

**BUILDING BETTER
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whakamāhorahora

Recommendations for Future Research

Activating WSUD for Healthy Resilient Communities



Contestable fund research: Activating water sensitive urban design for healthy resilient communities

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Sue Ira, Jonathan Moores, Robyn Simcock, Chris Batstone

Activating WSUD for Healthy Resilient Communities: Recommendations for Future Research

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Sue Ira (Koru Environmental)

Jonathan Moores (NIWA)

Robyn Simcock (Manaaki Whenua Landcare Research)

Chris Batstone (Batstone Associates)

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Page 1 'word cloud' reflects statements made by workshop attendees at Water NZ Stormwater Conference 2019 Pre-Conference Workshop: 'Activating WSUD NZ – Sharing the Learnings'.



Manaaki Whenua
Landcare Research



Batstone
Associates



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1. Introduction

1.1 Background

The Building Better Homes Towns and Cities National Science Challenge (BBHTC) has funded the ‘Activating Water Sensitive Urban Design (WSUD) for healthy, resilient communities’ research project. The project has delivered research to enhance capability and address critical current barriers to the uptake of WSUD in New Zealand.

The project began in late 2017 with a “discovery phase” (Phase 1), which involved working with practitioners in workshops and via surveys to explore barriers to the adoption of WSUD in New Zealand. A wide range of barriers were identified (see Table 1), leading to recommendations for a programme of research that could help address these barriers¹.

Recognising the relatively limited duration of the project (approximately 18 months in total), the research design focused on the delivery of a series of ‘quick wins’ (Phase 2) while also identifying the need for a programme of longer-term research. The Phase 2 programme comprised three core research activities, three further discovery activities and two activities involving the enhancement and dissemination of existing information sources (see Figure 1). Collectively, these activities have produced evidence and tools to support WSUD uptake across two broad areas: firstly, to help make the business case for WSUD; and secondly, to help with the implementation of WSUD approaches in New Zealand.

Phase 2 of the project has been completed, with a range of research outputs delivered.

What is WSUD?

WSUD is an alternative to conventional forms of urban development. It aims to integrate urban planning and water management in order to better manage, for example, water supply security, water quality in natural waterbodies, flood risk and amenity values of waterbodies²⁻³. The following concepts are particularly evident in a New Zealand ‘understanding’ of what WSUD comprises⁴:

- *minimising impervious areas: WSUD aims to limit stormwater runoff and contaminant generation at source by minimising the construction of impervious surfaces, such as roads and roofs, through urban design techniques such as clustering and innovative streetscapes.*
- *minimising site disturbances: WSUD aims to limit earthwork volumes and extent through careful urban design which complements the existing landscape.*
- *creating or enhancing natural areas: WSUD aims to protect, enhance or restore natural areas as well maintaining the functioning of natural drainage systems, rather than replacing stream networks with piped systems.*
- *use of green infrastructure (GI): WSUD uses green technologies (wetlands, swales, rain gardens, green roofs, infiltration) instead of conventional hard infrastructure.*

¹ Moores, J., Batstone, C., Simcock, R. and Ira, S. (2018). Activating WSUD for Healthy Resilient Communities – Discovery Phase: Results and Recommendations. Research report to the Building Better Homes, Towns and Cities National Science Challenge.

² Mouritz, M., M. Evangelisti, and T. McAlister. 2006. Water sensitive urban design. In: T. Wong, ed., Australian Runoff Quality. Engineers Australia, Sydney, Australia, pp. 5-1–5-22.

³ Hoyer, J., W. Dickhaut, L. Kronawitter, and B. Weber. 2011 Water Sensitive Urban Design: Principles and Inspiration for Sustainable Stormwater Management in the City of the Future. Jovis, Berlin, Germany, p. 144.

⁴ For instance, in Auckland – see Lewis, M., J. James, E. Shaver, S. Blackbourn, A. Leahy, R. Seyb, R. Simcock, P. Wihongi, E. Sides, and C. Coste. 2015. Water Sensitive Design for Stormwater, Auckland Council Guideline Document GD2015/004. Auckland Council, Auckland, New Zealand, p.193.

Table 1 – WSUD barriers identified during Phase 1 of the project

Category	Theme	Examples of barriers
Value case	1. Knowledge of WSUD concepts, vision and benefits	Lack of awareness/buy-in to WSUD philosophy, including professional and community sectors.
	2. Precedents / evidence of WSUD performance and outcomes	Lack of NZ / local examples of WSUD delivering measurably better outcomes than conventional approaches.
	3. Economics	Perceived higher costs, lack of cost-benefit examples, lack of information around maintenance costs.
	4. Innovation stance	Institutional risk aversion to new methods.
	5. Māori cultural benefits	Business case failure to consider culturally-specific benefits of WSUD.
	6. Social, health and environmental co-benefits	Business case failure to consider amenity, health, climate adaptation and other co-benefits of WSUD.
	7. Political will / social licence	Lack of political leadership and/or community-led demand mandating the adoption of new development approaches. ‘Like for like’ replacement of infrastructure.
Implementation	8. Regulation, policy, planning, consenting and compliance	Ambiguity in regional and district plans, inflexible consenting processes preventing innovation. WSUD enabling development in inappropriate places (like wetlands, or in areas with highly sensitive receiving environments).
	9. Design and construction	Poorly designed and built systems leading to substandard performance or inactivation (e.g. no water entry or no ponding) or inevitable failure of WSUD devices.
	10. Maintenance	Maintenance poorly understood and delivered including lack of compliance monitoring and asset rejuvenation.
	11. Project lifecycle	Poor integration / hand-over between design/construction/operations. Responsibility for asset ownership and management unclear and/or poorly delivered.
	12. Funding and incentives	Lack of funding and/or incentives leads to continued adoption of business-as-usual approaches.
	13. Organisational culture	Poor collaboration between and within organisations, continuation of silo mentality in delivery of different functions.
	14. Capacity, training and guidelines	Lack of WSUD expertise or education for upskilling relevant professions, including construction and maintenance contractors.
	15. Competing mandates	WSUD trumped by infrastructural needs of other functions such as road safety and flood control.

