own workshops for this research, preferring to put my time to increasing the number of interviews as this technique successfully attracted some new voices to the debate on building-scale WSUD. In addition, the workshops I attended, and particularly the ‘Activating WSUD’ workshop which coincided with the interview phase of my research, covered similar topics to those I would have raised, namely barriers to change, and possible solutions.

Summary

The methodology outlined in this chapter provides details of the background planning and thinking that, when put into action, provided the data that has informed the findings presented in Chapters 6 and 7. Combining local data gathered first and second-hand with the information presented in the literature review in Chapters 2, 3 and 4 has been an iterative process. One early key assumption was challenged resulting in a change to Objective 2, assessing the costs and benefits of building-scale WSUD. The use of NVivo was advantageous for looking at quantifying the frequency of a theme that was covered with a limited word list, but carrying out the bulk of the interview analysis using more traditional techniques of coding I felt did support my engagement with the data.
Chapter 6 - Barriers

Introduction

One of the purposes of this thesis is to understand the reasons for the absence of building-scale WSUD devices given the opportunity presented by the Christchurch rebuild and the population’s seeming support for the development of a sustainable city (Objective 1). Cost is reported as a significant barrier in the international literature, and Objective 2 is to understand the costs and benefits of building-scale WSUD to the developer or property owner. The methodology used to investigate these objectives was described in Chapter 5. Findings presented in this chapter incorporate analysis from interviews, policy documents, and other primary and secondary data. The findings are compared with barriers identified in international literature presented in Chapter 3.

Earthquakes - an opportunity for change or entrenchment?

Keath and Brown (2009) identified that a crisis can be a trigger for change. Following the Christchurch earthquakes the ‘Share an Idea’ consultation led by CCC identified community support for rebuilding a more sustainable city including green infrastructure (Lucas, 2014). The severely damaged stormwater network, increased risk of flooding in parts of the city and areas dependent on standpipes for water supply following the earthquakes could have acted as motivators for transition to a more sustainable and decentralised urban water supply and stormwater management system. Respondent #19, a consultant stormwater engineer, reported that a contact in a position of influence during the early decision-making phase following the earthquakes raised the potential opportunity for infrastructure change but was ‘shut down’. A consultant water supply engineer (#1) described a colleague seconded to the Stronger Christchurch Infrastructure Rebuild Team (SCIRT), the government-led infrastructure replacement alliance, who did not understand why their work wasn’t done more sustainably. Instead SCIRT staff were instructed to replace like with like (#6, #8). The reasons for this are likely multiple, including limited financial resources, pressure to reinstate infrastructure networks rapidly, and insurance restrictions.
These themes were also raised during the interviews in relation to individual responses to rebuilding with respondents reporting that people wanted to get back to a normal life as quickly as possible and doing things differently takes more time (#1, #17, #19, #22, #25, #28); and insurance companies stipulate like for like (#9, #19, #22, #25). Respondent #25 said, ‘People were controlled by the insurance companies who take over and people don’t get what they want or aspire to have.’ Higher cost, lack of policy and technical concerns were also frequently cited as barriers to change and are discussed individually in subsequent sections of this chapter. These barriers are relevant to the ongoing absence of living roofs, permeable paving systems (PPS), rainwater harvesting and on-site rain gardens and relate to failures of strategy and policy already apparent prior to the earthquakes, discussed in Chapter 4, and in common with barriers identified internationally presented in Chapter 3.

A further critical aspect needed for change to a new system is recognition of a problem and an alternative solution that is both viable and preferable (R. Brown & Clarke, 2007). The earthquakes did trigger improvements to the geotechnical and structural engineering systems used in the Christchurch rebuild (#23). The earthquakes presented many challenges and understandably avoiding a repeat of the failure of buildings and associated loss of life in future earthquakes was a priority. In the aftermath of the earthquakes there were so many competing needs for council staff time and financial resources, addressing policy changes needed to improve stormwater management and implement the Surface Water Strategy (SWS) was of low priority.

Absence of (immediate) drivers

In Chapter 3 several drivers for change were recognised as influential in cities that have begun to adopt a WSUD approach for managing urban water problems. The most common ones identified in developed cities with similar climates to Christchurch are drought and water supply shortages, flood, and frequent sewer overflows associated with combined sewer and stormwater systems. These significant issues have prompted changes to legislation and policy to increase the use of WSUD.

A number of interviewees highlighted the absence of any immediate drivers to motivate change in Christchurch. Respondent #4 observed that the city’s aquifers provide plentiful
clean water so there’s no driver for the council to investigate rainwater harvesting. The landscape architect described a ‘green’ Californian client, building in Christchurch, who said she’d have installed a rain tank in California but didn’t think it was needed in Christchurch (#13). He didn’t agree with this view and considered the lack of installation of rainwater harvesting in Christchurch to have been a missed opportunity given that Christchurch residents are high water users and water restrictions do occur.

The architecture student (#14) said, ‘Christchurch’s beautiful clean water is taken for granted, seen as an endless resource, so there’s not much thought put into it,’ presenting the contradiction between how it is valued highly in residents’ minds but not in practice. Since 2017/early 2018 when the interviews were carried out there have been two key incidents that may have shifted complacent attitudes to Christchurch’s water supply. One was the finding that nitrates can and are migrating under the Waimakariri River to the north of Christchurch passing into an aquifer that supplies much of the city’s drinking water, albeit dilution is keeping nitrate concentrations very low. Second was the realisation just before Christmas 2017 that many of the wellheads connecting the aquifer to the supply network were vulnerable to surface water contamination, resulting in temporary chlorination of the city’s supply. As one of only two cities globally that supplies untreated spring water to its residents these issues are of huge importance and therefore also a political priority to manage. The management of these issues however involves improving wellhead security and addressing rural land-use issues in the Waimakariri District. It is possible that these issues could motivate some individuals to seek an alternative backup water supply in the form of rainwater harvesting but supply disruption following the Christchurch 2010/11 earthquake sequence and the Havelock North campylobacter outbreak in 2016 has not resulted in any significant individual change.

Respondent #4 commented that although people were dependent on an alternative water supply immediately after the earthquakes their needs were met and rainwater tanks would be an expensive solution for an occasional earthquake supply. Respondent #1 investigated sustainable technologies to include in a rebuild home and calculated that it was cheaper to fill a standalone tank with tap water to provide a resilient supply in the event of a future earthquake, rather than connect it to the gutters. An engineer and sales representative for a company that installs rainwater harvesting systems (#5) recognised that the predicted
population increase would increase demand and may require a scaled-up water supply network, as reported in the city council’s Water Supply Strategy (WSS), which will come at a cost while rainwater is a free resource. However, whilst rainwater may be free, the infrastructure to capture and make use of it is not. As previously reported, mains water supply in Christchurch is charged in the rates so there is no payback mechanism for installers of devices that reduce mains water usage.

Low baseflows in Christchurch’s rivers could be a driver for localised adoption of infiltrating devices such as permeable paving systems (PPS) or rain gardens in suitable areas of the city, including on private property. However the issue of low flows did not appear to be front of mind for many interviewees with only two commenting on the issue (#3, #8).

The issue of flooding was seen as a priority or even ‘the’ priority for stormwater management in Christchurch, particularly amongst the public sector employees, with one (#6) commenting that there is media focus and community concern, ‘when the carpets get wet.’ It was also noted that it’s easier to make a business case for flood mitigation schemes since the financial impacts of flooding can be calculated (engineer, #7). Flooding has acted as a driver to national WSUD regulation and guidance in the UK. However, as evidenced in Chapter 2, and reported by two interviewees (#6, #12), although some building-scale devices can help reduce peak flows, detention basins and land use planning will continue to be the primary mechanism for limiting flood damage. Larger-scale devices are an important and integral part of the WSUD approach.

The impact of contaminants associated with stormwater were highlighted by most interviewees and were of particular concern to the community group representatives and Māori. Several engineers (#7, #11, #12, #19) emphasised the importance of reducing runoff volumes to reduce erosion in waterways caused by regular flows of runoff that would not occur at the same frequency naturally. A key benefit of building-scale devices is the potential to capture these small frequent runoff volumes. The SWS includes a goal to address flooding and a goal to address water quality, but does not explicitly recognise the need to reduce runoff volumes to improve ecosystem health and mahinga kai opportunities. Nor does the SWS link reducing volume with increased stormwater capture and reuse which could support
WSS goals. Volume reduction has been used successfully as a driver for increasing the use of on-site WSUD technologies in Auckland.

More interviewees commented on the need to remove contaminants at source through a change in building material, recognising metal roofs in the city to be a particular problem (#4, #8, #15, #19, #22, #24). Whilst roof replacement or painting is important it doesn’t affect the runoff volume, support baseflows or regulate runoff temperature and therefore is only part of the solution for improving ecological values and mahinga kai opportunities. In addition, whilst new Colorsteel® roofs contribute less zinc to runoff than older and poorly maintained roofs Colorsteel® roofs contain zinc alum. Their warranty gives confidence that paint peeling will not occur for between 15 and 18 years but these roofs will still need maintenance to avoid becoming a zinc source in the future.

It is well recognised amongst interviewees that densification and climate change will require improved management of stormwater to avoid greater flooding. The architect (#21) expressed frustration at the lack of urgency with respect to building more sustainably in general, with climate change already evident. Greater rainfall intensity and runoff volumes experienced in Auckland were considered to have acted as a driver there for a more proactive approach to stormwater management compared with Christchurch (#6, #13). In time, climate change and population increase may be sufficiently impacting to motivate the council to adopt WSUD at all scales, but not at present. A developer said:

_We’ll come to a point where the environment demands that we change our behaviour. We’re starting to see it with global warming although it’s not disadvantaging too many people at the moment to change mindset and behaviours. It’s going to take quite a massive environmental change that will impact on people to get change unfortunately._ (#26).

Christchurch residents’ attitudes to waterways and willingness to support improvements

The application of fees, rates rises or funding of incentives to mobilise changes in the management of stormwater by individuals is a political issue, as highlighted in Chapter 3. A view that ‘political resistance to implementing measurable numbers in [the] global stormwater consents [is] due to costs and responsibility.’ was expressed at the Activating
WSUD workshop in Christchurch (Moores et al., 2018). It is therefore important to understand the current electorates’ perspectives and level of knowledge relating to stormwater management and its effects. The Christchurch Waterways Survey Results (2018b) found that 55% of participants knew stormwater was discharged to waterways and wetlands and 71% considered car and house washing to at least moderately contribute to waterway pollution. However, 28% believed stormwater to be treated at the wastewater treatment plant and 14% didn’t know where it went indicating, over 40% of Christchurch’s residents are unaware of the potential for their activities to impact on the waterways.

The Christchurch survey, as with Cote and Wolfe’s investigation in Kitchener, Canada, into householder attitudes (Cote & Wolfe, 2014), explored personal responsibility and empowerment and found that 91% agreed or strongly agreed that it is important to reduce your own impact on the environment, and 72% agreed they are personally responsible for contributing to the environment’s problems. Nevertheless, 68% of the survey’s respondents continued to wash their car on a sealed driveway at least some of the time, despite 63% believing that washing the car on the lawn is the least environmentally impacting.

Two obvious explanations for the contradiction between Christchurch residents’ belief that it is important to take responsibility for your own impacts whilst knowingly continuing with an activity that causes environmental harm are: a lack of a suitable space on the lawn or other local grassed area to wash the car; and/or, a belief that their own car washing activity isn’t significant. The survey identified that 50% of participants believed car washing only had a little or no effect on their local neighbourhood, and 77% of people washed their car less than once a month, which may indicate the second possibility to be most relevant.

The Christchurch Waterways Survey explored activities people were prepared to do to reduce their impact on waterways. Sixty-two percent indicated that they would, or may be prepared to pay more in rates to improve the quality of the waterways - this also means 38% would not pay more. Whether individuals would invest in devices or changes to landscaping to reduce impacts generated by their own properties was not explored by the survey. The PPS survey carried out in Kitchener found that 70% of their residents would (theoretically) pay up to 15% more for an environmentally friendly alternative to an impervious driveway finish at the time of driveway replacement, although the ranges provided in the survey were coarse with the first range being 1% to 15% (Cote & Wolfe, 2014). In reality the willingness to
pay ceiling may be closer to 3%, as quoted by the subdivision and property sales specialist (#23). Following the Christchurch earthquakes many driveways were replaced through insurance claims. This could have provided an opportunity to install PPS for a relatively small additional cost to the property owner. Several respondents criticised the limitations placed on the rebuild by insurance however with like-for-like replacement restricting the use of alternative technologies (#1, #5, #12, #25).

Waterways Survey participants considered the top four causes of waterway pollution to be: stormwater from industrial sites; litter; runoff from residential building sites; and erosion-derived sediment. Although the researchers did not ask whether participants knowingly contributed to littering, it is reasonable to assume that most of the participants did not feel they have personal control over these top-four pollutants. This matters because recognition that individual behaviour can make a change is an important step towards taking action (Chawala, 2008 and Jordaan & Stevens, 2007, in Cote & Wolfe, 2014). Polluting activities that residents could more easily take personal control over were identified as 5th and 6th most significant, being stormwater runoff from driveways, roofs and roads; and car and house washing.

Asked about the impact of different organisations or groups, 46% considered farmers and horticulturalists to have an extremely negative effect on waterways. Business and industry were thought to have an extremely negative effect by 27%. These views are consistent with media reports with ‘dirty dairying’ being an election issues in 2017 and local news articles in Stuff highlighting the link between Christchurch’s industrial catchments and polluted waterways (Editorial, 2016; Morton, 2017). These issues are significant and the subject of national and regional legislative and regulatory change and increasing enforcement.

The regional council has developed guidance to address sediment generation from building sites which has been a very visible problem during the rebuild period, both from demolition and construction sites. Litter is another visible problem, addressed through education and peer pressure setting social norms. The annual ‘Mother of All Clean Ups’, which began in 2016 on the eve of Mother’s Day, is jointly organised by the Avon-Ōtākaro Network, the Ōpāwaho Heathcote River Network and the Avon-Heathcote Estuary Ihutai Trust with support from CCC. The event is helping to highlight the issue of litter in Christchurch’s rivers.

In comparison with the well reported impacts of industry, and the visible effects of sediment
and litter, it is understandable how the largely invisible contaminants leaving our own properties are overlooked or diminished in significance.

_People haven’t yet made a connection between waterway contaminants and what they can do; or they’ve made the connection and think that’s what they pay their rates for, for the local authority to fix it. I don’t think the recognition of responsibility is there yet, more education is needed…..[People] still think it’s about rubbish; it’s only the pollutants they see._

(Community representative, #22)

**Cost and externalities**

Cost was the most frequently and emphatically identified barrier, with 26 of the 28 interviewees identifying cost as a reason for the low uptake of sustainable stormwater management options on private property. There was particular emphasis on this barrier from the developers who ultimately control the finances, and the engineers, project manager, landscape architect and architect who are all close to the decisions made around options and budgets. The developers interviewed for this research are involved in subdividing land, converting a greenfield site to one with a series of sections with infrastructure installed to the gate, ready for house builders to construct on. House building is often carried out by group home builders who buy a few sections within a larger subdivision and offer a selection of housing styles and land and build packages to individuals. Alternatively individuals can buy a section and employ an architect or design and build company to build a property for them. Home buyers in this context are essentially a small time investor/developer. The architect said, observing the motivations and priorities of clients:

_Ultimately it’s all cost. Clients want energy efficiency measures but…they don’t do it unless there’s profit in it….Individuals look at the short term, not long term; or might look long term but don’t have the resources._ (Architect, #21)

Commercial and industrial properties will be built by investors and development companies who will employ a range of specialist consultants and contractors to plan, design and build a complete building with a view to either sell on, or to lease the property:
I think your property investors are of a certain breed. It’s profits first, and any holistic benefits secondary. The motives are purely financially driven……..Until you can show that the environmental features produce a return, you’re going to struggle [to get them included].

(Developer, #26)

Several other interviewees supported this view, commenting that developers are looking for a short-term profit rather than considering any long-term benefits (#13, #19, #21, #25). A couple of the Post-It notes left on the research poster also identified the difficulty of presenting a business case based on ‘woolly benefits’ rather than ‘cold hard numbers’. The Green Star assessor explained:

Nine times out of ten a client asks us to look at value engineering the job, but stormwater isn’t value engineering because it adds cost. I don’t believe there’s any long-term financial benefit of stormwater management, whereas some value engineering might mean more capital cost but in the long run will save you a lot of money, LED lighting for example. (#16)

Value engineering is a process of assessing the cost of components of a project and the value that they create. Components that are unnecessary or costly without adding recognised value are removed or replaced to provide the client with the best value for the lowest cost. Components that cost more upfront but generate a cost saving through the lifespan of the building may be retained.

For developers building to sell on upfront capital cost is most significant, although tempered by saleability of the final development. A developer building a property to lease long-term may have an interest in lower maintenance and operational costs. However, a consulting engineer (#12) involved in a rebuild project recounted how the developer value-engineered out good [sustainable] options despite retaining the building for lease with a long-term tenant. The tenant, a company that provides sustainability and environmental services, remained with the development despite the limited inclusion of sustainable solutions, arguably supporting the developer’s decision to minimize upfront costs – the limited adoption of environmental features did not influence even an informed tenant, so why spend extra?

One interviewee was a property and subdivision sales specialist who explained that new build development is an attractive option for those who struggle to save the 20% deposit
needed to buy an existing home since a deposit of only 5% is needed for a new build. Developers are offering smaller section sizes to supply this market. In his experience these low budget home builders are ideally looking to stay with the property for around 3 years and then move on, hoping to make a return in that period. They might spend two or three percent extra to make a home cheaper to heat or cool, but not much more than that (#23). In a similar vein a developer said:

_The predominant mindset is purely commercial return, you won’t develop anything the market doesn’t want. Recently there’s a lot of pressure on price, so that’s impacted on first time buyers….there’s a move away from the quarter-acre section. Developers are led by what the market wants. There’s not a groundswell in buyers wanting the environmental features, certainly not where they have to pay an additional premium to enjoy them._ (#26).

A former planner and developer of a sustainable subdivision said, ‘People don’t value the extra [sustainable] facilities that are on the property; real estate agents don’t point them out as useful things that will save you money in the long-term so they don’t get taken up.’ (#25). The landscape architect describing his experience with clients said, ‘the best people can have the best intentions [but managing rainwater on site] comes down to cost…..[with] solar they can see the cost benefit.’ Lamond et al. (2014) recognised that private owners will prioritise features that have a direct benefit to them over those that generate a wider social or environmental benefit. For new home buyers with a limited budget it’s hard to argue that improved stormwater management should be prioritized over increasing insulation or efficient lighting which brings long term savings or additional health and comfort benefits.

Descriptions accompanying each of 31 new build homes presented in the Registered Master Builders’ House of the Year Canterbury Mid and South Region 2018 magazine with a construction budget of NZ$700,000 were analysed. These short descriptions indicate which features are considered most desirable and marketable. All but one emphasised luxury materials, features or rooms, and 52% contained three or more bathrooms. These homes are not low budget homes but still environmental features are not prioritised. Energy efficiency measures such as additional insulation and high-quality double glazing were reported in 35% but only one identified minimizing environmental impact as a key design requirement, and none mentioned water efficiency. Of 87 homes featured across all
construction budgets and including both newly constructed and renovated residential properties, only one mentioned water efficiency.

There’s not enough incentive for those paying the bills to [include WSUD features]; the developer, council, mum and dad homeowner, infrastructure developers. Who’s going to spend the money? And why would they? We can look out and see trees. It’s a nice environment. We can get more out of stormwater but it takes effort and effort means cost.

(Consulting engineer, #19)

Living roofs have been almost entirely absent in the Christchurch rebuild. Acknowledged to be expensive, described by the landscape architect (#13) as the ‘Rolls Royce of stormwater management’, living roofs nevertheless provide tangible benefits to the building’s occupants if visible or accessible, and utilise space that is often wasted. In Christchurch ultraviolet (UV) light intensity is high compared with northern US and European cities where much of the living roof research has been carried out. As such the UV protection of the waterproofing layer provided by a living roof, reported to double the roof’s lifespan, could be even more advantageous in Christchurch. Getting plants to survive on living roofs through Canterbury’s long hot dry summers can be challenging and the need to incorporate irrigation adds to costs (#13). However, Colin Meurk, an ecologist from crown research institute Manaaki Whenua, is confident that ecologists can advise on suitably hardy native plants as long as sufficient soil thickness is provided. Again though, thicker soils add to the cost requiring additional structural support. In the UK a thin extensive turf or sedum roof finish would cost around NZ$100 to NZ$140 per square metre compared with around NZ$200 per square metre in New Zealand, while an intensive living roof suitable for use in Christchurch would be around NZ$350 to NZ$450 per square metre (Multiple suppliers, 2018). Local research could help overcome the perceived and real concerns of professionals, but living roof installation costs are significant and as such takeup is unlikely without a clear commercial benefit.

Lyttelton’s proposed crowd-funded development, Collett’s Corner, includes plans for a communal roof area with around 40% soft landscaped, to be accessible from multiple apartments.

Respondent #4 commented that Christchurch’s residents and businesses do pay for stormwater management, whether they think they do or not, through their rates. However, respondent #5 considered that since contaminants are shed from properties to waterways
without any form of treatment site owners do not pay the full cost of stormwater management. The negative effects on the ecological and amenity value of the waterways are a negative externality - the cost of managing stormwater in the traditional stormwater network is artificially lowered as the disposal of contaminants to the waterways is free.

Historically point source discharges from industries such as meat works were released directly to waterways; a community representative said, ‘I know the lower reaches of the Opawhō and you could see the purples and greens [in the water], you’d not throw a stick [in] for a dog.’ (#24). Businesses avoided the cost of managing waste by disposing of it into the river for free. The Resource Management Act (1991) restricts point source discharges and businesses are required to connect to the wastewater system, or otherwise manage their effluent, and thereby pay the associated treatment costs. In this way the negative externalities have been internalised with costs borne by the business rather than society and the environment. As explained in Chapter 4, the Resource Management Act (RMA) has been ineffective at managing pollution from dispersed sources such as stormwater runoff which continues to generate externalities.

The previous paragraphs in this section highlight how the cost of building-scale WSUD solutions is creating a barrier for inclusion in new build properties. In Chapter 4 it was seen that retrofit solutions are even more critical in Christchurch since much of the city is already constructed and, since greenfield sites are at least partially incorporating WSUD, the existing city will be the dominant contributor to waterway contaminants. Retrofitting WSUD solutions is more expensive than including in a new build. Respondent #1, a recent private home builder, considered it unrealistic to expect people to pay extra to implement stormwater management voluntarily, other than a few environmentally minded people. The Green Star assessor said:

‘It’s more difficult to make people implement something at an existing site. What would you put in? It’d have to be subsidised. People couldn’t afford it. There would be one eco-friendly early adopter in the street but the rest would put it off. How long would it take to make a change? You couldn’t mandate it, there would be an outcry.’ (#16)

This view reflects the experience of politicians in Elgin, Illinois, trying to introduce a ‘rain-tax’ (Ferrarin, 2013).
The Council recently consulted with rate payers on its Long Term Plan (LTP), planning priorities and funding for the next 10 years (Christchurch City Council, 2018). The summary consultation document indicated that the proposed rates would result in reduced pipe maintenance and acknowledged increased wastewater overflows to the rivers would result. The Community Water Partnership proposal, developed by CCC’s stormwater planning team, identified a budget of $1M per year for a programme of education, in partnership with community groups, to enable citizens to make informed choices about their impact on their local waterways. The proposal was excluded from the council’s recommended rates proposal. In a sense CCC, and citizens in supporting the LTP, implicitly confirmed that the cost of improving the quality of waterways is too high at present and the negative externalities will continue to be borne by the waterway ecosystem and those who participate in food gathering or contact recreation such as kayaking. The Christchurch Waterways survey found that 38% of those who responded to the survey were not prepared to pay more rates to improve waterway health, and 23% were not prepared to pay for a commercial car wash, confirming that cost is a barrier to improving environmental outcomes amongst individuals as well as developers, despite 98% of respondents agreeing that CCC should strive for waterways healthy for plants and wildlife.

Technical limitations and risk aversion

In Chapter 3 it was demonstrated that the four main building-scale devices considered in this thesis all have benefits and deciding which are most suited to a given site is dependent on physical, financial and regulatory factors and site end-user preferences. Several interviewees were clear that each site should be considered individually because constraints vary from site to site (#1, #7, #10, #14, #15, #25, #28). Christchurch has a challenging set of circumstances for stormwater engineers, with interviewees commenting on the very low gradients across the flat areas of the city, a high water table to the east, and a highly erodible low permeability soil covering the hilly suburbs. An engineer from the research sector warned, however, that there is a propensity to limit opportunities for WSUD: ‘I think we’re well aware of [site specific issues], but almost use it too much as an excuse; [saying] things like, “Our high water table.”’ and, “A lot of soils aren’t great for soakage.”’ (#15). These
factors indicate local limitations and therefore the need to be open to a range of solutions, but CCC appears to have focused almost exclusively on a single option - rain gardens.

Positive and negative observations associated with each of the four building-scale devices made by nine interviewees who are involved in planning or design decisions relating to stormwater management are presented in Table 6.1. The observations have been further sorted by employment sector, with five from the public sector and four from the private sector. Interviewees were not asked explicitly to discuss the merits and disadvantages of each device, but were shown an image of the four building-scale devices considered for this research and asked which had most potential in Christchurch and whether any were unsuitable. Interviewees involved in the sale of an individual WSUD device type have not been included to avoid over representation of a specific device type.

**Table 6.1:** Positive and negative observations attributed to private and public sector planning, engineering and landscape architect interviewees relating to four building-scale devices.

<table>
<thead>
<tr>
<th></th>
<th>Rain garden</th>
<th>Rainwater harvesting</th>
<th>Permeable paving system (PPS)</th>
<th>Living roof</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Public</td>
<td>Private</td>
<td>Public</td>
<td>Private</td>
</tr>
<tr>
<td>Positive</td>
<td>11</td>
<td>7</td>
<td>8</td>
<td>11</td>
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<tr>
<td>Negative</td>
<td>8</td>
<td>5</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Difference</td>
<td>+3</td>
<td>+2</td>
<td>+2</td>
<td>+7</td>
</tr>
</tbody>
</table>

From Table 6.1 it is clear that all four devices are considered to have both advantages and disadvantages or limitations. The aspects commented on included a range of benefits such as biodiversity, water reuse, avoids loss of land for other uses, ability to filter contaminants or capture small runoff events. Reported disadvantages included high cost, limited impact on volume reduction, difficult to construct or maintain or aesthetically unappealing.

The most notable difference between the public and private sector professionals was the complete absence of comment on living roofs by the public sector employees. This is surprising since living roofs are on the preferred device list in the SWS, ranking third for
residential urban intensification areas and forth for business and industrial areas (Table 4.1). Conversely the public sector interviewees identified a larger number of advantages than disadvantages for rainwater harvesting tanks and yet tanks are described as a single benefit option in the SWS and appear very low on the preferred device list for all land-use types. Rain gardens were discussed more extensively by the public sector professionals than those in the private sector.

Beneficial aspects of PPS were noted by the interviewees but PPS was the least supported of the devices based on response counts listed in Table 6.1. Council policy is to ‘promote the maximisation of pervious surfaces in developments and public spaces’ in residential urban intensification areas (SWS, 2009, p.37) and PPS can be useful for both new build and retrofit sites. Nevertheless, PPS remains almost entirely absent from Christchurch. In this regard it is an opportunity that has seemingly been missed.

There’s always a lag in New Zealand……There’s a reluctance to try new options. Clients will ask if they’ve been used elsewhere in New Zealand and if they’ve only been used once or twice they’ll say, “No, I don’t want to be a [guinea pig].” (Green Star assessor, #16)

Uncertainty about the long term effectiveness of PPS was the principle concern raised by just over half of the public and private sector engineers and planners. Compounding concerns was the lack of New Zealand research demonstrating effectiveness with three interviewees also expressing a confidence issue with supplier-led research or information (#6, #19, #21). One respondent commented that after attending a presentation by a UK PPS specialist, Bob Bray, he had ‘changed his mind a little to being open to some experimenting’ although he also had doubts based on a piece of research carried out in Auckland.

Meanwhile it is already in use in Auckland (#6, #13), and increasingly so since recent policy changes (Crossland, 2018).

One consulting engineer (#12) commented that examples of PPS were functioning well after 25 years in the UK. The managing director of Peninsula Medical Centre, Auckland, had permeable paving installed in the car park in 2008 to provide a safe surface for her customers. She reported it has worked very well and although more expensive to install, neither the pavers nor the stormwater filter and detention tank which were installed together had needed much maintenance. The PPS still allows rainwater to infiltrate, even in
heavy rain (Going, 2018). However, PPS is not included in Christchurch’s SWS preferred device list for business and industrial sites which seems particularly limiting, given the large areas of car park and therefore runoff associated with these land-uses.

Interviewee #1, speaking as a rebuild homeowner, considered that when techniques are supported by the council information is more readily available and the process to gain consent becomes easier as designers, planners and individuals become more familiar with the new device. When investigating the option of installing rainwater tanks interviewee #1 found the consent requirements to be unclear, as well finding rainwater harvesting not to be cost effective. The consultant planner (#10) found the detailed requirements needed to gain consent for installation on a residential property overly onerous. Neither installed a rainwater tank.

The project manager (#20) described the importance of certainty from a developer’s perspective, to avoid delays which add costs. The priority list of stormwater management techniques and devices in the SWS includes the four building-scale devices considered in this research. Commercial sites can now be required to include building-scale WSUD devices for stormwater treatment and reuse, but council guidance is almost exclusively for streetscape rain gardens and larger scale devices. The lack of guidance for the full range of device options, and the emphasis on devices that transfer to council maintenance after construction, appears to have limited the use of building-scale WSUD, despite SWS policy to encourage them.

The greatest concern relating to devices on private property (residential, industrial and commercial), expressed by stormwater professionals from both the public and private sectors, is the difficulty of ensuring that maintenance is carried out correctly and with sufficient frequency to ensure ongoing function (#4, #6, #11, #19). One engineer (#19) described residents ripping the orifice off rainwater tanks when they become blocked with leaves and rain gardens ceasing to exist after 15 years, despite efforts to inform owners. The commercial property manager (#27), however, felt that for commercial sites it’s about being aware of what’s on site. Products that are used roof wash needs to be biodegradable, for example, if a property has a rain garden. He said that maintenance isn’t more difficult or costly in these circumstances, but when maintenance is transferred to new owners or contractors they need to be informed. Similarly a planner, speaking as a homeowner, said
stormwater pipes on private property are the site owners’ responsibility so why not WSUD devices? (#10). However, the quality and consistency of maintenance on private property is known to be variable, with some roofs poorly maintained for example even though maintenance extends the life of the roof and reduces costs over the long term.

Participant #4 observed that at-source management of stormwater makes people more aware of the issues they’re causing and provides opportunities for them to deal with those issues efficiently. However, a contradiction exists with respect to the council’s preference for communal systems reliant on the council for maintenance (Christchurch City Council, 2009a). The importance of acknowledging personal responsibility to create behaviour change was raised in relation to Christchurch residents earlier in this chapter. With respect to stormwater management the council has had responsibility since the late 19th century. Council employees seem torn between acknowledging the benefit of individual responsibility and the risk that individuals won’t take responsibility. Private sector engineers are similarly sceptical about transferring responsibility to private individuals. It is not surprising that building-scale WSUD devices are not well supported, even in the areas of the city where they have been placed high on the SWS preferred device list, whilst this maintenance dilemma exists.

The SWS, published in 2009, identifies the need for the council to establish a process for ensuring ongoing maintenance of stormwater management installations on private property, but such a process is believed to still be absent (#4, #11). Further, the council has limited powers to challenge those who put contaminated water into the stormwater system without court proceedings (#4). As such council employees are understandably cautious about building-scale devices reliant on private individuals and conclude that collective council-maintained systems are more pragmatic, as stated in the SWS. However, two engineers observed that council WSUD devices are also poorly maintained. One consulting engineer (#12) pointed out that since building scale devices are not relied on for managing floods from large storms, which require larger-scale solutions, the risks associated with poor maintenance are lower. On this basis the risk posed by poorly maintained small-scale on site devices could be more than offset by the advantages.

In Chapter 2 the advantages of systems that support infiltration to underlying soils with respect to reducing flooding and augmenting groundwater were discussed. Christchurch’s
spring-fed rivers would benefit from additional baseflow. Soils to the west of the city centre are suitable for infiltration but the majority of homes are connected to the piped stormwater network. ‘Christchurch City Council strongly favours community soakage systems….rather than private facilities on individual properties’ because of concern that maintenance will not be carried out on private property (Christchurch City Council, 2012). Infiltration of roof water via an on-site soakage systems is accepted on commercial sites but the option is only available to residential properties if a connection to the piped stormwater network is unavailable (Christchurch City Council, 2016a). Opportunities to infiltrate rainwater with retrofit rain gardens or on new build infill residential developments are restricted with this policy and contradicts the SWS policy to maximise infiltration in the residential urban intensification areas.

A concern raised by several public sector interviewees is the risk of groundwater contamination (#4, #6, #8). Roof water is described as ‘relatively clean’ in the Waterways Wetlands and Drainage Guide (WWDG) but in Chapter 4 roofs are shown to be significant contributors of metals in Christchurch, particularly zinc. Groundwater contamination could occur from contaminants in the stormwater or from mobilisation of contaminants in the ground from previous land uses. Some of the city’s water supply is sourced from the shallower aquifer, and hence this is a particularly sensitive issue. Further research is needed to establish how to gain from beneficial infiltration and runoff volume reduction whilst minimising the risk of groundwater contamination. Research indicates that building-scale WSUD devices offer contaminant reduction opportunities and have the potential to safely support groundwater augmentation, as long as the maintenance issue is also addressed.