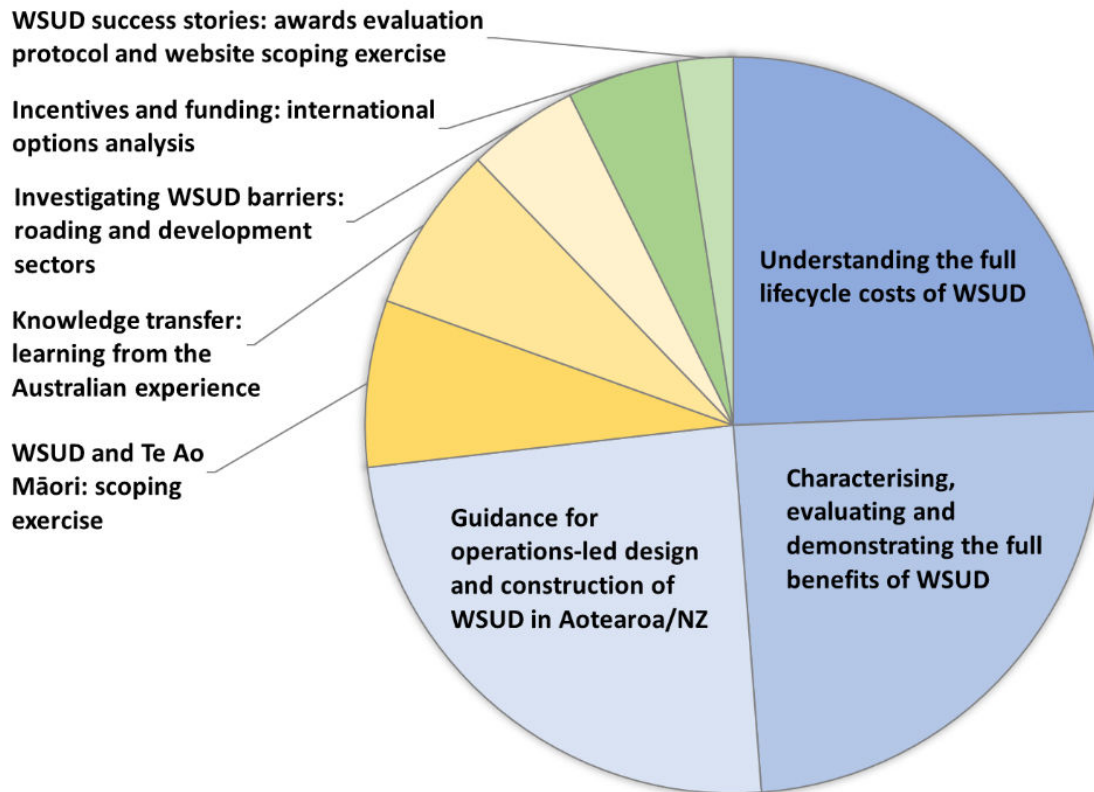


Figure 1 – Research design for Phase 2, showing approximate split of effort between core research activities (blue segments), further discovery activities (yellow) and enhancement and dissemination of existing information sources (green).

1.2 Report purpose and content

The purpose of this report is to reflect on progress made in meeting the research needs of WSUD’s community of practice and make recommendations on priorities for future research. Section 2 of the report provides a summary of the research outputs delivered under Phase 2 of the project. Section 3 presents a stocktake assessment, comparing the progress made against research needs identified in the first phase of the project. Section 4 makes recommendations for future research.

2. Research Summary

2.1 Introduction

Phase 2 of the project focused on the delivery of research in three 'core' research areas:

- Understanding the full lifecycle costs of WSUD;
- Characterizing, evaluating and demonstrating the full benefits of WSUD; and
- Providing guidance for low-maintenance-led design of WSUD.

Reflecting the very close links between these three themes, the research was conducted as an integrated exercise, in which a range of methods were used to investigate the topics concurrently. Those methods included field assessments, case studies, reviewing international literature and the development of tools and guidance material.

As well as these 'core' research activities, the project team also sought to continue to build the NZ knowledge base through further discovery and dissemination activities. These included visiting Melbourne to learn from the experience of practitioners and researchers on success factors in the implementation of WSUD in Australia. The project also initiated research to investigate how WSUD in Aotearoa values, recognizes, and provides for Te Ao Māori and how it could do better. Finally, the project has updated and made available information on financial methods for incentivizing WSUD.

The following sections provide a summary of each of these activities, grouped in accordance with the objectives of: (1) helping to make the business case for WSUD; (2) helping with the implementation of WSUD; and (3) further discovery.

2.2 Making the business case for WSUD

2.2.1 Costs

During the Phase 1 workshops, it became clear that a better understanding of the long-term maintenance and life cycle costs of WSUD in New Zealand was needed. A key component of the subsequent research has therefore been to better quantify maintenance costs via the collection of actual maintenance cost data for green infrastructure (GI) practices in New Zealand, as well as investigating how cost-effective WSUD is when compared with a conventional development approach⁵.

Cost data was collected from a total of 16 councils, consultants and contractors from around New Zealand. Existing life cycle cost models were refined and used to generate the most current indicative cost estimates for different WSUD practices in New Zealand. These life cycle costs will assist stormwater professionals in understanding the relative cost differences between different green infrastructure solutions.

This work was augmented by conducting a literature review to better understand international perspectives on the cost differential between WSUD and conventional approaches to stormwater management. The literature review highlighted that, in general, WSUD is a more cost-effective approach to land development than current conventional forms of development. It can result in significant savings on site preparation, earthwork costs, impervious area construction and piping. While some studies found landscaping costs can increase under a WSUD development, other studies have found these costs to be neutral or less than conventional development approaches when the landscaping components are integrated with GI. The review highlighted that maintenance costs of

⁵ Ira, S.J.T. and Simcock, R. (2019). Understanding costs and maintenance of WSUD in New Zealand. Research report to the Building Better Homes, Towns and Cities National Science Challenge.

green infrastructure practices are extremely variable, and that the quantum of cost is inextricably linked with GI design. However, because our knowledge around maintenance costs is scant, a significant part of the cost research focussed on the investigation of activities (and associated costs) relating to GI maintenance. An overview of the findings of this work is discussed in Section 2.3.1.

Overall, this component of the research has highlighted that while cost information is highly variable and difficult to obtain in a form which is usable and transferable, significant savings can be realised via the avoided costs of WSUD during the development phase. A detailed investigation into the Kirimoko Park Development in Wanaka highlighted that the developer saved, on average, 22% over a conventional development approach by using a WSUD approach to site design and stormwater management. Findings from this research can help to overcome the limitations of economic costing models which have historically focussed on life cycle stormwater costs incurred by a public operator, rather than considering the full range of avoided costs and cost efficiency. This need for a wider consideration of cost-related factors has been captured in the development of an integrated decision-making tool on costs and benefits of WSUD (see Section 2.2.3).