Interview findings discussed in previous paragraphs have highlighted several reasons why building-scale devices have not been more encouraged by the council; in particular concerns about technical performance and lack of trust of private individuals, compounded by inaction in setting up an enforcement programme for ongoing maintenance.

**Short-term thinking and absence of leadership**

The positive effect of policy that directs development to include WSUD devices is highlighted in Chapter 3. A recurrent theme from stormwater professionals is the absence of supportive
national guidance in New Zealand (#4, #9, #11, #12). The absence results in a variable approach across New Zealand and no policy driver at the local level (#12). The short term political cycle at the local level with councillor elections every three years was felt to make it difficult to create change (#4, #8), instead creating ‘populist’ decision-making with residents seeing the impact on themselves and their rates, rather than thinking about intergenerational equity (#12). One engineer (#19) explained the that a large selection of well thought out generic designs would facilitate the installation of well constructed and easy to maintain devices. When asked who should lead on the development of these designs he said the government, but went on to say that, ‘in New Zealand that would never happen.’

The absence of national policy for freshwater until 20 years after the adoption of the RMA evidences the hands-off approach of the New Zealand government to addressing environmental problems.

‘Our regulations are nowhere near good enough, and some are inhibiting, the Building Code in particular, so for stormwater it’s about draining from the infrastructure.’ (Engineer, #19). The limitations caused by the Building Code were raised by several interviewees in that rainwater is considered a problem to remove rather than a potential resource (#6, #11). It also permits the use of contaminating building materials such as copper roofing and guttering (#8).

Green Star or Homestar also permit building materials that pollute the freshwater environment and a high rating can be achieved whilst using copper products (engineer, #7). The council’s own civic building has a Green Star 5 rating, but includes copper spouting (#8). The Green Star assessor (#16) explained that the Homestar and Green Star ratings are points based. Describing a school development he showed how the cost of incorporating water sensitive options, such as rainwater harvesting for internal uses and rain gardens, was relatively much more costly per point than other measures such as increased insulation. Further, there is no payback to incentivise solutions that capture and use rainwater (#16). A Green Star or Homestar assessor will advise clients on optimal combinations of sustainable options to achieve the desired star rating. With WSUD options being more costly per point they are usually only included in development seeking a high rating.

In the absence of government guidance and regulation, Environment Canterbury and/or the Christchurch City Council need to be sufficiently motivated to prioritise and address the
impacts of development on the water environment in Christchurch. The National Policy Statement for Freshwater Management (NPS-FM) has driven changes to regional plans, but with a focus on rural water quality. ECan is reportedly one of only two regional councils to specify urban water quality standards, including metals, in its Land and Water Regional Plan (LWRP) (#4). The global stormwater consent sets the standards CCC must meet when discharging from the stormwater network. The LWRP urban river water quality targets requires a reduction in contaminant loads from the network, which also includes runoff from private sites. Participant #4 commented on the degree and speed of change required to meet the targets by the deadline of 1 January 2025. This conclusion is borne out by modelling discussed in Chapter 4 which demonstrates that an extensive programme of rain gardens, basins and wetland development over several decades, together with roofing improvements, will still not meet the LWRP requirements. Nevertheless, the LWRP is providing a stimulus for change (#8).

A few interviewees felt that in their experience ECan and CCC do not work as effectively together as they could (#1, #10, #24). Two respondents (#3, #4) reported that upper management and councillors at CCC have only relatively recently begun to understand the issues caused by stormwater. Over half of the interviewees, including public sector, private sector and community group leaders, saw CCC and ECan as central to driving change. Without leadership support in CCC and determination from ECan to push CCC to achieve the targets set out in the LWRP, improvements will be extremely slow.

Interviewees acknowledged CCC’s historic leadership role in improving local waterways with the development of the WWDG, first published in 2003, and updated as recently as 2012. A key change was the introduction of the six-values approach which incorporates biodiversity, landscape, cultural, heritage and recreational values into decision-making, as well as drainage, when comparing stormwater management options. The change in approach resulted in daylighted waterways, restoration of springs, and planting of wetlands rather than utilitarian stormwater basins. A few interviewees observed that CCC had not continued to lead on stormwater management, however, and had lost momentum (#1, #19).

The Waterways Wetlands and Drainage Guide has been around a really long time, like more than ten or twenty years and it is founded on WSUD principles. It’s funny, I think [CCC] perceive that that’s all they need to do. And in new subdivisions they are generally putting in
those green features. For CCC they believe they are already there, they do. It’s mandated at subdivision level and [developers] have to consider it, but there’s nothing at the homeowner level or existing houses and areas. (Rebuild homeowner/engineer, #1)

Respondent #8 considered the earthquakes to have changed CCC’s focus, but Lucas (2014) reports that wetland and waterway restoration had largely ceased before the earthquakes. Team restructures and changes in councillors lead to changes of focus at the local level (#6, #8).

Whilst the WWDG and a change in attitude within the council resulted in improved surface water management on public land (including on greenfield development) it did not create a step change in management on individual property. Similarly the post-quake blueprint for the city centre which could have catalysed change did not:

_I don’t think the blueprint was founded into a local structure plan or policy. It was a vision. It didn’t have steps to force or allow for offsets in terms of delivering the vision. Great idea but didn’t put processes in place to make it happen._ (Engineer, #12)

Another engineer (#19) identified the Auckland Unitary Plan as the only one that directly addresses building-scale WSUD devices and places WSUD at a high planning level, rather than addressing it at the resource planning level. Auckland Council’s responsibilities combine those of a local authority and a regional authority. This may help Auckland Council respond more rapidly when particular environmental issues are prioritised. An attendee at the Activating WSUD workshop highlighted the difficulty of integrating water quality objectives and development policy dealt with by separate institutions saying:

_Issues concerning streams and water quality are dealt with through [the] regional council’s plans and the actual building on land, so building consents, are issued by T[erritorial] A[uthorities]. Stormwater sits between these two things, and I don’t think it is well managed in terms of.....integrating the details of land development and connecting these to the water quality outcomes._ (Moores et al., 2018)

Some areas of Auckland have a combined sewer/stormwater network and sewage overflows have regularly affected popular local beaches (Russell, 2017). This has created a stronger driver for stormwater improvements compared with Christchurch. Combined sewer overflows have been a driver identified in international literature (Schofield, 2012). A few
interviewees commented on how Auckland stormwater management practices migrate to Christchurch in time (#6, #12, #13). In a sense Auckland Council is filling a gap left by the absence of national government leadership in stormwater and WSUD development.

Respondent #11 said:

*If the regulations aren’t there in the first place no one’s going to do it…..ethically it’s pretty poor as a professional, but you can also see where your client is coming from, you don’t want to spend money if you don’t have to.*

For those wanting to incorporate solutions that have a greater environmental outcome it is more difficult than following standard stormwater management methods that only meet the minimum requirements as it’s for the designer to prove that it’ll work and therefore it’ll cost more (#9, #20).

*As an early adopter it’s getting the council to recognise a treatment will work and sometimes means you have to jump over more hurdles….being an early adopter has its challenges, but it’s not insurmountable.* (#20)

Those who highlighted this issue also acknowledged the importance of providing the additional detail. The project manager (#20) also explained the need to get the developer on board really early and have answers at the right stages or the alternative won’t be taken up to avoid delays. For developers the time taken from land purchase to selling on is critical (Engineer, #19).

Demonstration projects together with long-term monitoring were identified in Chapter 3 as an important way to provide greater assurance to potential adopters of new technologies. The project manager (#20) said that the council doesn’t just say no to alternative proposals but wants to know about them. The resistance to new technologies was raised in the previous section, but the subdivision/property sales consultant (#23) made the link between resistance to technologies and the potential for councils to influence change:

*’What are the top guys doing here and abroad? What does it cost? How do we get it here? It’s cool and helps the environment so why wouldn’t you? There’s too much commoditised. “We’ve done it this way for 30 years so why would we change?”* The building industry more
than in general… Ideally in CCC there would be someone who can pre-approve systems, but councils don’t work in a particularly innovative way.’

Seven interviewees with experience working on development projects emphasised the benefit to WSUD outcomes that can be achieved with early involvement by a range of professionals (#11, #12, #19, #13, #23, #28, #29). Consulting engineer #19 explained the need for a collaborative approach saying, ‘There’s a lot of competing interests; landscapers want green stuff, engineers’ first priority is drainage. The reality is [WSUD] is in the middle, not either-or, but both.’

A drive towards cost-efficiency is reducing that early engagement. The landscape architect felt that he was increasingly being brought in at the end of a project ‘to put in some trees’, when rain gardens and wetlands could have been incorporated into the site design with early involvement (#13). The ecologist (#29) felt that ecology is often excluded from decision-making with other professions too often second-guessing what an ecologist would recommend; instead ecologists are only brought in when there’s a problem. The property sales specialist talked of the increasing use of engineers to design ‘efficient’ subdivisions with maximum section numbers, resulting in a loss of amenity and aesthetics and, ironically, hard to sell subdivisions. The architect (#21), having practiced internationally, observed a specific issue for building-scale WSUD in New Zealand being that WSUD requires integration from the building into the surrounding landscape and beyond, but there is currently no single profession charged with responsibility for that overview.

A public sector engineer (#6) described how his values had shifted by working in a team with multiple disciplines. ‘I flipped over one day. My training [as an engineer] is that stormwater is a nuisance and your job is to mitigate it. I was listening to one of the landscape architects which inspired me as he said it’s not a nuisance it’s an asset.’ He felt that young engineers were more highly educated and specialised today, but were also less able to appreciate other disciplines’ values. The restructuring of teams into narrower specialisms, and a reduction in the opportunities for graduates to spend time in different teams as part of their professional development, was further limiting exposure to different perspectives. Similarly, a consulting engineer working for a multi-disciplinary consultancy expressed frustration that
it had taken three years to be able to discuss stormwater quality and quantity improvements that could be applied at a building-scale with in-house architects (#12).

A number of interviewees felt let down by architects with respect to their level of knowledge of sustainable development, including building scale WSUD devices (#1, #10, #17, #18, #24). A community representative went further:

_Industry has been well behind the eightball. The fact that architects have been specifying copper roofs and getting away with it speaks to how little education there is for people you’d expect to have best practice in mind - education needs to happen at that level._ (#22)

The New Zealand Institute of Architects (NZIA) recognises the need to provide leadership if development is to become more sustainable stating, ‘The NZIA will aim to promote a shift in values throughout the profession, and become known as an industry leader in the philosophy and practical application of sustainability in the built environment.’ (New Zealand Institute of Architects, n.d.; Ruggles, 2018). To date the NZIA appears to have had little influence with regard to increasing architects knowledge or application of sustainable design. The architecture student (#14) explained that sustainability gets limited attention in New Zealand’s architecture schools currently. His own knowledge was predominantly from an elective course on sustainability which tended to be less popular than other courses because, ‘people think it’s bland and boring’.

The professional architect interviewed was well versed in and committed to sustainable design but acknowledged limitations in architect’s education. However, he argued that environmental education is needed much earlier in the education system than university, adding:

_[Sustainability] is an approach, not a specific technology; there’s loads of solutions. We have to keep up to date with current technologies, but it’s not the technology, it’s the culture. We need to think it’s one big house and we’re all neighbours._ (Architect, #21)

The same theme was reiterated by developer #26:

_Don’t forget [architects are] working for the developer though, who has the purse strings……[A developer] won’t produce something the market doesn’t want….a groundswell in terms of change has to come from society._
Summary

Although the earthquakes seemed to provide an opportunity to create a more sustainable city because of the scale of reconstruction, instead it was a difficult time to transition because people wanted to get back to normal quickly and like-for-like was the easiest way to achieve that. However, barriers preventing the inclusion of building-scale WSUD were present prior to the earthquakes and continue to exist. Cost is the most commonly cited barrier. There is a lack of stormwater knowledge amongst residents around 40% of whom are unaware that runoff is discharged to waterways without treatment. Even informed developers, however, when faced with the cost, remove WSUD options and prioritise energy efficiency measures, luxury items or much bigger floor areas because there is no payback. Drivers that exist elsewhere that motivate greater attention on stormwater management, such as water restrictions or combined sewer overflows, are not present in Christchurch.

Architects are influential and could advocate for more sustainable development and increased inclusion of building-scale WSUD but many lack the necessary knowledge. The NZIA is not advocating for improvements effectively. Architectural courses are not embedding sustainability sufficiently. Early collaboration on projects by several different professional specialisms is needed if WSUD opportunities are to be maximised since the building and surrounding landscaping needs to integrate to achieve a transition in water management. There is some evidence that this collaboration is becoming less common and the design process increasingly focused on cost efficiencies, however.

SWS policy identifies the benefits of on-site treatment but the District Plan only weakly supports this policy. The need to develop a maintenance enforcement regime was identified in the SWS implementation plan, published in 2009, but has not yet been addressed. A body of knowledge and guidance relating to engineered rain gardens has been built up within CCC. Nevertheless, small scale rain gardens for voluntary installations by homeowners are not supported despite the need for retrofitting to reduce runoff in areas of existing development. There is very limited or no guidance on other building-scale devices. Demonstration projects are not well publicised although there are examples of all types of building-scale device in Christchurch, albeit an extremely limited area of living roof.
The different barriers influence each other. A common theme is the need to change mindsets, recognising that existing mindsets amongst professionals and residents are limiting change. The aspirations for improved mahinga kai, biodiversity and water recreation set out in the SWS needs to be seen as achievable and desirable by the city’s residents and businesses such that they are prepared to invest money and commit to maintaining devices on their own properties, supporting the council’s long-term goals. Equally the council needs to find ways to build trust and common purpose with the majority of people so some responsibility for stormwater improvement can be placed back onto private property owners.
Chapter 7 Solutions

Introduction

In Chapter 2 building-scale devices were demonstrated to have a place in restoring high quality waterways in urban environments, and the most beneficial application of devices on a given site will vary with the physical setting. It was clear from Chapter 3 that building-scale devices are underused in cities around the world and that the lack of take up is caused primarily by cost. This chapter addresses Objective 3, which is to make recommendations that could increase the uptake of building-scale WSUD solutions in Christchurch. The recommendations reflect on the Christchurch-specific barriers discussed in Chapter 6, site-specific aspects relating to individual devices that are raised in Chapter 2, physical variation across the city described in Chapter 4, and solutions that have been applied elsewhere in the world which were presented in Chapter 3. The differences in terms of motivating uptake in new build and retrofit projects have been raised throughout this thesis. Solutions are identified that address these different circumstances.

Financial motivators - fees or incentives

The cost of sustainable solutions was identified as the most significant and consistently reported barrier in global studies and in interview responses gathered for this research specifically in relation to building-scale WSUD devices. Solutions discussed in Chapter 3 to overcome the cost barrier discussed payback mechanisms including the application of fees for water supply or stormwater management; the provision of financial incentives in the form of subsidised devices, such as rainwater tanks and barrels; and rates rebates. Ten interviewees advocated for incentives in some form, particularly with regard to motivating voluntary retrofitting of on-site stormwater management including the use of building-scale WSUD devices.

One mechanism already operating in Christchurch that can provide a payback to subdivision developers is a reduction in developer contributions for stormwater management that exceeds minimum standards. A developer contribution for stormwater management is a
payment made to the local authority to cover the cost of upgrading the stormwater network to accommodate additional runoff generated by the new development. If a subdivision is designed to reduce the impacts beyond the statutory requirement the developer contribution is reduced commensurate with the reduced future costs to the local authority (project manager, #20). Stormwater infrastructure on subdivisions is designed to accommodate the maximum runoff that would be generated if all individual sections were developed with the maximum permissible impervious surface cover (District Plan activity standard 8.6.9). Smaller sites (<1000 m²) on the flat can be sealed with impervious surfaces covering up to 70% before needing any on-site stormwater storage (“Stormwater and your property,” n.d.). In theory measures to reduce runoff and contaminants from each individual section could be required using rules in a covenant. Developments with a sustainable focus and strict covenant to ensure new homes are of a high environmental standard exist in Christchurch and are saleable (developer, #25) but, in general, developers would be reluctant to impose such rules:

_We use [covenants] for the look and finish of the build and that’s it to date. We put no pressure on purchasers to incorporate any environmental aspects, that’s up to them at this stage. It would be quite onerous, with additional expenses to the owner._ (Developer, #26)

The developer contribution currently acts as a motivator for larger-scale WSUD devices, such as planted swales in roadways and the inclusion of planted basins and wetlands. These features are now commonplace in newer subdivisions on the periphery of the city. With changes to the District Plan policies and rules for individual properties there could be scope for subdivisions to fully integrate WSUD at all scales. This can bring economic benefits with developers able to sell more land for property development (Bastien et al., 2010; Morzaria-Luna et al., 2004), but also introduces the potential for enhanced shared amenities and aesthetic benefits for residents which improves the salability of a subdivision.