2.2.2 Benefits

The findings of Phase 1 of the project indicated that, without a better understanding of the full range of benefits of WSUD and ways to evaluate those benefits, making the business case for WSUD in New Zealand is likely to remain a significant challenge. Reflecting this need, one of the three core activities in Phase 2 of the project was the development of guidance for characterizing, evaluating and demonstrating the full benefits of WSUD. This involved reviewing international literature describing WSUD co-benefits and economic assessment methods and tools developed for WSUD practitioners overseas⁶.

The review found that the potential water-related benefits of WSUD, relative to conventional urban development approaches, are well documented. Typically, a successful WSUD project might be expected to deliver restored hydrology, improved water quality and healthier aquatic ecosystems. While there remain evidence gaps on the delivery of these outcomes, especially in New Zealand, monitoring and modelling methods for their assessment are well developed.

However, assessments of the benefits of WSUD that focus solely on these water-related outcomes are incomplete. Through the principles of working with nature and employing green technologies, WSUD has the potential to deliver a wide range of other co-benefits, in addition to those relating to water. Some of these are other (non-water) environmental benefits: for instance, the preservation of natural soils, microclimate moderation and terrestrial habitat provision. Others can be framed as social benefits, both water and non-water related. Water-related social benefits include the provision of supplementary water supplies and enhancement of opportunities for contact recreation. Non-water social benefits include public safety, property values and improved health and wellbeing deriving from the use of GI.

2.2.3 More Than Water assessment tool

In combination, the research activities described in Sections 2.2.1 and 2.2.3 demonstrated that conventional assessments of the costs and benefits of WSUD are incomplete. These findings prompted the research team to develop a 'quick win' method by which practitioners can take account of the wider-ranging benefit and cost considerations that might otherwise be excluded from a business-case assessment of a WSUD project. The name of the resulting 'More Than Water' (MTW)

⁶ Moores, J. and Batstone, C. (2019). Assessing the Full Benefits of WSUD. Research report to the Building Better Homes, Towns and Cities National Science Challenge.

assessment tool reflects the notion that WSUD can deliver multiple co-benefits and cost-related advantages, in addition to more familiar considerations associated with management of the hydrological and water quality effects of urban development.

The tool employs a qualitative assessment method that is easy to use and provides graphical demonstration of benefits and cost outcomes and how these might vary under different scenarios⁷. It is suited to screening level assessments and communication processes that involve both technically-familiar and lay audiences. Use of MTW involves making assessments of the level and importance of a series of benefits and costs criteria, along with the reliability of the assessment, drawing on guidance information provided with the tool. While assessments can rely on expert judgement, they can also be informed by the results of supporting analyses, such as hydrological modelling and life cycle cost calculations, where these are available. MTW represents each of these three aspects (level, importance, reliability) through differences in the length, width and colour intensity of sectors of a circle representing each benefit or cost criterion (Figure 2).

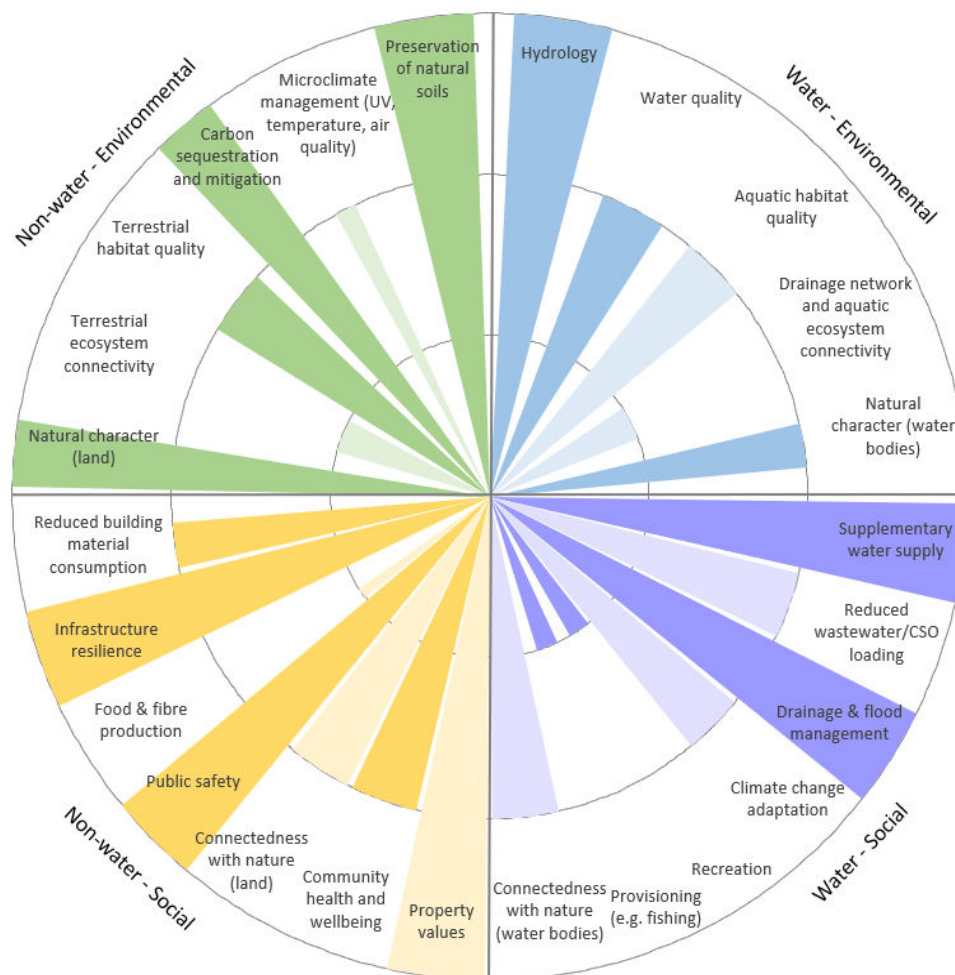


Figure 2 - MTW tool: output of an illustrative assessment of WSUD benefits

Typically, use of the tool will involve comparing an assessment of the benefits and costs of a WSUD project with those of some alternative, such as a 'business as usual' scenario employing conventional

⁷ Moores, J., Ira, S., Batstone, C. and Simcock, R. (2019). The 'More than Water' WSUD Assessment Tool. Research report to the Building Better Homes, Towns and Cities National Science Challenge.

development practices. This approach has been demonstrated through the application of the MTW tool in three case studies: Kirimoko Park residential subdivision, the AMETI transport project and Talbot Park Community Renewal project. In all three cases, the use of the tool demonstrated that a WSUD approach delivers a greater range and level of benefits and performs better across a range of cost outcomes.