Charging fees for water supply and stormwater runoff on a volumetric basis was discussed in Chapter 3. Payback within a reasonable time period is only achieved with rainwater harvesting installations and then only where both fees are applied (Montalto et al., 2007), or a linked wastewater and mains supply fee as in Auckland (BRANZ, 2018). Water supply charges were suggested as a solution by only a few interviewees, although one (#9) was strongly opposed, arguing that it would impact on low socio-economic groups who may
want to use the water for growing healthy food, for example, and that education to encourage good use of water was a more constructive solution. Volumetric charging for mains supply has been mooted previously by CCC but has not received sufficient support to be implemented (Mitchell, 2017). Experiences in Elgin, US, shows that even introducing low fees is not straightforward politically (Ferrarin, 2013). Fees in Germany are sufficiently high to motivate the uptake of rainwater harvesting in both new build properties and in retrofit projects but Germany’s acceptance of fees, associated with polluter pays principles and usage charges, has built up over many decades. They have been accompanied by programmes to establish an understanding of their purpose, generating both public and political will over a long period of time.

Christchurch is currently undergoing at least two politically sensitive water issues: Cantabrian farmers are consented to use large quantities of water for irrigation without volumetric charging, and a consent for a foreign-owned water-bottling company to abstract from the city’s aquifer without charging for the take has been approved. These are legitimate consented uses with a maximum take and metered data collection but environmental issues associated with water use have increased, together with public awareness, and these issues are now very contentious, the latter motivating a recent street protest (Broughton, 2019). Proposing to charge Christchurch residents and businesses sufficiently high fees to adopt rainwater harvesting and water conservation at present would be very unpopular. Rates rises have been controversial and the Waterways Survey indicated that a significant minority were not prepared to pay more for improved waterways health (Global Research Ltd, 2018b).

There is a also cost to charging fees as there needs to be a mechanism for calculating the bill. There is already some coverage of the city with water supply meters. Nevertheless, the cost of setting up and collecting mains water fees is cited as a reason not to implement volumetric charging. Charging for stormwater runoff from each property is more complicated and would need extensive data collection involving both aerial imagery and ground truthing, together with hydrological expertise to accurately estimate runoff generation from different surfaces and therefore individual properties. Ongoing monitoring would be needed to record hard surfaces added to sites subsequent to the first mapping exercise. Once runoff estimates are available an additional process is required to generate
bills and collect payments. Modern digital technology will make this a much less tortuous exercise than in the past, but it would nevertheless be a significant technical and bureaucratic exercise, and therefore costly.

An alternative financial mechanism is subsidies which could take the form of rates rebates. A rates rebate can be applied to newly constructed and older properties. International examples of subsidies for runoff reduction from individual sites have been included in Chapter 3. Where a stormwater component of rates is charged a clear link can be made between the implementation of a practice that reduces runoff and a reduction in the rates. In Christchurch stormwater and mains water charges are included in rates without being clearly identified. These charges could be explicitly presented on rates bills and a reduction offered. Clearly a rate rebate would reduce CCC’s income, but there is a cost-saving to the council if water supply or runoff volumes are reduced. The community also benefits from improved waterway health and reduced nuisance flooding. In Portland, US, the rate rebate for runoff reduction only applies to the portion of rates that is for on-site stormwater management. The portion that supports the communal system continues to be charged (The City of Portland, 2018). A rates rebate is more likely to be politically acceptable if the benefits to the community and council are well communicated. It is unlikely that a rebate would be sufficiently high to motivate extensive uptake of building-scale devices, but it provides an opportunity to raise discussion around runoff and its impacts, as well as acknowledge and nudge those who are motivated to ‘do the right thing’.

A disadvantage of a rates rebate for runoff reduction would be the need to also establish a mechanism to ensure runoff reduction measures continue to function whilst the rebate is claimed. If a rebate were connected to more permanent WSUD devices, such as a permeable paving system (PPS), redirection of roof or driveway runoff to a rain garden, or installation of a rainwater harvesting system for internal supply, sporadic checks could be sufficient. Simpler on-site changes could be motivated with one off incentives. Wellington City Council provides 200 L rain barrels at less than half the market rate (Wellington City Council, n.d.-a), and supplies free native plants for residents to plant in road reserves recognising one benefit as regulating runoff, as well as increasing biodiversity and urban aesthetics (Wellington City Council, n.d.-b). In Portland, US, a small one-off financial incentive together with practical support was offered to property owners for disconnecting their gutters and redirecting the
water to the lawn or a rain garden, achieving the disconnection of 56,000 gutters. Planting garden trees has been similarly incentivised (Schofield, 2012). Education and practical support, discussed later, played a key part.

Developers selling on will not be motivated by small annual rate rebates. In Chapter 3 two mechanisms were identified that have been used elsewhere to motivate developers to install WSUD solutions in new build construction projects. The first mechanism is reduced consenting fees and/or an expedited consent process. A reduction in consent fees has a cost to the council, and expedited consenting presupposes there is sufficient capacity amongst the planning team to progress some consents more quickly while still meeting statutory obligations relating to processing standard consent applications. These options could be discussed with the consenting team at CCC, but as a city still in a period of considerable construction and bearing additional ongoing costs as a result of the earthquakes, adding extra demands on staff and financial resources may be resisted.

The second mechanism is to offer a density bonus for increased on-site stormwater management. There is scope for density bonuses to be used with a variety of development types. The Seattle Green Factor for example is applied to commercial sites (Water Environment Research Foundation, 2009). A review of current development policy for different development types and locations, together with physical considerations such as areas with higher soil permeability, could define areas where a density bonus would offer the greatest public benefit at least cost to the developer. In areas where the stormwater network is approaching capacity and public land is limited there may be justification for the council to contribute financially and subsidise WSUD installations and maintenance on private land (Montalto et al., 2007).

Council policy in the SWS is to ‘encourage on-site stormwater management where possible’ in all areas except greenfield development (Christchurch City Council, 2009a). There are also policies relating to landscaping, car park spaces and site coverage which relate to zones defined in the Christchurch District Plan (Christchurch City Council, 2017). In the Residential Central City Zone 20% of a site is to be retained for landscaping, half of which must be soft landscaped (District Plan rule 14.6.2.6). There is scope to slightly reduce the landscaped area to provide additional saleable floor area in return for incorporating building-scale WSUD
devices. A stormwater volume reduction policy could be applied, as used in Auckland (David Kettle et al., 2013). As an example, on a 500 m² site, if the maximum building size is increased by 5% the saleable floor area would increase by 100 m² in a four-storey development. Additional costs associated with WSUD devices can be recouped through profits on the additional floor area.

It is important that the quality of landscaping is not compromised despite the reduction in landscaping area. In Seattle landscaping features visible to the public are prioritised to ensure an attractive streetscape as part of the city’s Green Factor policies. Vertical green walls and rain planters⁹ could also provide opportunities for maintaining landscaping in a more compact area, as well as supporting healthier building temperatures and attractive views for occupants.

Density bonuses have been used in several US cities to motivate the installation of living roofs, including Philadelphia and Chicago (Water Environment Research Foundation, 2009). In Christchurch the potential to improve damping during an earthquake is an additional advantage that should be explored further. Charles Clifton, Associate Professor of Civil Engineering and Structures Group Leader at the University of Auckland, wrote:

*Green roofs are very feasible in Christchurch buildings and I expected that many more would be used. The seismic penalty of a green roof on the cost of the structural system is very minor, in the order of a few % and less than 5%...[and so] there is no actual economical barrier from implementing green roofs in a high seismic zone. They can actually be used to add additional damping to the structure in a severe earthquake.* (Clifton, 2018).

Parts of the city centre are underlain by gravel with sufficient capacity to support buildings with an additional floor and higher roof load. Within the central city buildings can almost completely cover a site with limited landscaping or open spaces to negotiate with. A living roof with additional building height however, provides the potential to reduce stormwater impacts, enhance local biodiversity and provide an immediate payback to a developer.

To implement density bonuses policy changes are needed. Other policy options and considerations are discussed in the next section.

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⁹ A compact rain garden in a planter style container.
Policy and guidance

Auckland has been able to incorporate WSUD at all scales with local policy, albeit focused on priority catchments rather than city-wide, despite the absence of national policy. National level change, whilst advantageous, is generally slow to enact. The Canterbury Land and Water Regional Plan (LWRP) provides a local driver for improving the quality of runoff entering the council’s stormwater network, requiring CCC to instigate change. The Surface Water Strategy (SWS) includes policies and recommends implementation measures to increase on-site stormwater management. However, as one engineer (#12) said, policies are needed to support strategies, otherwise strategies risk remaining a vision.

Local expertise in the full range of building-scale WSUD solutions exists to some extent within Christchurch, although focused amongst the private sector landscaping, environmental and engineering consultants and suppliers, supported by expert advice on specific devices available from local or national research establishments. However, there is an immediate need to broaden guidance to include all the building-scale WSUD devices for all urban land-use types to give designers and developers the confidence to incorporate building-scale WSUD.

Building-scale WSUD solutions for stormwater management are usually more expensive to a property developer than a conventional solution. Payback periods, even for long-term site owners, are exceptionally long. In the absence of fees or large financial incentives policies are required that mandate building-scale WSUD. Evidence demonstrating the positive impact of policy in terms of WSUD uptake is presented in Chapter 3. It is clear that cities that are incorporating WSUD on individual sites most effectively have required change through policy. Dodge Data’s international survey evidences the influence of environmental policy with 64% of respondents in the UK and 46% in Australia citing environmental regulation as a top three trigger for developing a certified green building (Dodge Data & Analytics, 2016). International and Auckland experience can be drawn upon in Christchurch. Just over half of those interviewed identified policy as an option to force property owners and developers to address stormwater management on their property, including private sector engineers (#1,
#7, #11, #12, #19), a planner (#10), landscape architect (#13), architect (#21) and Green Star assessor (#16).

If externalities generated by all types and scales of development are internalised through policy it is equitable for all developers. At present those who choose to incorporate building-scale WSUD do so at a personal cost, while others retain a larger profit and leave the public purse to pick up the cost of managing the externalities. A visually attractive waterway suitable for a range of recreational activities in the local community is of benefit to all, including developers, but can only be achieved if everyone plays their part. In addition, compulsory aspects of development are defined in the budget at the outset of a project and accommodated (Green Star assessor, #16; engineer/home builder, #1). Nevertheless it is unlikely that developers would welcome such a change:

If [on-site stormwater management] were made mandatory you’d get a lot of kick back from the industry, ‘Look our margins are tight enough, you’re increasing my costs and lowering my returns.’ Maybe developers need to lower their expectations in terms of returns from developments, they certainly need to take some responsibility for impact on the land to offset some of the profits they receive. (Developer, #26)

New commercial property in Christchurch is now required to, ‘incorporate principles of low impact design including energy efficiency, water conservation, the reuse of stormwater, on-site treatment of stormwater and/or integration with the wider catchment based approach to stormwater management, where practicable.’ (District Plan policy 15.2.4.2 a. vii). Applied effectively this policy should increase the use of some building-scale WSUD devices in commercial properties (Christchurch City Council, 2017). However, without increasing the confidence of stormwater planners and engineers in the full range of building-scale technologies some will continue to be avoided despite having the potential to offer both the site user and the environment significant benefits. Consenting delays are costly to developers and can act as a barrier to innovative solutions (project manager, #20). Whilst technical uncertainty continues to exist, either real or perceived, only a limited range of device types will be included in development proposals or be approved by the planning authority.
Rainwater tanks are not limited by shallow groundwater or low permeability soils (#13) and could therefore be installed across Christchurch. One engineer (#12) commented that thousands of communities worldwide live off rainwater. Some interviewees had rainwater tanks at home (#4, #6, #11) and the technology is well established in rural New Zealand. The benefits of augmenting the council’s water supplies, the redirection of contaminants away from the stormwater system, potential to enhance resilience following hazard events, and modern tank designs that can be accommodated more readily were all advantages recognised by interviewees (#1, #5, #10, #13, #24). Despite these benefits rainwater harvesting has been poorly supported by CCC until recently, as discussed in Chapter 4.

The District Plan policy for commercial development does still leave the potential for developers to avoid the inclusion of stormwater reuse and treatment on site with the case for what is ‘practicable’ made by the developer and the final decision taken by the consenting officer but rainwater capture and reuse should become more prevalent with the introduction of this policy. Industrial areas, however, are only ‘encouraged’ to include multi-value stormwater management approaches ‘using swales, wetlands and infiltration and retention basins.’ Rainwater harvesting is not included in the list although industrial areas are particularly suitable since some activities can use large volumes of low quality water.

_Councils take a conservative view. I can understand why, they’ll own it for the next 50 years. They do accept things, but councils are conservative and it’s the biggest barrier to new technology. If the council won’t accept it it doesn’t go in, it’s as simple as that. They are cautious about new technology until they’re satisfied it does what it says it does._ (Project manager, #20)

Research and demonstration projects are important for increasing confidence and will be discussed further in the Mindset and Behaviour Change section below. A device called a Storminator™ is currently being developed by the hydrological and ecological engineering group in the department of Civil and Natural Resources Engineering the University of Canterbury. It connects to downspouts to capture metals in roof runoff (“UC researchers invent Storminator™ weapon in battle for survival of healthy waterways,” 2018). This is an example of technology that could reduce technical concerns relating to devices that allow infiltration to groundwater. The lack of maintenance equipment in Christchurch for PPS was
also raised as a concern but this is a temporary resolvable issue since maintenance equipment is available in Auckland. A portable attachment that connects to cleaning trucks already in use in Christchurch is all that is needed (Crossland, 2018). One engineer thought living roofs to be unsuitable for earthquake zones but they could in fact have a damping effect (Matta & De Stefano, 2009; Omenzetter et al., 2009). A consulting engineer (#19) highlighted the ‘tension’ between providing volume for detention when it’s needed and storage for reuse. An intelligent rainwater tank system called Tank Talk has been developed in Australia that automatically releases water in advance of a storm, enabling smaller tanks to support both peak flow reduction and reuse (“Monitoring rainwater with Talking Tanks,” n.d.). The UK Standards provide a low-tech but space-consuming equivalent. Tanks for detention or reuse can be combined with PPS to reduce the impact on space. Advances are being made in WSUD technology to solve the problems identified. If the full suite of building-scale WSUD devices is available to designers there will be few sites where it can be reasonably argued that the inclusion of such devices is not practicable.

There is no explanation in the District Plan (Christchurch City Council, 2017) as to why low impact design (LID) and water reuse is required for commercial development while industrial development is only ‘encouraged to use a multi-value approach’ for stormwater management and no reuse requirement (District Plan policy 16.2.3.3). Industrial areas are known to contribute particularly high concentrations of contaminants to the waterways via stormwater runoff, including zinc from roofs. Treatment trains are known to improve water quality outcomes and at-source devices are an important component to such a train. Capturing roof runoff for internal low-grade reuse provides an opportunity to redirect contaminants shed from galvanised roofs, commonly associated with industrial properties, into the wastewater treatment system. Where a site poses a greater risk of surface water or groundwater contamination designers can adapt WSUD design to mitigate the risk by combining WSUD and conventional treatment systems, as seen with the Te Atatu Medical Centre car park. It can be reasonably argued that bioretention and PPS reduce the direct connection between a contaminant source and a receiving waterbody. If a contaminant spill occurs the contaminants are trapped within the soil or paving layers, depending on the device, delaying pollutants migrating to the watercourse and remaining visible and accessible for excavation and removal. Small amounts of hydrocarbons are volatilized or
broken down by bacteria when they are retained in PPS or rain gardens (Newman & Coupe, 2017).

In addition to providing practical solutions for reducing contaminants from industrial areas entering the stormwater network, the use of rain gardens or tree pits in particular also provides an opportunity to inform site users of the connection between the site and the waterways as well as increasing biodiversity, improving air quality, providing shade and attractive green features. The importance of creating a greater connection to and understanding of the environment to motivate positive environmental behaviour is discussed later. Green infrastructure is also known to improve workers’ wellbeing (Cinderby & Bagwell, 2018). The cost-benefit of green infrastructure varies with the context, with the installation of green infrastructure being more valuable in areas currently devoid of green space or with poor air quality (Whitehouse, 2017). Whilst Christchurch is a leafy city on the whole, less built up than many cities, the industrial areas can be bleak and devoid of plants. Issues of equity with regards to green infrastructure have been raised by An and Dubney (2017), albeit with a focus on low-value housing areas. Incorporating planted WSUD solutions, such as rain gardens and tree pits, could offer more value in industrial areas than in any other, both to the environment and to the workforce who are there for many hours during the working week. On this basis it can be argued that building-scale WSUD, and green infrastructure in particular, should be prioritised in policy for industrial sites rather than left to developers to incorporate if they wish. Jayasooriya (2016) uses a combination of modelling and stakeholder engagement to weight multi-benefit criteria to design optimal green infrastructure treatment trains for industrial sites using a case study on the Brooklyn Industrial Precinct, Melbourne, Australia.

Residential sites, both greenfield and infill, also offer great potential for the use of building-scale WSUD solutions, but again policy avoids requiring them although they would support the creation of a full stormwater treatment train. The absence of such policy validates the criticism that CCC thinks WSUD is already being done (#1). Policy can be devised that will push some stormwater management back onto residential properties, such as requiring the use of rainwater harvesting which can be incorporated easily into new build properties if planned early in the design stage. At present, however, the District Plan restricts
the council to motivating uptake of sustainable building, including water efficiency, through non-regulatory methods only (District Plan policy 14.2.4.8) (Christchurch City Council, 2017).

It is important to acknowledge that the inclusion of building-scale WSUD devices may not be the most environmentally or socially beneficial use of financial resources in a low budget construction project. Any policy proposal would need to be carefully assessed for unintended consequences. The Royal Institute of British Architects (RIBA) however argues that financial implications are too often promoted by developers at the expense of social and environmental benefits and expert opinions are needed to review the validity of such arguments (Beagle et al., 2014). Architects can, and should, bring a holistic perspective to urban development, but in New Zealand the profession has a much narrower remit focused on individual buildings only (architect, #21). Subdivisions and commercial properties developed by Ngāi Tahu Property demonstrate that enhanced environmental outcomes can be compatible within the current context of private sector development in Christchurch if environmental outcomes are elevated in the decision-making process. With changes to policy these standards could be achieved by all developers and become commonplace.

Policy to require building-scale WSUD devices could be linked to the impact of a property on the water environment. Properties with more than one bathroom, or greater than a specified footprint, or that use copper spouting could be required to include rainwater harvesting for example. Homes with larger garage and car parking areas could be required to incorporate PPS or rain gardens. In this way the properties that have the greatest impact are required to provide mitigation. New Zealand homes have increased from an average of 140 m$^2$ in 1980 to an average of 205 m$^2$ by 2010 (QV, 2011). With this increase in size comes an increase in environmental impact, including the generation of runoff. The architect (#21) said, ‘[Sustainable] costs more money so would have to sacrifice on size. Does it make sense to build a 500 m$^2$ house on a 1000 m$^2$ section? Maybe we should say no unless you pay for the impact, but that doesn’t happen.’ The cost of building to the current Building Code minimum standard is currently advertised at around NZ$2000/m$^2$. With the cost of WSUD being reported as the most significant barrier to WSUD, there is scope to transfer some budget from floor area to environmental features. Politically this will be difficult but there is
scope for policy to improve waterway health on all land-use types without excessive impact on budget or site-end users.

To implement any policy changes there needs to be political and therefore public support. The importance of creating understanding about the purpose and benefits of WSUD solutions, together with demonstration projects and/or pilot schemes, to build public and political will is discussed in the next section. At present the majority of Christchurch’s politicians, residents and businesses are not acting with the long-term future in mind. Longer term the benefit of building-scale devices will become more significant with climate change and infill development increasing the pressure on ecosystems and the water supply network. New buildings last for many decades and it is important that they are designed for the future (planner #9; architect #21). The RMA is intended to support sustainable development with future generations in mind. The cost of including at least some building-scale WSUD in a new build property is not excessive and can be accommodated in many construction budgets.

Retrofitting later adds cost and is disruptive. By avoiding responsibility for environmental effects that are easily mitigated in the present there is a financial and environmental burden being placed on future generations. The longer sustainable construction measures are avoided the greater the adjustment and scale of costs in the future. As a minimum, new buildings should at least be designed to simplify adaptation. In the case of rainwater harvesting, incorporating the plumbing needed for using a rainwater tank into a new build property would reduce the retrofit cost and disruption (supplier, #5). The rain tank and pump can be easily added in the future in the same way that some homes are future-proofed ready to connect to solar panels, batteries and electric car charging ports. These future-ready requirements could be mandated but place a lower financial burden on home builders today.

The advantage of WSUD is that it has multiple benefits (#6). Living roof policy in Sydney demonstrates well the linkages to a broad range of urban improvements beyond just stormwater management (City of Sydney, 2014). Thirty percent of Australian respondents to Dodge Data’s survey identified healthier neighbourhoods as a top three trigger for building a certified sustainable building (Dodge Data & Analytics, 2016). By identifying the additional
benefits of applying WSUD at all scales, and highlighting linkages to multiple strategies, it is more likely that the public and politicians will be supportive of more stringent policies that strive to reduce the negative externalities that affect local communities and local environments generated by all types of development.

There is scope to emphasise how different building-scale WSUD solutions contribute to the strategic goals set out across a selection of related council strategies: Biodiversity; Water Supply; Public Open Space; and Climate Smart; as well as Surface Water. Changes at the individual property scale in the Avon/Ōtākaro catchment will support the ecological outcomes of the proposed Avon/Ōtākaro River Corridor Plan increasing biodiversity values, supporting goals in the Biodiversity Strategy (Christchurch City Council, 2008). Augmenting groundwater through infiltrating WSUD solutions also supports biodiversity by increasing resilience of the Avon/Ōtākaro ecosystems which are affected by dry winters. Rainwater harvesting will increase resilience in the event of a future earthquake, drought, or even flood when water supply can be impacted, the latter increasing in likelihood with climate change. The Climate Smart Strategy includes a goal to increase resilience of ecosystems to future changes (Christchurch City Council, 2010a). Planted ‘green’ building-scale WSUD solutions, particularly in the more densely built up central city areas can enhance streets and support the Garden City image, a goal of the Public Open Space Strategy (Christchurch City Council, 2010b).

The SWS does recognise the benefits of some building-scale WSUD devices and their potential to support some of the strategy’s goals, but the ‘preferred device’ list, presented in part in Table 4.1, is too prescriptive. The list order is based on council needs rather than on developer or site end user needs or preferences. It inhibits innovation by pushing designers towards a narrow selection of devices high up the list in the belief that planning consent will be more easily gained with these devices. They are also better supported with design guidance. Policy and guidance changes are slow to implement and therefore providing a prescribed list of preferred options risks installations lagging behind the latest technological advances. Interviewees were very clear that the most suitable device or devices for a given site is site specific. Auckland has created an outcomes-based policy to protect the most ecologically valuable waterways requiring the first 5 mm of a rainstorm to be retained on site to mimic the pre-development hydrological response (David Kettle et al., 2013). Stormwater
engineers in collaboration with developers and their architects and landscape architects can identify the most suitable methods for achieving this requirement on their site. This policy addresses the importance of reducing volume to mimic the pre-development hydrological cycle within the urban environment (Burns et al., 2012).

The ease with which volumes can be retained on site varies with soil permeability. Sites with high permeability soils would naturally receive more rainfall before generating runoff. Policy could be created whereby rainfall retention requirements are related to the underlying soil type which can be easily determined on a site-by-site basis by a geotechnical engineer or landscape architect, or more generally from a soils map. Christchurch soil permeability is highly variable and not as simple as permeable to the west and impermeable to the east (Figure 4.2). It is more cost-effective to manage runoff on sites with higher permeability since smaller storage volumes are needed to hold the excess runoff while it infiltrates. However, rainwater tanks are viable on most or even all sites if pre-planned, regardless of infiltration rates. Modern solutions enable them to be incorporated into buildings and aesthetics have been improved. Arguments of space loss or poor aesthetics are no longer as valid. It may be preferable to keep policy simple and use a single requirement for rainfall retention, as used in Auckland. Auckland’s policy for its most valued catchments demonstrates that policy can be adopted in New Zealand to reduce the effects of property on waterways. Local community connection to its waterways has been cited as important for building support for environmental policy (Buehler et al., 2011), although it is not know how significant local support was in introducing this policy in Auckland.

In Christchurch there is no reason why a volume reduction policy could not be applied to improve the ecological value of waterways across the city. Connection to the waterways has historically been promoted as part of the city’s identify. Council strategy and the activities of community groups continue to recognise their value. There is scope to improve the ecological, recreational and aesthetic quality of tributaries as well as the main rivers with the inclusion of building-scale WSUD devices. Applying treatment to streams immediately before they enter the larger waterways only creates a downstream improvement. CCC has recently installed a large filter system at the end of Bells Creek which drains via a combination of open concrete-lined channels and piped sections into the Heathcote/Ōpāwaho. The filter system does not improve Bells Creek which passes through a small local park as a dead
smelly anoxic ditch. Bells Creek will only improve upstream of the filter if at-source devices are installed to capture contaminants, as well as a rehabilitation project to naturalise the channel.

A lack of confidence in ongoing maintenance of building-scale WSUD devices on private property was a significant concern to both private and public sector engineers and planners. These concerns are in common with those expressed in international research, identified in Chapter 3. Developing an approach to maintenance on private-property needs to be prioritised by the council, as identified in the SWS, if building-scale WSUD devices are to become more widely installed. Three possible approaches taken from (10000 rain gardens, 2005) are:

1. Instigate an enforcement regime with inspectors and fines for non-compliance and include devices on private sites in catchment management models;
2. Assume a proportion of devices on private property are functional at any given time and use a conservative estimate in early stormwater models, refining with evidence over time; or
3. Develop catchment models with no reliance on individual sites and consider any building-scale devices to be a bonus.

Instigating an enforcement regime with mapping of new installations, tracking associated consent conditions, monitoring and enforcement notices should be more straightforward in 2019 than it would have been in 2009 with advances in Geographical Information Systems, database design, online reporting and automated generation of emails. Efficiency could be established by prioritising more critical devices such as those treating above a specified volume, or those located in a more sensitive groundwater areas for example. In the short-term, recording WSUD installations on private sites and including a consent condition requiring ongoing maintenance will provide the basis for enforcement in the future. The absence of an enforcement regime therefore should not inhibit the use of building-scale WSUD devices, as long as they are well designed with maintenance in mind.

Policy that supports the take up of building-scale WSUD will also drive demand which can influence the provision of support and guidance; increase competition in the market, possibly reducing cost over time; and improve knowledge within the construction industry.
and amongst planners resulting in better design and a smoother consent process. In this way policy changes can help to overcome several barriers described in Chapter 6. Policy changes are difficult to implement without public and political support (Ferrarin, 2013). Further, the reach of policy is limited to new build properties. Change to existing development is dependent on voluntary action. For these reasons there is a need to build awareness of the impacts of urban runoff on the environment and, perhaps more importantly, the benefits of improving stormwater management.

**Mindset and behaviour change**

Retrofitting WSUD solutions to achieve stormwater improvements through previously developed areas, essential for meeting the LWRP minimum standards and more importantly achieving objectives relating to biodiversity and mahinga kai. Where installations cannot be placed in public roads or spaces improvements are dependent on voluntary actions by private property owners. The catchment-scale field trials presented in Chapter 3 demonstrated that even immediate payback will not motivate most property owners to install WSUD devices. Even the most successful trial, which offered fully funded rain garden or rain barrel installations and 3 years of maintenance, only motivated 30% of potential participants (Mayer et al., 2012). Cost is not the only barrier and providing financial incentives or charging fees alone is unlikely to result in significant voluntary uptake of building-scale devices. Changes to policy to mandate WSUD or even to introduce density bonuses will require public and political support, and will only impact new development resulting in gradual change. Twelve interviewees explicitly discussed the need to change values so that stormwater is seen as a resource and not a waste. A professional involved in stormwater management programmes in the US promotes a simple shift in language from stormwater to rainwater management to help change attitudes and improve support amongst the community (“The way we see the world is shaped by our vocabulary,’ observes Metro Vancouver’s Robert Hicks - Green Infrastructure,” 2010).

Change can be supported through advocacy by those in positions of influence and knowledge. In the UK RIBA advocates at a national level for sustainable development including WSUD, stating in Building a better Britain - A vision for the next government:
All elements of the water cycle need to be considered when designing and developing new places. This necessitates changing our perception of water from threat to the lifeblood of our cities, and thinking about the water cycle at the earliest stages of the planning and design processes. Fundamentally, water sensitive design can be applied at all scales, from a single house to an entire city, and it can be retrofitted to existing developments as well as built in from the start. We need policies that see this thinking adopted in every local plan and a commitment from the government to a comprehensive water management programme for the UK. (Beagle et al., 2014).

A barrier identified in Chapter 6 was a lack of leadership. Interviewees most commonly identified CCC and ECAN as organisations that should be taking a lead. Ngāi Tahu was also seen as well placed to influence. Community groups such as Avon-Ōtākaro Network and the Ōpāwaho Heathcote River Network, and others with an interest in water such as Fish and Game and water-related recreation groups were identified as organisations trying to change our attitudes to and behaviour towards waterways. Findings presented in Chapter 3 indicate that change will be slow and implementation will involve many different organisations, professions and individuals. International evidence suggests local government actions are key but community groups exerting pressure to improve environmental outcomes has driven change within local government organisations that have successfully embedded environmental policy and programmes (Portney & Berry, 2016).

Māori perspectives

A Māori interviewee (#24) explained that the best assessors of water quality are those who regularly harvest eels from the river. The importance of an intimate connection with a waterway in order to understand the needs of that waterway is described in detail by Ngata (2018). The responsibility for caring for a waterway is placed on individuals and traditionally a strong link existed as the river’s kaitiaki lived with and harvested from the stretch of river for which they had a duty of care, ensuring both knowledge and motivation. Mahinga kai was explained in Chapter 4 and, whilst most Māori today are not dependent on waterways and the natural environment for food, culturally it remains important and acts as a driver for waterway improvements for both Ngāi Tahu and CCC. Interviewee #8 said that Māori simply don’t put contaminants in the water while non-Māori think it’s impossible to avoid. Māori
respondent #24 gave the more nuanced explanation that water quality needs to be good enough to harvest from, but knowing what is good enough is difficult to agree. Ngata (2018) explains the difference between the notion of conservation which is based on an untouched ecosystem and the Māori perspective in which ecosystems include the human component.

Several non-Māori interviewees recognised Ngāi Tahu as a potential lead organisation for supporting the implementation of WSUD. Ngāi Tahu Property have incorporated larger scale WSUD devices extensively within subdivisions such as Te Whariki in Lincoln and Prestons in Christchurch (“Portfolio | Developments & Investments | Ngāi Tahu Property,” n.d.), but have avoided including covenants that place a requirement for stormwater management on individual property builders on these sites. Ngāi Tahu Property’s King Edward Barracks commercial development has incorporated a rain garden. The property development wing of Ngāi Tahu is showing leadership with the inclusion of technologies that mitigate the effects of runoff, motivated by cultural values. There is an opportunity to highlight these developments and the purpose of WSUD more explicitly. As with CCC’s rain gardens, the King Edward Barracks development does not provide signage explaining their purpose to staff or the public.

A recurring theme when talking to Māori interviewees is the importance of maintaining a healthy environment for future generations. Māori are connected spiritually to their tribal waterway through ancestors and see themselves as temporary guardians (kaitiaki) on a continuum with future generations (Ngata, 2018). Two interviewees (#3, #12) identified the need to find ways to share the cost of stormwater management improvements intergenerationally, for example through a loan that is repaid via the rates over an extended period. For Māori, motivation for environmental maintenance or improvement is values based and responsibility lies with the current generation of kaitiaki. Short-term profits are the primary motivation for most developers, based on interview findings, but Ngāi Tahu Property demonstrate through the voluntary increased use of WSUD solutions that their responsibility to future generations as kaitiaki influences their commercial decisions.

This theme is in common with other indigenous cultures - Chief Oren Lyons of the Iroquois Onondaga Nation, quoted in Raworth (2017), explains, ‘What you call resources we call our relatives....If you can think in terms of relationships, you are going to treat them better,
aren’t you?’ But the Māori community representative #24 felt that the notion of caring for land extends to all cultures, ‘I don’t think our Māori values are unique, they’re universal, [but] it’s having the ability to act out those values.’

It is also important to recognise that Māori culture has been substantially altered and influenced by colonisation, migration and urbanisation (Himona, 2013). Some younger urban Māori for example now value ancestral land in terms of its economic worth (Walker, 1990 in Williams, 2014 p.59). Colonisation has separated many Māori from their lands and marae impacting on their ability to care for their traditional lands having lost both knowledge and connection (Ngata, 2018). Environmental values and understanding are not static amongst a population or a culture. Nevertheless, Māori leaders are guided by traditional Māori practices (tikanga Māori) which includes guardianship of the environment as a key value. In New Zealand the Maori perspective offers insights that could help the population as a whole develop a greater understanding of and connection to the environment.