2.3 Helping the implementation of WSUD

2.3.1 Designing for low-maintenance

The project's third core research activity has addressed another leading barrier identified in Phase 1, the perception of WSUD as a high-maintenance alternative to conventional stormwater management. Because this research activity has focused on functional and operational aspects of WSUD that influence maintenance effort, it was closely linked with the cost-related research described in Section 2.2.1.

As part of this component of the research, guidance on the likely maintenance activities, frequencies and costs for different GI practices have been developed⁸. These take into account different objectives: delivering high amenity (high frequency maintenance); delivering good functionality; and a 'bare minimum' level of care. This three-fold approach acknowledges that the two key drivers of maintenance costs are the frequency of the maintenance and the unit cost of the activity. While the bare minimum approach provides for the lowest maintenance frequency, the unit rates for this level of maintenance are higher than those for the amenity and functional levels. The reason for this is that it takes a maintenance person longer to weed, remove litter, landscape and maintain vegetation every 6 months than if they were doing it monthly or bi-monthly, as the level of weed infestation and sediment /litter accumulation is likely to be far greater. The 'bare minimum' also has a higher risk of much more expensive remedial works being required. As a result of these various influences on maintenance costs, the research has found that a 'bare minimum' approach can be less cost-effective than the 'functional' approach.

Factsheets summarising the key factors which influence maintenance costs, along with tips for on-going maintenance have been developed. The team also produced assessment and hand-over checklists to identify the most common design features that are linked to efficient, less frequent maintenance. Conversely, this guidance material also identifies features and defects in design or construction that inflate maintenance costs. The checklists aim to help reduce the number of defective devices that are accepted by Councils.

2.3.2 Funding and incentivising uptake

It has long been acknowledged in New Zealand that there are significant challenges in securing funds for stormwater operators to address the cost of maintaining desired levels of service, and for planning for future growth while meeting community aspirations to maintain or enhance the quality of the environment. Across New Zealand, the estimated cost of renewing the three waters network (wastewater, potable water and stormwater assets) is in the order of \$30 billion to \$50 billion over the next 15 years⁹. Local Government New Zealand has identified that property rates (the primary

⁸ Ira, S.J.T. and Simcock, R. (2019). Understanding costs and maintenance of WSUD in New Zealand. Research report to the Building Better Homes, Towns and Cities National Science Challenge.

⁹ National Infrastructure Unit. (2015). The Thirty Year New Zealand Infrastructure Plan 2015: <http://www.infrastructure.govt.nz/plan/2015>

funding mechanism for stormwater infrastructure across New Zealand) are not the best and only tool to address the funding challenges which are facing local authorities¹⁰.

Building on previous studies, a literature review was conducted to identify alternative funding options that are or could be used in New Zealand under the Local Government Act 2002 and Local Government Rating Act¹¹. The review also investigated how where and how successfully these mechanisms have been applied in cities around the world. The review found that application of a runoff-based stormwater fee is a common means of funding stormwater services in the United States, Canada, United Kingdom and Europe. Additionally, many of the cities within these localities also include incentive-based fee credits/savings to promote behaviour change and incentivise the use of green infrastructure. The “Cap and Trade” approach (i.e. a quantity-based market instrument that restricts the total allowable level of emission, allocates this level among individuals as allowances, and permits the transfer of these allowances through free trade) is also commonly used in the United States.

It is evident from the review that there is no silver bullet which can solve the funding gap facing councils and network operators in New Zealand. Rather, a toolbox approach to funding is needed with funding strategies guided by five principles:

- **Sufficiency:** The need to secure adequate funds to renew existing infrastructure, improve service levels consistent with public priorities, and provide for growth.
- **Certainty:** The need to ensure that sufficient funds will be available when required.
- **Equity:** The principle of exacerbator (polluter) pays, i.e. those that generate additional demand for stormwater services (e.g. in relation to the extent of impervious surfaces connected to the stormwater network) should significantly contribute to its provision. This includes commercial properties, road users and developers.
- **Efficiency:** The principle that a funding mechanism should provide incentives for behaviour consistent with the goal of reducing stormwater volumes and contaminant to levels that achieve the desired environmental and social outcomes.
- **Acceptability:** The likelihood that the recommended strategy would be politically acceptable.

The main premise behind any funding strategy is that of “polluter-pays”. A key funding principle is that while the whole community may benefit from stormwater infrastructure, the people who generate the effect should be required to pay to mitigate it. Furthermore, the international experience clearly demonstrates that effective implementation of WSUD requires that the funding strategy encompass fee credits and/or programme incentives to assist in creating behavioural change within the community and increase awareness of stormwater effects.

2.4 Continued discovery activities

2.4.1 Melbourne study tour

Members of the project team visited Melbourne in late November 2018 to learn about the WSUD characteristics, activating factors and implementation approaches that have delivered successful WSUD projects in Australian cities. The team met with researchers and practitioners from a wide range of disciplines as well as seeing many examples of the practical application of WSUD through

¹⁰ National Council of Local Government New Zealand. (2015). Local government funding review – 10 point plan: incentivising economic growth and strong local communities.

¹¹ Ira, S.J.T. (2019). Incentives and Funding: an international literature review and recommendations for New Zealand. Research report to the Building Better Homes, Towns and Cities National Science Challenge.

the city. Meetings held at the Cooperative Research Centre for Water Sensitive Cities (CRCWSC), based at Monash University, and Melbourne Water, the city's principal three-waters agency, covered a wide range of topics, including:

- The development of benefit-cost assessment methods and tools;
- Strategies for transitioning to water sensitive cities;
- Understanding social influences on community engagement and uptake of water sensitive behaviours.
- An incentives scheme for promoting WSUD uptake by local councils (The Living Rivers programme);
- Stormwater strategic planning and regulatory activities, including ongoing challenges facing WSUD implementation across Melbourne; and
- Capacity building in Melbourne's water management sector (delivered by a dedicated team: Clearwater).

In addition, the team were taken by Melbourne University researchers on a tour of the Little Stringybark Creek catchment, the location of a long-established research project to investigate environmental outcomes in response to the retrofitting of GI devices in a suburban neighbourhood.