Education, communication and connection

Over a third of interviewees identified a need for professionals to upskill with regards to WSUD. To increase WSUD device use on site it is essential that the broad range of professions involved in design have an overview of all the WSUD options available and their relative merits. Opportunities to share knowledge and lessons gained from making mistakes are important for improving professional capabilities, such as through continuing professional development and local forums (#11, #15, #19, #21). Professionals seeking to implement new technologies in the immediate future need to support each other and help to build momentum. Keath and Brown (2009) highlight how transitions to a new norm can easily be destabilised and revert to business as usual. It is critical that professionals recognise and value each others areas of expertise and influence clients to involve a range of specialists early in the design stage of a new project. Water needs to be managed carefully to avoid building damage but also offers opportunities for reuse and landscaping and therefore involves multiple disciplines.

Good design that is easy to maintain is important for residents and businesses (engineer, #19). This view was echoed by the community representatives interviewed for this research.
Engineers described how the lack of collaboration between designers and the contractors that install and maintain WSUD devices is creating sub-standard WSUD installations (#11, #12, #19). A suite of standard designs developed collaboratively with designers, installers and maintenance teams could improve installations and ease of maintenance (engineer, #19). CCC’s rain garden manual is a large piece of work and is well supported by local, national and international research as well as the city council’s own expertise. A similar guide with multiple standard designs for all the building-scale WSUD devices would be a significant undertaking for CCC. Ideally national guidance would be developed, as in the UK (Woods Ballard et al., 2015), but Auckland Council’s guide (Auckland Council, 2017) provides a starting point. Greater flexibility, confidence and choice of designs suited to a wider range of site conditions supported by a comprehensive guide should reduce the problem of WSUD being avoided because those recommending stormwater solutions see more problems than advantages.

Community group interviewees highlighted the limited support available in Christchurch in terms of providing cheap simple solutions for reducing property impacts on the water environment. Finding viable solutions that are accessible to many is critical if residents in existing properties are to voluntarily participate in stormwater improvements. Examples of simple solutions seen internationally are disconnecting gutters and redirecting to lawns, rain gardens and rain barrels, increasing areas of mulched landscaping and planting large tree species. To achieve these goals small incentives or subsidies may be useful, but simple guidance and on the ground support is essential (Schofield, 2012). One community representative described uncertainty relating to rain garden design and how that affects take up even amongst the willing:

*There are lots of people disgusted with the state of the rivers and they want to do something at home but aren’t sure what they can do or where to go for information and [where] to see an example in operation. Most people, including myself initially, thought of a rain garden as a soak pit; just a sump with a bit of shingle and some permeable stuff and a growing layer. It’s more complicated than that, or maybe it’s made to look more complicated than that, I don’t know. But the more complicated it gets the more it turns people off it so it becomes too hard. (#22)*
The website www.700milliongallons.org provides a huge amount of easy to access information relating to green infrastructure. The website is supported by a collaboration between Seattle Public Utilities and King County Department of Natural Resources and Parks. The website provides information on the reasons why change is needed, what homeowners can do and the support available. Information is sufficient for competent DIY enthusiasts or gardeners to follow, but a list of contractors that have attended a ‘RainWise’ training programme is also available. The site also includes a digital map of Seattle, US, showing where rain gardens and other devices have been installed providing an opportunity to view very local examples of building-scale WSUD devices which can act as a catalyst to others. The approach to motivating WSUD uptake on private property in Seattle is multipronged. The barriers are multiple and inter-related and therefore the solutions must be also.

Building-scale WSUD devices are not cost-effective to a private property owner or developer under the current policy and rates regimes in Christchurch, or in many parts of the world as seen in Chapter 3. Several interviewees (#12, #13, #15, #16, #29) talked of the need to improve the WSUD ‘sales pitch’ and find a wider appeal than to just the few environmentally motivated individuals. Instead of focusing on the stormwater benefits, what advantages does the WSUD device provide to the client? The Te Atatu Medical Centre chose permeable paving despite the additional cost because it was a safe surface in all weathers for their customers (Going, 2018). Colletts Corner in Lyttelton is promoting a garden roof as a pleasant outdoor space for residents. A rooftop garden with mountain views could benefit employees or cafe-goers in the central city. As discussed in Chapter 6, WSUD infrastructure with a planted component, such as rain gardens, rain planters or tree pits, could particularly enhance industrial areas.

It is much easier to justify flood management projects because the financial value of flood damage can be calculated and compared with the cost of flood mitigation options, such as the council buying a property within a flood zone or installing a detention basin (engineer, #7). The value of ecological and recreational benefits created by reducing runoff volumes, frequency of flows, and improving stormwater quality is much harder to calculate. A Post-It note commentator observed that the current (non)quantification of intangible benefits results in failure at the cost benefit analysis stage of a project, as identified in Chapter 6, and
is therefore ‘easy to politically destabilise as a waste of resources’. Presenting an alternative to the current dominant economic model Raworth (2017) quotes Otto Scharmer, ‘[We need to] begin to care and act, not just for ourselves and other stakeholders but in the interests of the entire ecosystem in which economic activities take place.’ Raworth (2017) argues for a fundamental change to the way economics is applied to decision-making in the 21st century from the current model based on economic growth to one where the environment is prioritised. She argues we need to recognise the planet’s limits if we are to provide for our own wellbeing and for future generations.

Those involved in development, from developers and investors, to architects and landscape architects, to stormwater engineers, to councillors and politicians who set policy direction, and perhaps even judges who determine cases of law, are not separate from the culture in which they grew up. They will be influenced by their education, the media, their family and friends, the dominant culture. Those in positions of power believe themselves to be objective when making decisions based on figures, but we are all subjective (Ecologist, #29). The NZIA membership comprises 90% of registered architects and submissions made by NZIA represents the majority-view of that membership, although the process used internally to ensure submissions are representative has not been shared. The response objecting to CCC’s Homestar 6 proposal on the grounds of upfront costs can therefore be assumed to reflect the mindset of the majority of architects in New Zealand. It may also demonstrate how the dominant mindset acts to influence current policy at the expense of future generations. This emphasises the importance of instilling environmental values throughout school education. Children are the adults of tomorrow. A generation with stronger individual environmental commitment will increasingly influence business and politics.

Wheen (1997), as discussed in Chapter 4, highlighted that environmental values were being considered as secondary to economic values in judgements taken using the balancing approach under the RMA and wrote:

[W]e might choose to accept the balancing, or value judgment, approach and instead focus our attention on improving (that is, greening up) the values which decision-makers bring to the decision-making process. This would tend to reduce the chances of nature’s interests being devalued in decision-making without requiring a huge resource investment or inviting
the problems encountered in other jurisdictions which have sought to protect nature by standard- and rule-setting.

A shift in mindset is required so that an increasing number of individuals view improvements in the wider environment as of benefit to themselves and their descendents, as seen in traditional Māori culture. In this way the likelihood of widespread pro-environmental behaviour, including willingness to prioritise spending on environmentally beneficial technologies would increase. Without a change in mindset, even when water sensitive devices are installed there can be problems with acceptance, further emphasising the need to instill environmental values. The property manager said:

*We have grey water*¹⁰ *but the tenants kept complaining because they didn’t like the colour of the water in the toilet. In the end we had to disconnect which was disappointing, so we need to change expectations and explain the reason, changing the social norm.....* We explained, *but they thought they were better than having grey water in their toilets. (#27)*

Raworth (2017) recommends teaching eco-literacy in every school so that future generations understand the interdependency of the world’s systems. The theme of education to generate change with respect to individuals taking more responsibility for water on their own property was raised by well over half of the interviewees across all sectors. One Post-It note said, ‘Start young: I was surprised when I spoke to a group of school kids how few of them knew where the water in their tap came from or the water in the drain went to.’ The ecologist (#29), however, said, ‘I’m sceptical that you just need to educate and [people] do the right thing. It doesn’t always work. How do you start to increase literacy when you have a population who aren’t on board?’

Two interviewees involved in planning promoted the idea of making water more visible in the urban landscape to enhance its value to us as a society (#9, #10). In order to shift mindsets there is a need to create connection, just as Māori respondents highlighted the need for both knowledge and a connection to motivate care.

*Most promising is to get people to learn by experiencing the environment. The more they experience the more they value it, and then want to learn more. Our reserve, I keep giving information on different tree species.....and how animals use them, so people understand*

¹⁰ Water collected and recycled from hand-wash basins and showering for example.
the complexities and how things depend on each other, and then how we depend on nature. Then people can realise how washing the car on the drive can impact. The information about washing the car on the lawn is there, but I don’t see anyone doing it. (Developer #25)

A community representative also spoke of the need to build connections and learn through fun:

A lot of this environmental stuff can be a bit rammed down your throat so coming up with creative ways [to educate]; an event, a family event that connects...doing something in the environment outside near the river. A fun thing with a message as well, so it becomes more than just a lecture, being told what you should be doing. Something you can engage in and understand and connect with. You might not take it all in at the start but you slowly get the message. (#28)

Well coordinated local environmental and community groups are recognised as particularly influential when applying pressure to local government to adopt environmental policies and programmes (Portney & Berry, 2016). A Community Water Partnership involving local community groups, to be led by CCC, ECan, Department of Conservation and Ngāi Tahu, has been proposed to create behaviour change around water with the aim of reducing contamination in the waterways and conserving water resources. A budget of NZ$1,000,000 per year for 20 years was proposed in the most recent council Long Term Plan (LTP) process. The budget was for an education programme; a public marketing and behavioural change campaign and a grant for on the ground projects (Workshop handout). The proposal was not funded through the council’s LTP process however. Engineer #7 explained it is easier to get funding for a major capital project which doesn’t affect future rates (although maintenance of a new asset does), whilst much lower cost proposals with ongoing costs, such as education programmes, are more difficult because they require an annual rates rise, which is often resisted. This demonstrates the difficulty of building political and public support when funding is needed to improve that support. It also highlights a problem with the council’s funding mechanism which skews decisions away from some certain types of project regardless of potential benefits. Nevertheless, the growing relationship between the community groups and key decision-makers is a positive step.
Multiple interviewees suggested promoting the wider societal benefits of on-site stormwater management, such as the potential to improve opportunities for contact recreation, mahinga kai/angling and biodiversity within the heart of the city to motivate behaviour change. This reflects the sentiment presented by Matapore, described in Chapter 4, in identifying shared values of mahinga kai, the urban food movement and the historic Garden City (Tau, 2016). Again reflecting on the traditional Māori culture, their care for resources was motivated by valuing the benefits of a healthy ecosystem in terms of tribal wellbeing and ensuring access to resources now and for future generations. As mentioned in the policy section, a clear vision that is of direct benefit to the city can improve political and public support, particularly where goals from multiple strategies can be supported. The Avon-Otakaro Network has proposed an inspiring goal of swimming in the Avon/Ōtākaro by 2030. They are working hard to raise awareness amongst decision-makers and residents in the city of the opportunities greater care for our waterways could bring, together with increasing connectedness through community gardens, food forests and community celebrations. Submissions to political processes, such as the LTP, are also used as a way to drive change through political reprioritisation of funding.

Several of the community groups and organisations identified for involvement in the Community Water Partnership provide education programmes that give school children the opportunity to visit their local waterway and build on that experience in the classroom. Follow up work includes planning projects to improve their local environment and sharing their experience with family members and the local community. This style of education can build a real connection with the environment and permeate through the local community. Future funding proposals should review the balance of funding attributed to different aspects of the Community Water Partnership proposal. A marketing campaign cannot create the same long-lasting connection that makes people care. The waterways survey results showed that although people know that washing the car on the lawn or a grass berm is better for the environment the majority continue to wash the car on the driveway or road - the message has largely been received but is not acted on. If messages are shared during fun outdoor activity days so the connection is made between car washing and harming the eel you fed and touched, action is more likely. These connections are essential if a cultural shift to one where the environment is intrinsically valued is to take place.
In Portland, US, a school clean rivers education programme was run for two years ahead of the Disconnect a Gutter programme (Schofield, 2012). The Enviroschools programme is a well established education programme operating in 26 schools in Christchurch (“Enviroschools : Participating Schools Canterbury,” n.d.). The programme cannot expand because of funding shortages. There are at least 40 more schools in Christchurch waiting to join the scheme, demonstrating a willingness in the education sector to incorporate environmental education with the right support. Both Cashmere Primary and Cashmere High are Enviroschools. Cashmere High School won a grant of NZ$100,000 to become the first school in the world to install paving to harvest energy from foot fall (O’Callaghan, 2016). There are several grant schemes available for sustainable and environmental projects in Christchurch. Enthusiastic and creative pupils with support and encouragement can turn ideas into funding proposals and tangible projects. Those that gain funding can tap into the wider local network for volunteer support including family and businesses. Well funded schools education could, with time, bring about a wholesale change in environmental awareness and on the ground action.

Nevertheless attempting to shift values in order to achieve greater environmental outcomes risks not only taking time, but also ‘uncertain and unpredictable’ results (Wheen, 1997). Hence, there must be a focus on multiple activities, running concurrently with education, including incentivisation and gradual amendments to policy discussed above and research and demonstration discussed below. This will not only gradually build public and political will but will also provide sufficient protection to the environment in the interim before an ‘environmentally literate’ population emerges.

Research and demonstration

A lack of confidence in the technical capabilities of PPS is a particular barrier to the implementation of this WSUD device which has the potential, based on international research and Auckland experience, for widespread use, including in retrofit areas. The importance of providing options that can be accommodated despite physical constraints and site layout restrictions has been highlighted already, and PPS provides flexibility in this regard. In order to overcome concerns research and demonstration projects are critical:
Walk and look at it, see it with your own eyes...... I’m thinking from my own personal perspective, but also from an engineering perspective, people seeing it for themselves.....Nothing replaces actually seeing with your own eyes. (Home builder/consultant engineer, #1)

Local PPS trials can be carried out in less critical locations such as on driveways or lower use parking lots with an underdrained system providing a low risk situation to analyse the quality and quantity of stormwater water exiting the PPS. The maintenance requirements and changes in infiltration can be monitored over time. Ideally such research would be conducted by a university to ensure impartiality. Research requires funding but is an investment worth making to enable a wider choice of building-scale devices to be endorsed, given the benefits outlined. Research findings from Auckland and abroad, presented in Chapter 2, show that all the devices types considered in this thesis have potential. This is not cutting edge technology with high risk of failure; it is research to establish the best operating systems for the local conditions and to increase local expertise.

Streetscape rain gardens which are now well established in Christchurch could motivate developers to incorporate them on site but there needs to be information with them demonstrating their benefit (engineer, #12). Rain gardens have been absent in private car parks developed since the earthquakes, instead raised kerbs and grassed areas that need irrigating are used (engineer, #7; landscape architect, #13).

The Causeway has a rain garden and people don’t realise what that is. It looks different but there’s no thought about it. If there was a sign, like a nature interpretation board [they would know]. There’s not enough being made of the good changes. (Developer, #25)

The government, local authority and Environment Canterbury (ECan) were most frequently identified as potential instigators of demonstration projects. Internationally the public sector, driven by policy changes, has been required to lead by example with WSUD installations on their own buildings which can then act as demonstration projects and provide research opportunities in collaboration with local research establishments (United States Environmental Protection Agency, 2009b). The Ministry of Education had a policy that all new schools were to achieve a Green Star 5 rating, but this is no longer in place due to cost. Halswell School in Christchurch was constructed whilst the policy was in place and
rainwater harvesting and rain gardens were included, also helping to meet stormwater management requirements in an area prone to nuisance flooding. Prior to the earthquakes two of the city’s libraries (South and Upper Riccarton), designed by local architects Warren and Mahoney, used rainwater for toilet flushing with signage on the flush (“South Christchurch Library and Service Centre,” n.d.). The systems, built in 2003 and 2005, are no longer functioning and post-quake public buildings have not obviously incorporated rainwater harvesting. South Library is presented as a case study by the Ministry for the Environment with an early summary of lessons learnt dated 2006 (“Case study: Community library | Ministry for the Environment,” n.d.). Ideally a further review would have been used to inform design and construction of new systems. With new technologies there is risk of failure but those failures can also be a source of information and improve design (Farrelly & Brown, 2011).

The Melbourne Docklands urban renewal project provided an opportunity to demonstrate WSUD at all scales across a large site with a specific aim to improve the quality of stormwater before it entered the Port Phillip Bay. The 200 hectare site has been developed for almost 20 years and is expected to be complete around 2025. Lessons were shared relating to WSUD design, installation and maintenance as the project evolved since techniques used at the beginning of the project were innovative (Burge, Allison, Wong, & Breen, 2008). The project is led by the Victorian Government but individual developments have been privately developed in accordance with minimum performance standards set out in the Melbourne Docklands Ecologically Sustainable Development Guide (VicUrban, 2007). The draft concept for Christchurch Cathedral Square integrates water and native planting (“Key move 5: Integrating water and native plants,” n.d.). There is potential to connect surrounding buildings to WSUD features within the square, for example capturing roof water and diverting it through a rain garden and this could provide an excellent opportunity to demonstrate and promote WSUD opportunities. It is not known whether there is an intention to go beyond managing the rainwater that falls on the square only.