While important to note the difference in context between Melbourne and NZ, with WSUD in Melbourne primarily driven by a need for drought security, the project team reported on a range of success factors that may be influential in activating uptake in New Zealand¹². These include: the importance of engaged leadership the highest levels of public agencies; collaborative and co-ordinated approaches between agencies; the use of incentives schemes; and a significant effort in industry engagement and capacity building.

Despite widespread success in the implementation of WSUD, the team also found that Melbourne continues to face a number of challenges, some of which New Zealand practitioners are very familiar with. They include an aversion to WSUD among sectors of the development community and some local councils and problems with the consenting regime. Melbourne researchers are also investigating issues around the social equity of WSUD, recognising that the market appeal of WSUD gives the potential to result in locale gentrification and its uneven implementation among different socio-economic groups.

2.4.2 Te Ao Māori and WSUD

The Activating WSUD project has also started to investigate how WSUD in Aotearoa values, recognizes, and provides for Te Ao Māori, and how it could do better. A comprehensive literature review¹³ has been conducted, finding that the principles of WSUD closely mirror Te Ao Māori values. Rather than trying to integrate Te Ao Māori, the review emphasised the need to recognise that WSUD and its intended outcomes already draw upon fundamental Māori values – for example: whakapapa, whanaungatanga, kaitiakitanga, manaakitanga, and mātauranga māori.

Building on this work, the project team has begun to investigate ways to make consideration of Te Ao Māori values an inclusive part of any WSUD assessment through the on-going development of the MTW tool described in Section 2.2.3.

¹² Activating WSUD (2018). Activating WSUD for Healthy, Resilient Communities Study trip to Melbourne, November 2018 – Findings. Research report to the Building Better Homes, Towns and Cities National Science Challenge.

¹³ Afoa, E. and Brockbank, T. (2019). Te Ao Māori and Water Sensitive Urban Design. Research report to the Building Better Homes, Towns and Cities National Science Challenge.

3. Stocktake of research progress

This section reviews progress in addressing research needs identified through the discovery phase of the Activating WSUD project. Table 2 summarises those needs, responses to meeting those needs, action taken to date, and the further work required¹⁴. As well as considering the extent to which the ‘quick win’ research activities of the past 12 months have met needs identified during Phase 1, this stock take also takes account of views of WSUD stakeholders expressed at a recent workshop on the project’s findings¹⁵ and knowledge of other WSUD research and training activities in progress.

The summary presented in Table 2 indicates that the range of ‘quick win’ research identified for Phase 2 has largely been delivered as planned and that the anticipated longer-term research needs remain relevant. This is the case in relation to:

- the development of WSUD approaches that embrace and cater for Te Ao Māori (A);
- recognising and rewarding WSUD success stories (C);
- updating lifecycle cost databases and models (D);
- developing and providing guidance on methods for CBA/CEA (E);
- designing and implementing a plan for long-term monitoring and evaluation of WSUD (I); and
- implementing ways of promoting change toward more water sensitive practice among professionals and in and between organisations (K).

In certain cases, the research activities of the past 12 months and further engagement with WSUD stakeholders have highlighted alternative or additional elements to the scope of these longer-term research needs. These include the following:

- guidance on methods for retrofitting green infrastructure in areas of existing development, for instance as part of brownfield redevelopment projects (G);
- scoping out how NZ central and local government could act on the alternative funding and incentive options (H)
- including consideration of the potential for climate change adaptation and mitigation in assessments of WSUD benefits (J);
- developing transitioning strategies, institutional and governance arrangements and methods for promoting behaviour change in the NZ context (L).

In addition, further engagement with WSUD stakeholders¹⁶ has also added to the scope of other (non-research) activities identified in Table 2. These include:

- the need to build industry capacity to better reflect Te Ao Māori values in WSUD design and implementation and improved models for including Māori in decision-making and governance (A); and
- the need for a media strategy to raise awareness of WSUD and build political will for a change to urban development practices (C).

¹⁴ This updates a similar table (Table 3) in: Moores, J., Batstone, C., Simcock, R. and Ira, S. (2018). *Activating WSUD for Healthy Resilient Communities – Discovery Phase: Results and Recommendations*. Research report to the Building Better Homes, Towns and Cities National Science Challenge.

¹⁵ Activating WSUD pre-conference workshop at Water NZ Stormwater 2019 Conference, 30 April 2019, Auckland.

¹⁶ Water New Zealand Stormwater Conference 2019: Pre-conference workshop on ‘Activating WSUD in NZ – sharing learnings’

Table 2 – Responses to the findings from the Phase 1 WSUD surveys and workshop. A stocktake of progress made in Phase 2 and implications for future research needs are shown in italics.

Response to findings from discovery phase (Phase 1)	Theme															Description of responses, with rationale <i>and reflection on Phase 2 progress and future research needs</i>		
	Knowledge	Evidence	Economics	Innovation	Cultural	Co-benefits	Politics	Regulation	Design	Maintenance	Lifecycle	Incentives	Organisations	Capacity	Comp. mandates	Phase 2 quick wins	Longer-term research	Other (non-research)
(A) Targeted engagement with Māori stakeholder groups, leading to development of WSUD approaches that embrace and cater for Te Ao Māori	x	x			x	x			x			x	x	x		Required to address major gap in discovery phase – the need to develop an understanding of the extent to which WSUD does and could further deliver culturally-specific benefits. Engage with key Māori practitioners to scope a research and engagement plan for the development of guidance on Aotearoa-specific forms of WSUD and evaluation methods that incorporate mātauranga Māori.	Acting on the scope developed in Phase 2, engage, research and develop guidance for Aotearoa-specific forms of WSUD and evaluation methods that incorporate mātauranga Māori.	Multi-party implementation of guidance when consulting on, planning, designing and operating WSUD.
																<i>Stocktake: Research to address this gap has been initiated with a literature review of relationships between Te Ao Māori and Water Sensitive Urban Design¹⁷. This provides a platform for a wider programme of engagement and research, leading to the development of design and evaluation methods that incorporate mātauranga Māori. Refer to Section 4 for detailed recommendations on future research. In addition, WSUD stakeholders have identified the need to build industry capacity to better reflect Te Ao Māori values in WSUD design and implementation and improved models for including Māori in decision-making and governance.</i>		
(B) Targeted engagement with roading and development (public and private) sectors	x			x					x	x	x		x	x	x	Required to address major gap identified in discovery phase – the need to develop an understanding of the relative influence of other mandates in determining the actions of these sectors. Audit relevant WSUD examples and review codes of practice. Present to roading and development sectors, respectively, as a means of initiating discussion and eliciting feedback at targeted workshops.	Acting on the findings from Phase 2, conduct targeted partner research e.g. on materials and methods, value chain analysis, commercial models.	Ongoing actions to raise WSUD profile. WSUD community to actively engage with these sectors via professional meetings etc. Establish champions from within these sectors.
																<i>Stocktake: These themes were investigated through discussions with the development and transport sectors as part of the Kirimoko Park and AMETI case studies. These case studies highlight key barriers and successes and provide evidence for the development of business cases. There remains a need for wider engagement with the development community, to disseminate evidence on the benefit-cost case for WSUD and promote behaviour change.</i>		

¹⁷ Afoa, E. and Brockbank, T. (2019). Te Ao Māori and Water Sensitive Urban Design. Research report to the Building Better Homes, Towns and Cities National Science Challenge.

Response to findings from discovery phase (Phase 1)	Theme															Description of responses, with rationale <i>and reflection on Phase 2 progress and future research needs</i>		
	Knowledge	Evidence	Economics	Innovation	Cultural	Co-benefits	Politics	Regulation	Design	Maintenance	Lifecycle	Incentives	Organisations	Capacity	Comp. mandates	Phase 2 quick wins	Longer-term research	Other (non-research)
(C) Recognise WSUD success stories: Establish and promote web-based database and awards systems for successful examples of NZ WSUD implementation.	x	x			x	x			x	x					x	Helps build capacity and provides hub for WSUD community. Can be initiated immediately and added to over a longer time frame. Resurrect the LIUDD case study database and scope enhancements, for instance: linking to walking tour examples from the Phase 1 workshops; developing an awards system and linking to cost database.	Acting on the scope developed in Phase 2, build, populate and promote an enhanced NZ WSUD case study website.	Requires long-term ownership by identified parties in WSUD community to maintain, update and promote it.
																<i>Stocktake: The Activating WSUD project web page¹⁸ hosts all of the research outputs: reports, tools, case studies, walking tours and maintenance guidance material. The case studies pay special attention to identifying WSUD successes and missed opportunities. There remains scope for a dedicated website hosted by a national agency responsible for promoting WSUD, with on-going resourcing to maintain and update the website. This same agency/website would be the ideal host for an awards system and programme of public engagement. WSUD stakeholders have identified the need for a media strategy to raise awareness of WSUD and build political will for a change to urban development practices.</i>		
(D) Update lifecycle cost databases and models, including data on maintenance and avoided costs. Model case studies including avoided costs.	x	x	x						x	x	x				x	Compilation of the database builds on well-progressed work in this space and addresses a high frequency theme. Through interrogation of existing costs database and the inclusion of data to address key gaps (maintenance costs, avoided costs), derive guidance on unit costs (e.g. dollar per square metre, dollar per kg sediment retained) of implementing WSUD relative to conventional approaches.	Using the updated database, model case studies including actual and planned WSUD developments to demonstrate cost differential when the full range of costs are considered (novel research). Regularly collate additional cost data and review models accordingly. Liaise with the NZ Asset Metadata Standards to determine protocols for collecting, storing and analysing acquisition and maintenance cost data as part of the public network asset data management standards for NZ.	Requires long-term updating of cost databases and could be linked to the WSUD “hub” above.
																<i>Stocktake: Cost databases and life cycle cost models have been updated and applied in case studies to demonstrate the cost effectiveness of WSUD¹⁹. These have informed the development of the More Than Water assessment tool (see ‘H’ below). There remains a need to ground truth the costing models with data from further WSUD projects and to update the costing database at regular intervals. Refer to Section 4 for detailed recommendations on future research.</i>		

¹⁸ <https://www.landcareresearch.co.nz/science/living/cities-settlements-and-communities/water-sensitive-urban-design>

¹⁹ Ira, S.J.T. and Simcock, R. (2019). Understanding costs and maintenance of WSUD in New Zealand. Research report to the Building Better Homes, Towns and Cities National Science Challenge.

Response to findings from discovery phase (Phase 1)	Theme															Description of responses, with rationale <i>and reflection on Phase 2 progress and future research needs</i>		
	Knowledge	Evidence	Economics	Innovation	Cultural	Co-benefits	Politics	Regulation	Design	Maintenance	Lifecycle	Incentives	Organisations	Capacity	Comp. mandates	Phase 2 quick wins	Longer-term research	Other (non-research)
(E) Develop and provide guidance on methods for CBA/CEA, including assessment of indirect benefits	x	x	x			x						x		x		Assembling and reviewing information on existing methods draws on well-developed familiarity of this topic area. Characterise the full range of benefits of Aotearoa/NZ WSUD and provide a critical analysis of the methods for assessing these benefits. Liaise with CRC for Water Sensitive Cities to gain insights from Australian research in this area.	Developing tools for implementing comprehensive CBA / CEA is a significant research undertaking, but a key part of a longer-term research programme.	
	<p><i>Stocktake: Guidance on benefits assessment methods have been reviewed²⁰ and the More Than Water tool developed as a quick win method (see 'H' below) for screening level assessments of the benefits and costs of WSUD projects. There remains a need to enable robust, quantitative assessments of benefits. This involves conducting NZ benefits valuation studies and exploring the transfer and customisation of benefits assessment methods and tools developed overseas. Refer to Section 4 for detailed recommendations on future research.</i></p>																	
(F) Review effectiveness of WSUD-related plans and regulations.				x		x	x	x						x				Central/local government to review existing RMA plans to develop policy and planning guidance, including on NPS, regional plan and district plan cohesiveness. Implementation of best practice guidelines by councils. Regular review of effectiveness of provisions could be co-ordinated at central government level.
	<p><i>Stocktake: WSUD stakeholders have identified that there remains a pressing need for a review of relevant statutes and regulations (e.g. Building Act, Resource Management Act, Local Government Act) to investigate potential improvements to address barriers arising poor alignment and implementation.</i></p>																	

²⁰ Moores, J. and Batstone, C. (2019). Assessing the Full Benefits of WSUD. Research report to the Building Better Homes, Towns and Cities National Science Challenge.