A theme raised by several interviewees including all the community representatives (#22, #24 and #28) with reference to demonstration projects is the need for them to be simple and applicable to homeowners. The importance of and difficulties associated with retrofitting WSUD to existing development, including homes, has been raised in previous
chapters. Demonstrations are needed that show people what they can do for themselves.

Respondent #3, reflecting on his experience as a farmer involved in trying to change practices in the rural environment to improve water quality said:

*Are there really simple things that someone could do that either the builder or homeowner could retrofit and pick up off the shelf?.......As a farmer, in a slightly different environment, the easier [a solution] is that someone puts in front of me, the easier it is for me to adopt it.*

(#3)

Some potential pilot projects are described below that tie in with existing proposals, policy, current local waterway concerns or future development and connect with existing community groups that could be considered for council support are outlined below.

**Port Hills dual purpose rainwater harvesting pilot scheme**

New residential development in the Port Hills is required to include large tanks for runoff detention to reduce erosion and flood effects downstream. Incentives such as a rate rebate or one-off payment can be used for the promotion of sustainable development (District Plan policy 14.2.4.8). Upgrading detention tanks to dual-purpose rainwater harvesting systems brings multiple benefits for the homeowner and council. Developments in these areas are typically suburban spacious enough to include a dual-purpose tank and with relatively large gardens that can benefit from irrigation supplies, including the potential to set up a drip feed system. A backup water supply in earthquake-prone Christchurch could be of interest to some homeowners. Mains water is pumped to reservoirs on the hills and therefore reducing mains water demand will lower electricity use and cost to Christchurch City Council providing a justification for a rates rebate.

The streams that flow from the Port Hills are susceptible to erosion from frequent runoff events which rainwater harvesting for internal uses mitigates. The well established Cashmere Stream Care Group and/or the Heathcote Ōpāwaho River Network could be involved in promoting and explaining the benefits of such a scheme to encourage uptake. Providing clear information such as the types of tanks available, where from, who can install them, maintenance requirements, costs and annual water saving would overcome the problem of poor information commented on by interviewees who’d investigated the use of
rainwater tanks. Information can be targeted with direct mail outs to owners of sections and subdivisions waiting to be developed. Other sustainable construction information already available from the council, including one free hour with the council’s eco-build advisor, could be promoted at the same time, providing cost efficiencies.

**Disconnecting gutters, building rain gardens and PPS trials in the western suburbs**

More permeable soils to the west of the city centre are particularly suitable for small-scale rain gardens. Higher permeability soils reduce the size a rain garden needs to be relative to the area of impermeable surface being diverted to it. DIY guides showing how to build a rain garden to receive roof runoff have been published and promoted by several states in the US to enable residents to make changes to their own properties (Hinmann, 2013). Enhancing infiltration in the western suburbs will augment the groundwater table and improve summer flows in the Avon/Ōtākaro providing the local community with a motivation for making changes on their property, as long as this is well communicated. Permeable soils need more summer watering and the reduced need for irrigation in the longer term could be seen as advantageous to both the council and homeowners.

Australian and US field-scale catchment studies described in Chapter 3 showed that devices that provide a direct benefit were preferred by homeowners, although the benefits of rain gardens had not been widely accepted. Rain gardens can provide an attractive planted area that requires minimal watering once established (landscape architect, #13). A guide designed for Christchurch should include lists of suitable native plants to support local biodiversity. However, in the tradition of the Garden City and to appeal to as wide a group of gardeners as possible, a non-native plants list that provides more variety and colour could also be considered. The landscape architect commented that rain gardens could become ‘cool features’ so everyone wants one (#13). Landscape architects and magazines that promote their work are influential and garden fashion changes over time. The Christchurch Beautifying Association or the Canterbury Horticultural Society, neither of which are included in the Community Water Partnership at present, could be approached to collaborate on some initial demonstration projects. A local competition could incentivise action and creativity with limited cost to the council. Local schools could be motivated to design and build a rain garden on site if the right financial, educational and technical support
is made available. Educational signage would promote its function more widely. A themed school garden competition is run annually by Oderings, a local garden centre franchise, with entrants receiving a budget to spend in Oderings. A rain garden theme could be used one year. As one community representative said, schools have now become the focal point of communities (#24).

In addition PPS trials in the western area would provide an opportunity to test and demonstrate the technology which can be set up to infiltrate if testing of underdrained devices demonstrates suitable water quality.

**Small-scale interventions around the Avon-Ōtākaro red zone**

The Avon-Ōtākaro Network has begun to install a network of small-scale educational installations that demonstrate options for homeowners to reduce their impact on the water environment (Figure 4.5). The proximity of the installations to the river is significant as it provides an opportunity to emphasise the connection between the installation and the environment (Community representative, #22). The installations are also in publicly accessible places rather than on private property. There is potential to encourage more voluntary building-scale WSUD installations.

A few interviewees emphasised the importance of recognising that ‘every little bit counts’. One community representative (#28) proposed subsidising rain garden plants or rain barrels as a simple way to begin to incentivise people to make changes on their property. Subsidised trees could also be included for their ability to reduce runoff (Schofield, 2012). These types of change are only likely to result in a very small difference to total runoff but programmes seeking voluntary change provide people with knowledge of the issues, encourage them to take some responsibility, provide tools that make some positive changes and leave people feeling like they can ‘do the right thing’. This is a starting point. Highlighting the link between on-site changes to improve stormwater management and the proposed wetlands in the Avon-Ōtākaro red zone is important. These wetlands could become a highly valued ecological and amenity asset. Although seen as a tool for improving stormwater quality, as discussed in Chapter 4 wetlands are not immune to the effects of poor quality water inputs and can become a source of contaminants over time (Newman & Coupe, 2017). Encouraging
the local community to make small changes in support of the proposed wetland provides a link between action and local benefit.

**Styx-Pūharakekenui River catchment**

The Styx/Pūharakekenui has higher water quality than the Avon/Ōtākaro or Heathcote/Ōpāwaho. Development within the Styx-Pūharakekenui catchment could be prioritised for more stringent policy on water quality management with a requirement for on-site volume retention, as seen in Auckland high-value catchments. Policy in the Port Hills has required stormwater detention for peak flow reduction, but where quality is a priority volume retention is essential, as seen in Chapter 2. Using policy to require retention on individual sections as well as at the site-scale avoids reducing the area available for housing development whilst still improving water quality outcomes. An innovative developer may be interested in creating a subdivision with WSUD at the heart of its design, in line with Earthsong (Fig 1.1) but to achieve this the council would need to be flexible in its approach to site design. Positive alterations to site layout can be achieved working closely with the council planners if the right evidence is provided (property sales, #23).

**Industrial demonstration**

An industrial site is needed to showcase the multiple benefits of green infrastructure. CCC or ECan staff may be able to identify potential development sites or existing business owners who could be approached with a proposal to install a rain garden or tree pits. Alternatively streetscape green features could be installed opportunistically during infrastructure upgrades or maintenance. Tree pits could be more practical in this setting than rain gardens as they minimise parking space losses whilst, in time, providing shading and air quality improvements. Industrial areas present some complexities with respect to WSUD installations, but suitable multi-benefit solutions can be found that are suitable for an industrial setting, including rain gardens and bioswales to create a treatment train (Jayasooriya, 2016). The significant input of contaminants from these area supports placing attention on them, particularly in light of recent research indicating that zinc is more toxic to aquatic ecosystems than previously thought (NIWA, 2017).
Summary

Christchurch residents, based on CCC’s Waterway Survey findings, do support improving the city’s waterways in principle, but many are unaware of the connection between stormwater and waterway degradation. Additionally a large minority are not prepared to pay more to achieve an improvement. Fees could be part of a solutions package to address the cost barrier but they would be very unpopular and difficult to implement. Density bonuses could incentivise developers to incorporate building-scale WSUD devices without significant cost to CCC and could also enhance the urban landscape, biodiversity and reduce mains water demand. The advantages of building-scale WSUD devices to developers and site end-users needs to be better promoted. The use of rainwater harvesting or rain gardens should begin to become standard in new commercial developments which are now required through the District Plan to incorporate LID and water reuse. PPS needs additional research to build confidence if it is to become commonplace. Living roofs are likely to need demonstrations and a density bonus mechanism if they are to become a more regular addition to commercial properties due to their high cost. On industrial development a multi-value approach to stormwater is only encouraged. An opportunity to enhance industrial areas to improve the local environment for the benefit of workers and to provide a visible connection between activity on industrial sites and the effect on the wider environment is being missed which could be addressed with policy. In the absence of policy, demonstrations could help to motivate change.

Local testing of the full variety of building-scale solutions is needed to increase confidence amongst professionals in stormwater design and in the council. Good guidance supports the uptake of devices by providing developers with choice, limiting the number of sites that could not practicably incorporate a device, and reducing concerns about a delayed consent process. An enforcement regime to ensure future maintenance of devices on private property needs to be considered, but absence of such a regime should not be used to avoid promoting building-scale devices. Conditions can be included in consents requiring maintenance which can be enforced later. A shift in the council’s culture is needed if some responsibility for stormwater management is to be transferred back to ratepayers, moving away from the traditional model where the council to take on all responsibility.
It is important to make the most of new build opportunities, whether on greenfield sites or in the inner city. Building-scale WSUD installations are most cost-effective at the time of construction. A new building may not offer an opportunity for a major retrofit for several decades and is therefore a significant missed opportunity if not constructed today using currently available technologies to reduce environmental impact, or at least built to be technology-ready. The majority of contaminants over the next few decades will be generated within existing areas of development and therefore even small changes, if widely incorporated in these areas, are important. A combination of pilot schemes, incentivising or requiring best practice in new builds and improving awareness and providing simple but effective guidance on methods to reduce runoff volume in existing development areas should see an increase in uptake of building-scale WSUD devices.

Public and political will is needed to implement the policies and investment that will achieve inclusion of building-scale WSUD in all property types. The Māori concept of kaitiaki in which the current generation accepts a duty to care for the environment on behalf of future generations needs to become widespread. Ngāi Tahu Property demonstrates that an attitude of care towards the environment can result in developments designed to reduce stormwater impacts beyond the statutory minimum. A wholesale shift from reliance on conventional collective stormwater management practices to including building-scale WSUD devices will require a change in mindset to one that values the environment intrinsically. School environmental education that provides opportunities to physically engage and connect with the local environment is paramount if mindsets are to change. School pupils with the right support could also be involved in planning and implementing demonstrations on school property by accessing existing sustainability funding. School children influence those around them, but also become voters, property owners and construction industry professionals.
Conclusion

Introduction

This final chapter consolidates the key findings of this research and reflects on limitations with respect to the objectives outlined in Chapter 1. In addition opportunities for future research that could build on the findings are discussed.

Objectives

The first objective was to identify the reasons for the lack of adoption of WSUD at the individual property level, with particular reference to Christchurch. The methodology primarily relied on semi-structured interviews which provided a huge amount of information. The interviewees all had an interest in stormwater management or sustainable development more generally, either professionally or as a community group leader, and were from a range of professional backgrounds, sector types and experience. A few were also able to contribute a Māori perspective. There was commonality evident in their responses which gives confidence in the identification of key issues presented in this thesis.

The initial assumption prior to conducting interviews was that the earthquake sequence offered an opportunity to create a sustainable city, predicated on the council’s consultation, ‘Share an Idea’, which identified public support for a sustainable rebuild (Lucas, 2014). Whist a significant rebuild seems like an opportunity for transition the reality of people wanting to get on with their lives created a major barrier. Transitions to a different urban water paradigm can be motivated or curtailed by a crisis, as seen in the differing responses to drought in Melbourne and Brisbane, Australia (Keath & Brown, 2009). In the case of Christchurch, until late 2017 with the introduction of policy for commercial developments in the District Plan, there is no evidence that CCC actively promoted building-scale WSUD either prior to or post-earthquake, despite supporting policy in the Surface Water Strategy (SWS). The future water supply shortage identified in the Water Supply Strategy (Christchurch City Council, 2009b) has also been overlooked by CCC, even when presented with an opportunity for change during the development of a bylaw mandating rain tanks in
Akaroa in 2014 (Christchurch City Council, 18-19 September 2014). In depth interviews revealed that barriers exist that prevent both developers and the council from increasing the use of building-scale WSUD devices in new build properties.

The original publication of the Waterways, Wetlands and Drainage Guide (2003b) marked a change in CCC’s attitude towards the stormwater network with a realisation that it could deliver more than just drainage. Greenfield subdivisions from around that time began to incorporate the larger scale components of a site designed with WSUD principles, including swales and wetlands. Building-scale WSUD devices were not included in that guide or the more recent 2012 revision. Residential properties are directed to connect to the piped network even in areas with permeable soils suited to devices with infiltration. The Avon/Ōtākaro in particular, which is susceptible to low baseflow following dry winters, could benefit from infiltrating WSUD devices. Research identifies the need to address stormwater volumes and frequent flows to restore ecological values and a hydrologic response comparable with pre-development patterns (Ladson et al., 2006). Building-scale devices address this issue, particularly if installed to allow infiltration, as seen in Auckland where policy requires on-site volume retention in catchments with highly valued waterways. To date CCC’s policy has not progressed beyond peak flow and contaminant load considerations.

Cost was identified as the primary barrier. This was not unexpected as it is frequently cited in international literature (Dodge Data & Analytics, 2016). Building-scale WSUD devices do not provide a financial return to either the developer or the property end-user in Christchurch. Even developments with large budgets do not incorporate water sensitive features. Evidence from other cities, both in New Zealand and abroad, suggests that a local driver with direct impacts is required to motivate policies and behaviour change that supports more water sensitive practices. Drought, combined sewer overflows and flooding have been particularly effective motivators elsewhere. These issues gain public and therefore political attention. Christchurch suffers from flooding, which has worsened since the earthquakes, but there is sufficient space to incorporate detention basins and streetscape rain gardens which mitigate flooding more effectively than building-scale solutions. Building-scale WSUD devices are therefore not required for CCC to manage its responsibilities in relation to large-scale flood management, although they can be beneficial for reducing nuisance flooding. Further, the
literature review found that even when rain gardens and rain barrels or tanks were offered for free with three years of maintenance 70% of property owners did not take them up (Mayer et al., 2012) indicating that there is an opportunity cost associated with these devices; in particular loss of space (Parikh et al., 2005). The benefits they provide are not well recognised.

Environmental improvement can motivate those who want to ‘do the right thing’ (Dodge Data & Analytics, 2016), but the Waterways Survey showed that whilst residents would like to see an improvement in the quality of the city’s waterways many do not carry out actions and are not prepared to spend more in rates to support that goal (Global Research Ltd, 2018a). There is also evidence that a sizeable proportion of Christchurch residents are unaware that stormwater is delivered directly to the waterways without treatment and are therefore unable to link their actions and impacts on the waterways. Building-scale WSUD should deliver wider environmental benefits, although field studies are still limited in scale and too recently implemented to confirm this (Shuster & Rhea, 2013; Walsh et al., 2015).

Rainwater harvesting offers resilience in the event of an earthquake or water supply contamination event. At present, however, these advantages are not sufficiently valued or understood to motivate voluntary uptake amongst the community.

CCC staff and professionals from the private sector involved in stormwater planning or design are concerned that individuals will not maintain devices sufficiently. This apprehension about transferring some responsibility for runoff back to property owners could explain the lack of policy and guidance to increase the uptake of building-scale WSUD devices, despite SWS policy in support of them. There was particular doubt amongst the council staff and some private sector engineers about the capability of permeable paving systems (PPS) long term, even with maintenance. Instead of supporting a range of solutions through policy and guidance there has been an almost exclusive focus by the council on streetscape rain gardens. This narrowing of choice and guidance impacts on designers’ confidence to propose alternatives in case of delays to the consent process; makes it more difficult for those interested in pursuing alternatives to find the information they need; and restricts the number of sites that can incorporate WSUD solutions since options that avoid taking up space, such as PPS and living roofs, are not supported.
There has been a lack of leadership by CCC with regards to developing policy, incentives or demonstration projects that could motivate change, although a recent change in District Plan policy for commercial properties is a start. Architects, recognised as particularly influential, are not promoting the use of WSUD options. Those with personal experience rebuilding homes post-quake with sustainable design in mind have struggled to find architects that are sufficiently knowledgeable to contribute constructively to sustainable development, such as the use of rainwater harvesting. Developers respond to market demand and demand for development that minimises impacts on the water environment is low. Even New Zealand’s leading sustainable certification schemes, Greenstar and Home Star, provide limited motivation for incorporating devices that reduce runoff or encourage water reuse unless a client is seeking the highest star ratings.