Response to findings from discovery phase (Phase 1)	Theme															Description of responses, with rationale <i>and reflection on Phase 2 progress and future research needs</i>		
	Knowledge	Evidence	Economics	Innovation	Cultural	Co-benefits	Politics	Regulation	Design	Maintenance	Lifecycle	Incentives	Organisations	Capacity	Comp. mandates	Phase 2 quick wins	Longer-term research	Other (non-research)
(G) Investigate and develop NZ/regional guidance on WSUD design, maintenance and lifecycle planning, including both greenfield and brownfield settings.	x							x	x	x	x				x	Reviews (documents and in the field) of NZ regional design and maintenance practices draws on well-developed familiarity of this topic area. Involves: (1) conducting field 'training and assessment' workshops in up to three regions (esp. where limited exposure to WSUD to date), to reveal and resolve specific local issues; and (2) Reviewing guidelines and practice in relation to role of WSUD in brownfields development and/or stormwater retrofits/upgrades.	A longer-term programme can extend the reviews to cover additional regions / contexts. Regular updates of design and maintenance 'living document' guidelines to enable practitioners to be informed of evolving best practice.	Multi-party implementation of guidance in planning, designing and maintaining WSUD.
	<p><i>Stocktake: Assessments of maintenance practices and related design characteristics have been completed as part of the case studies, leading to guidance for design and maintenance at varying levels of service²¹. Site tours and checklists have been produced to help disseminate this guidance. WSUD stakeholders have identified that there remains a particular need for guidance on methods for retrofitting green infrastructure in areas of existing development, for instance as part of brownfield redevelopment projects. Refer to Section 4 for detailed recommendations on future research.</i></p>																	
(H) Review and provide guidance on potential options for incentivising uptake of WSUD and potential alternative funding mechanisms for WSUD implementation	x	x	x	x			x	x				x			x	Review of international incentives and funding mechanisms can build on previous work to collate and evaluate US/European approaches, with input from workshop participants involved in this work. Liaise with CRC for Water Sensitive Cities to gain insights from Australian research in this area.		Implementation by councils and/or central government.
	<p><i>Stocktake: A review of international literature on alternative funding mechanisms and incentives has been completed²². Work is now needed to scope out how NZ central and local government could act on these options (refer to Section 4), with a particular focus around the use of incentives in New Zealand to accelerate uptake of WSUD.</i></p>																	

²¹ Ira, S.J.T. and Simcock, R. (2019). Understanding costs and maintenance of WSUD in New Zealand. Research report to the Building Better Homes, Towns and Cities National Science Challenge.

²² Ira, S.J.T. and Batstone, C. (2019). Incentives and Funding: an international literature review and recommendations for New Zealand. Research report to the Building Better Homes, Towns and Cities National Science Challenge.

Response to findings from discovery phase (Phase 1)	Theme															Description of responses, with rationale <i>and reflection on Phase 2 progress and future research needs</i>		
	Knowledge	Evidence	Economics	Innovation	Cultural	Co-benefits	Politics	Regulation	Design	Maintenance	Lifecycle	Incentives	Organisations	Capacity	Comp. mandates	Phase 2 quick wins	Longer-term research	Other (non-research)
(I) Design and implement plan for long-term monitoring and evaluation of WSUD across multiple indicators.	x	x	x		x	x					x			x	x	Plan design only. Sets out a co-ordinated approach to gathering the essential evidence to support WSUD uptake. On-going engagement in phases 2/3 provide vehicle for multi-stakeholder input.	Implementation of the monitoring plan is likely to take years to decades, depending on indicators. Results should be regularly and reviewed reported, allowing revisions to programme over time.	Feeds into the review, revision and implementation of WSUD policy, plans, design, maintenance and guidance.
																<i>Stocktake: WSUD stakeholders have reaffirmed the critical need for evidence on the performance of WSUD. Externally to the Activating WSUD project, long-term field studies for assessing WSUD performance and outcomes have been proposed at locations near Hamilton and Auckland, and these are expected to commence in the near future. These studies need to be appropriately supported and resourced to enable them to be of sufficient duration and spatial extent to generate meaningful datasets to build the WSUD evidence base. Multi-party collaborations (central government, local government, iwi, research organisations etc) are likely to be the most effective way of supporting and steering these studies to maximise their value. In addition, similar field studies should be established in other parts of New Zealand (especially the South Island) to investigate the performance of WSUD under different environmental conditions (e.g. soils and climate). Refer to Section 4 for detailed recommendations on future research.</i>		
(J) Develop and apply software models and assessment tools to demonstrate the contrast in outcomes between WSUD and conventional approaches across multiple indicators.	x	x	x		x	x	x							x		Assemble summary / review of existing tools, building on well-progressed familiarity with this topic. Review international examples (e.g. SuDS tool, UK) and liaise with CRC for Water Sensitive Cities to gain insights from Australian research in this area.	Developing and applying models and tools for conducting assessments of WSUD outcomes is a key part of a longer-term research programme. Some tools are ready for application in case studies while others will emerge or evolve as the evidence base on WSUD improves.	
																<i>Stocktake: Tools for benefits assessment methods have been reviewed²³ and the More Than Water tool developed as a quick win method²⁴ for screening level assessments of the benefits and costs of WSUD projects. There remains a need to enable robust, quantitative assessments of benefits. This involves conducting NZ benefits valuation studies and exploring the transfer and customisation of benefits assessment methods and tools developed overseas. WSUD stakeholders have also identified the need for assessments of WSUD performance to consider potential benefits for climate change adaptation and mitigation, for instance through scenario modelling. Refer to Section 4 for detailed recommendations on future research.</i>		

²³ Moores, J. and Batstone, C. (2019). Assessing the Full Benefits of WSUD. Research report to the Building Better Homes, Towns and Cities National Science Challenge.

²⁴ Moores, J., Ira, S., Batstone, C. and Simcock, R. (2019). The 'More than Water' WSUD Assessment Tool. Research report to the Building Better Homes, Towns and Cities National Science Challenge.