The second objective was to investigate the costs and benefits to the developer or site end user of individual building-scale WSUD devices in both new build and retrofit projects. Reductions in contaminant loads and small but frequent ecologically-damaging flows are beneficial for improving biodiversity and mahinga kai opportunities for example, but these benefits are difficult to quantify in financial terms. These benefits are shared societal benefits rather than direct benefits to the installer who bears the brunt of the costs (Montalto et al., 2007). Direct benefits are usually prioritised by property owners (Lamond et al., 2014). Water is very cheap for CCC to supply which limits the council’s scope to justify financial incentives sufficiently large to motivate developers or property owners to take up rainwater harvesting. Research literature confirmed that water supply and stormwater management fees combined can motivate the uptake of building-scale WSUD devices but these would not be viable politically in Christchurch at the levels needed to generate a payback within the three to five year period considered reasonable by property owners in New Zealand (BRANZ, 2018).

In addition interviewees with extensive WSUD design experience explained that whilst WSUD devices come with multiple benefits they also take up space, and are relatively expensive to install and maintain. The council are pursuing WSUD installations on public land to reduce contaminants over an extended period of time. Evidence in Chapter 2 shows that this is a cost effective strategy for the council to take. The building-scale devices do provide a benefit to site end users, but their value is subjective; PPS creates a puddle-free surface; rain
gardens can be an attractively designed and drought-resistant landscape features; and rainwater harvesting offers a backup supply in the event of an earthquake. A living roof is the one device that has the potential to create a direct financial benefit if designed to provide an attractive outdoor space with views in built up areas of the city. However, the focus of communication around building-scale devices is more often based on contaminants and the wider environmental benefits rather than end-user benefits.

Whilst a traditional economic model will only rarely find building-scale WSUD devices to provide a cost-benefit to private property owners that does not mean that cost should be accepted as a barrier to uptake. Stormwater generates externalities. Externalities generated by stormwater can be internalised through policy, as has occurred with point source discharges in the past. Humans are also capable of valuing the environment intrinsically, as demonstrated by traditional Māori and other indigenous cultures, as well as environmentally-motivated individuals from many backgrounds. Pro-environmental choices can be made with all but the most limited budget if sustainable options are valued sufficiently and therefore prioritised, such that a rainwater harvesting system or a rain garden is included instead of copper guttering or a third bathroom, for example. Choices are more limited in retrofit situations with living roofs and rainwater harvesting for internal uses being more complex to install retrospectively, but rain gardens and/or PPS and external rainwater tanks for irrigation can be included easily on many existing properties.

**The third objective** was to make recommendations to increase the uptake of WSUD at the individual building-scale in Christchurch. The most important recommendation is to prioritise school environmental education that includes field activities to build a sense of connection to the local environment as well as developing knowledge of natural ecosystems and urban impacts on them. The emotional connection is important to change mindsets so that the environment becomes valued intrinsically. Enviroschools is well placed to provide this type of education but has a waiting list of over 40 schools in Christchurch, indicating that there is a willingness to increase environmental education if resources and support is available. Creating a more water sensitive city will take an extended period of time and schools education needs to be seen in this context - there is no quick fix (Buehler et al., 2011). Children influence family in the more immediate future and a school education
programme is therefore also an effective way to communicate with the community more widely.

Policies that mandate the uptake of building-scale WSUD, supported by good guidance on a variety of devices, will result in change, as seen in Auckland. Policy should be outcomes based rather than prescriptive to allow site owners to select the best option for their development. This also reduces the risk that good innovative solutions are excluded because of a lag in the development of council policy and guidance. Change that places additional cost on developers will be resisted. Density bonuses could be used in the first instance to motivate inclusion of building-scale WSUD. For example a living roof which provides a public good with biodiversity and stormwater management could be rewarded by permitting an additional floor or increased building footprint. The full range of building-scale WSUD devices is not well represented in Christchurch and incentives would begin to create demonstration projects without cost to the council. Existing devices should have better educational information to promote their purpose and advantages, such as rain gardens which cleanse stormwater, but also provide drought-tolerant landscaping. With improved education, demonstration and communication uptake will gradually increase, together with the political will for policy change as the advantages are seen and understood (Tayouga & Gagné, 2016).

Additional research is needed to build confidence in all the building-scale devices and adjust designs for local circumstances. Collaborative working across multiple disciplines at the outset of projects is important since WSUD requires rainwater management to be integrated into both building structures and the surrounding landscape. Professional development and forums can provide opportunities for sharing knowledge between professionals with a common background, but promotion across a wider range of professions involved in construction is needed. Organisations such as BRANZ or the New Zealand Green Building Council promote building-scale WSUD. A focus on improving architects and landscape architects’ awareness of these devices and their benefits is essential since many smaller projects will not involve specialist stormwater practitioners and do not fall within District Plan criteria requiring installations. Universities and professional bodies also have a role to play. CCC through direct mail to section owners promoting WSUD solutions and a free hour with their in-house environmental advisor could help to generate interest and demand from
future developers - a bottom up approach. Pilot schemes can test receptivity to devices, focus on the local connection and the solutions most suited to the area, establish effective communication methods and practical support needed to aid those interested in including WSUD on their own property.

Policy changes only affect new-build development. Motivating the retrofit of rainwater management solutions is more difficult both practically and in terms of influencing voluntary changes on private property. The critical messages for retrofit is to acknowledge that small changes are still valuable and encourage all easily achieved amendments. This may include planting additional trees on a section, or diverting roof runoff to a DIY rain garden. Financial incentives in the form of subsidised plants could be beneficial but creating a fashion for rain gardens could be even more influential, perhaps through a competition with the Horticultural Society or Christchurch Beautifying Association. Creating local links is important. Again pilot studies are recommended to enhance that local focus, such as in the catchment of the proposed Avon-Ōtākaro red zone wetlands. Guidance for simple rain gardens is needed and ideally on-the-ground staff or a list of knowledgeable contractors that can support interested homeowners and businesses.

Ultimately however, many adults are limited in the actions and investment they will contribute because of the cultural norms of the day. Hence why environmental education throughout school is critical to generate a significant and lasting change in urban development practices. WSUD has the potential to not just minimise environmental effects but can create a net benefit as water is used visibly as a resource rather than hidden and disposed of as a waste.

Further research

The need to install and monitor examples of all the building-scale WSUD devices to build confidence in their efficacy and make alterations specific to the local circumstances, such as climate or geology, has been raised. There is particular scope to test PPS, living roofs and dual tank systems in Christchurch as these are under-represented. Pilot schemes offer the opportunity to learn by doing and broaden research opportunities to encompass techniques to influence take up, or understand barriers specific to a particular suburb.
GIS support tool

It has been emphasised that each site should be considered individually. There are limitations to the viability of installing each of the building-scale devices. Selection tools have been devised that account for physical constraints to support decision-making (Lerer, Arnbjerg-Nielsen, & Mikkelsen, 2015; Urrutiaquyer, Lloyd, & Lamshed, 2010). The range of factors that need to be taken into account in determining which options have potential include whether a project is new build project or retrofit, the ground conditions such as permeability, minimum depth to groundwater, aquifer protection zones, the presence of contaminated soils and site gradient. There is also the preferences of the site end-user to consider; for example, is a backup water supply important, retaining parking spaces, including more ground-level planting or creating a rooftop garden? Cost will be important; for example, a living roof may be viable if creating a shared space for an apartment block or a commercial opportunity for a cafe or restaurant, but would be a significant part of any budget used on an individual residence because of the hot dry summer climate limiting the use of extensive roof systems. Ballpark upfront costs could be included, together with longer-term maintenance information. There is scope to develop a Geographical Information System based product that supports decision-making covering these aspects. The policies that apply to stormwater management from both ECAN and CCC are complex to understand with variations in allowable site coverage, minimum landscaping and car park areas for each zone and property type. Policy information could be shared based on defined policy areas and/or development type. A layer outlining historic watercourses and the stormwater network may even offer scope for daylighting a stream on a larger site. Importantly the location of example devices and links to supporting guidance should be made available with the selection tool.

WSUD and resilient Christchurch

There is scope to assess WSUD as a complete concept, rather than investigating on-site solutions only, and to review the broader environmental and social benefits. These may alter over time with the anticipated effects of climate change. For example, living roofs and urban trees are recognised for their ability to reduce the urban heat island effect, which is currently not a significant issue in Christchurch but could be with an increasing number of hot days.
per year. Urban landscaping and suburban gardens that make best use of rainwater and are drought-tolerant could be another advantage. There are also advantages for earthquake resilience. Rainwater storage is obvious and is encouraged as part of earthquake preparations in Wellington, but living roofs provide a damping effect, block-type PPS can be relaid, reducing waste compared with removing and replacing cracked concrete driveways, and even rain gardens take the pressure off the piped stormwater network which was severely damaged in the last major Christchurch earthquake. How should policy change now to create a resilient city for the future? How can councils be motivated to prepare for the long-term more effectively? How can the city best take advantage of the opportunities offered by the Ōtākaro/Avon River Corridor Regeneration Plan? Interviewees untapped for this thesis that would be particularly relevant to this broader research would be the New Zealand Green Building Council, Christchurch’s Urban Design Panel representatives, Matapore, urban designers and consent planners.

**Insurance**

Whilst a direct link between the installation of building-scale WSUD and damaging floods was considered unlikely on the basis of the international literature, nevertheless a huge investment in Christchurch redevelopment has come from private and government insurance. Several interviewees, from both private rebuild and public sector horizontal infrastructure perspectives, expressed frustration that the rules around spending insurance money in the rebuild limited opportunities to build back a more sustainable city. Neither strict like-for-like policies, or lump sum payouts promoted sustainable development. WSUD incorporated widely at all scales could deliver flood benefits reducing risk to insurance companies in the future. Sustainable development in general, such as improved insulation standards, high quality double or triple-glazing and LED lighting, reduces carbon footprints which mitigates global climate change, again of great importance to future insurance models. Is there an insurance policy design that could support a more sustainable rebuild following a major catastrophe such as an earthquake, cyclone or major flood?

**Water quality standards**

The Land and Water Regional Plan has set urban river water quality standards based on the Australian and New Zealand Guidelines for Fresh and Marine Water Quality for protecting
90% of aquatic organisms, rather than a 95% or 99% standard. If WSUD is being pursued and promoted because of the opportunities cleaner rivers offer in terms of societal and cultural benefits, such as mahinga kai, whitebaiting, angling, or even swimming, a set of standards could be derived that link to those opportunities. This is the approach is now recommended with an adaptive management strategy that entails consultation to understand opportunities and priorities, setting targets, agreeing actions, monitoring and checking against goals before reviewing and refining targets and actions again (Water Quality Australia, n.d.). Māori view water quality in these terms - is the water clean enough to have confidence eating this fish? The LWRP may set standards too high. There is an opportunity cost and a political cost if the council directs more resources into stormwater rather than another issue, such as wastewater overflows or fixing potholes. Alternatively the 90% standard may not be high enough. Different goals may require different standards and a series of steps making progress towards a long term goal with interim successes may be a constructive way of engaging the community and planning finances. There may be significant barriers, such as wastewater overflows, which mean swimming could only be achieved in catchments upstream of wastewater overflows, and resources should be focused initially in those areas, again to achieve a positive outcome to motivate further action.

Summary

It is clear from the literature review and the research findings that there is no single simple action that will achieve a widespread uptake of building-scale WSUD solutions. Some responsibility for stormwater impacts has to be taken by property owners together with a transfer of responsibility from the local authorities, requiring a change in the expectations of both individuals and institutions. This will take a combination of actions including: demonstration and pilot projects, incentives, policy changes, professional development and school education that creates strong connections with the local environment.

A mindset shift is needed if the waterways are to be valued sufficiently to motivate behaviour change but the funding required to implement change strategies requires political and therefore public will, creating a block to progress that will be difficult to overcome. Local community groups are already active in promoting both the problems and opportunities associated with stormwater improvement and are raising public and political awareness. The
increasing connection between the key decision-making organisations and community groups is a positive start to a long process of change, more difficult in the absence of drivers affecting the majority of residents at present. The experiences from other cities can be applied to Christchurch but will be most successful if adapted to make the most of local circumstances at the catchment or sub-catchment scale so that local residents and businesses can recognise the direct benefit improvements in stormwater can bring to them.

The SWS, WSS and LWRP provide a good foundation for changes to policy in the District Plan. In addition, Māori cultural traditions and values are increasingly influential in the city’s post-earthquake development, both through plan-making and providing buildings that demonstrate, albeit too discreetly, some of the building-scale WSUD technologies available to developers. Environmental education programmes, including those focused on stormwater, are available if funding can be increased. The streetscape rain gardens and larger devices in the newer subdivisions demonstrate what a change in mindset together with clear policies can achieve, but transition to a city that integrates WSUD more completely will require further leadership from CCC.
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Appendix A: Invitation to participate and consent form

Increasing the uptake of sustainable stormwater management options at the individual building-scale in Christchurch

Dear Sir/Madam

Information Sheet for potential interviewees

I am a Master’s Student and I am investigating whether the installation of stormwater management options that increase re-use, infiltration and evapotranspiration of rainwater at the individual building-scale could improve waterway quality and reduce flood risk. To understand the current low rate of uptake of building-scale stormwater management options, such as rainwater harvesting tanks, permeable paving systems, and rain gardens, I would like to interview a wide range of stakeholders from those involved in the planning, design and construction of commercial and residential buildings, to end users and others with a financial interest in property such as developers, home owners and insurance industry representatives.

I am interested in your knowledge, opinion, and/or personal experiences relating to stormwater management. I will be asking questions about:

- Perspective on water management for reduced environmental effects and flood mitigation – Whose responsibility? Importance? Viability of building-scale options to make a difference.
- Knowledge of building-scale stormwater management options and their individual benefits (or not)
- Barriers to building-scale WSUD – perceived and experienced
- Success stories

Please email or call me if you would like to take part in this study and I will contact you to arrange a convenient time and place where I can interview you. I anticipate the interview will take about 40 minutes. If you agree to participate in the study, please complete the consent form and return by email in advance or bring a completed form to the interview.

Following the interview I will provide you with an interview summary clearly indicating direct quotations. If you are willing for quotes to be attributed, a suitable form of words will be agreed with you, identifying either you personally and/or your organisation, or a
broad stakeholder group only (see attached form for further details). No comments will be attributed without permission.

I have NOT contacted your employer about your participation in this study. If relevant, please check with your employer if you think their approval is necessary.

Participation is voluntary and you have the right to withdraw at any stage without penalty. You may ask for your raw data to be returned to you or destroyed at any point. If you withdraw, I will remove information relating to you. However, from mid-October 2018 it will become increasingly difficult to remove the influence of your responses from the analysis of all interview responses.

The results of the project may be published. The final thesis will be a public document and will be available through the UC Library. However, you may be assured of the complete confidentiality of data gathered in this investigation: your identity will not be made public without your prior consent. To ensure anonymity and confidentiality, your name and other identifying details will be removed from your interview transcript and replaced with a code. Paper copies for the researcher’s use will only be made once the transcripts are anonymised. A list of codes and interviewee details will be kept in separate folders and stored on the researcher’s password protected Google Drive account and personal UC account for the researcher’s use only. On completion of the thesis the data will be removed from Google Drive but stored long term (5 years) in separate files on the UC server. After 5 years all transcript records will be deleted.

Please indicate on the consent form if you would like to receive a copy of the summary of results of the project.

The project is being carried out as a requirement for a Master of Water Resource Management by Vicky Southworth (contact details above), under the supervision of Professor Eric Pawson, who can be contacted at eric.pawson@canterbury.ac.nz. He will be pleased to discuss any concerns you may have about participation in the project.

This project has been reviewed and approved by the University of Canterbury Human Ethics Committee, and participants should address any complaints to The Chair, Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz).

Yours faithfully
Increasing the uptake of sustainable stormwater management options at the individual building-scale in Christchurch

Consent Form for interview participants

☐ I have been given a full explanation of this project and have had the opportunity to ask questions.

☐ I understand what is required of me if I take part in the research.

☐ I understand that participation is voluntary and I may withdraw at any time without penalty. Withdrawal of participation will also include the withdrawal of any information I have provided should this remain practically achievable.

☐ I understand that any information or opinions I provide will be kept confidential to the researcher and that any published or reported results will not identify the participants or their organisations, unless specific consent for quotation attribution has been provided (see additional form).

☐ I understand that a thesis is a public document and will be available through the UC Library.

☐ I understand that all data collected for the study will be kept in password protected electronic form and will be destroyed after five years. Paper copies of interview transcripts will only be printed once anonymized and will be for the researcher’s use only.

☐ I understand that I can contact the researcher (Vicky Southworth – details above) or supervisor Professor Eric Pawson (eric.pawson@canterbury.ac.nz) for further information. If I have any complaints, I can contact the Chair of the University of Canterbury Human Ethics Committee, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz).

☐ I would like a summary of the results of the project.

Signed:

Name: Click here to enter text. Date: Click here to enter text.

Email address: Click here to enter text. Phone number: Click here to enter text.

Please return the consent form to Vicky Southworth by email at vicky.southworth@pg.canterbury.ac.nz; or post to V. Southworth, c/o Waterways Centre for Freshwater Management, Private Bag 4800, Christchurch 8140