Response to findings from discovery phase (Phase 1)	Theme															Description of responses, with rationale <i>and reflection on Phase 2 progress and future research needs</i>		
	Knowledge	Evidence	Economics	Innovation	Cultural	Co-benefits	Politics	Regulation	Design	Maintenance	Lifecycle	Incentives	Organisations	Capacity	Comp. mandates	Phase 2 quick wins	Longer-term research	Other (non-research)
(K) Investigate and implement ways of promoting change toward more water sensitive practice among professionals and in and between organisations	x			x			x					x	x	x	x	Liaise with CRC for Water Sensitive Cities to gain insights from Australian research in this area. Scope methods (new research and/or knowledge transfer from Australia) for the development of guidance on activating change in NZ professions and organisations.	Acting on the scope developed in Phase 2, engage, research and develop guidance on activating change in relation to Aotearoa-specific forms of WSUD.	Relies on stakeholder organisations to implement this. Could involve establishing disciplinary champions and multi-disciplinary / organisational exemplars.
	<p><i>Stocktake: Engagement with staff involved in the delivery of Melbourne’s Clearwater programme has provided information on approaches and resources for industry capacity building²⁵. The Activating WSUD team have been involved in a WaterNZ training initiative in Auckland. WSUD stakeholders have identified a need to fund wider industry training and capacity building to promote WSUD uptake by professionals involved in the development sector.</i></p>																	
(L) Investigate and implement ways of promoting stronger support for water sensitive practice amongst decision-makers and broader society	x				x	x	x					x	x	x	x	Liaise with CRC for Water Sensitive Cities to gain insights from Australian research in this area. Scope methods (new research and/or knowledge transfer from Australia) for the development of guidance on activating a ‘social licence’ for WSUD.	Acting on the scope developed in Phase 2, engage, research and develop guidance on activating change in relation to Aotearoa-specific forms of WSUD.	Relies on the buy-in of politicians, communities and the market.
	<p><i>Stocktake: Engagement with researchers at the CRCWSC has provided information and insights into transitioning strategies, institutional and governance arrangements and methods for promoting behaviour change. WSUD stakeholders have identified a need to explore these topics further in the NZ setting in order to better enable and/or obligate WSUD uptake.</i></p>																	

²⁵ Activating WSUD (2018). Activating WSUD for Healthy, Resilient Communities Study trip to Melbourne, November 2018 – Findings. Research report to the Building Better Homes, Towns and Cities National Science Challenge.

4. Recommendations for future research

4.1 Introduction

This section sets out recommendations for future research, reflecting the results of the stocktake described in the previous section and drawing on assessments of knowledge gaps made in the Phase 2 research reports. This is not intended to prescribe a single programme of research to be implemented by any one group of researchers nor to be funded by any particular entity. Rather, it is a broad sweep of continuing needs aimed at helping guide the development of research projects and funding applications by any parties interested in improving the evidence base and guidance for implementation of WSUD in Aotearoa New Zealand. No particular priority is assigned to any of these recommendations.

4.2 Te Ao Māori and WSUD

With the aim of better recognising and providing for Māori values in the delivery of WSUD projects, the following research activities are recommended:

- Build on the 'Toolkit For Kaumātua Housing'²⁶ presented at the Shift Aotearoa Conference 2019, to provide guidance on incorporating GI in papakāinga developments. This would aim to empower Māori in their role as kaitiaki, through developing guidance, demonstration studies and upskilling Māori housing practitioners and communities.
- Evaluate a range of WSUD case studies for the degree to which each project incorporates Te Ao Māori. These case studies can serve as reference projects illustrating good and bad practice, informing the design of future projects and the wider building of industry capacity.
- Review international literature to identify examples where indigenous knowledge and alternate worldviews have been successfully integrated into mainstream WSUD.
- Engage widely to build a wider research team and better understand WSUD's actual and potential role from varied perspectives, from Māori individuals and communities both within and outside the urban water management sector.
- Continue to explore how the MTW tool can be developed further to provide for WSUD assessments to consider Te Ao Māori values, noting that the aim of the further development of MTW is not to integrate western and Te Ao Māori world views, but rather to allow an inclusive assessment that considers both perspectives.

4.3 Costs and maintenance

With the aim of continuous improvement of cost information to help reduce uncertainty in business case assessments, the following research activities are recommended:

- Survey local councils and stormwater utility operators to ground truth the maintenance model framework. Specifically, a project could be set up with 3 or more councils to:
 - understand their existing maintenance processes and costs;
 - develop a maintenance model for trialling on GI devices which they maintain; and

²⁶ Rangimahora Reddy (2019). Presentation on 'He Kāinga Pai Rawa Atu Mō Ngā Kaumātua: He Keteparaha Tēnei Mō Te Whare Kaumātua / A Really Good Home For Our Kaumātua: A Toolkit For Kaumātua Housing'. The Shift Aotearoa Conference 2019, 5–7 June 2019, Wellington.

- track and document costs associated with the trial to compare with existing processes.
- Further refine the cost assessment criteria within the MTW tool. Specifically, the impact of green infrastructure on housing affordability needs to be further investigated and quantified at the house lot scale. Seek feedback from WSUD practitioners on the value and usability of the cost assessment criteria within the MTW tool.
- In accordance with requests from councils around New Zealand, update the existing COSTnz life cycle cost model to include the information assembled in Phase 2 of this project and make it available to the New Zealand stormwater community again.

4.4 Benefits

With the aim of conducting comprehensive assessments of GI benefits to improve the robustness of business case assessments, the following research activities are recommended:

- Seek feedback from WSUD practitioners on the utility of the MTW tool, especially on the most challenging aspects of assessing benefits to guide the setting of priorities for research to develop underlying assessment methods.
- Survey representatives of regional and local councils to investigate decision-makers' requirements and attitudes towards methods that involve the monetization of benefits.
- Conduct comprehensive assessments of overseas benefits assessment tools (the UK BEST tool and the benefit-cost tool under development by the CRCWSC Australia) for their potential application in New Zealand. This would involve exploring the scope of any customization needs.
- Take opportunities provided by WSUD projects to conduct benefits valuation studies, contributing to the development of an NZ database for use in benefits assessments (for instance by providing the customization data sought for the recommendation above).
- Explore the potential of public health economics to contribute to a more comprehensive assessment of the benefits of WSUD/GI (i.e. via its influence on the incidence of mental and chronic health conditions).

4.5 GI design and construction

With the aim of enabling the more widespread adoption and greater effectiveness of GI devices, the following research activities are recommended:

- Investigate the viability and relative performance of green infrastructure as an option for retrofitting stormwater controls in areas of existing development, as an alternative to hard engineering solutions. Provide guidance on viable methods, for instance as part of brownfield redevelopment projects.
- Investigate the role of large trees and soil amendments in general landscaping areas to contribute to stormwater mitigation and wider benefits.

4.6 Performance and evaluation

With the aim of building an evidence base on the actual and potential performance of WSUD under current and projected environmental conditions, the following research activities are recommended:

- Conduct long-term field studies of WSUD at representative locations in both the North and South Island to assess the performance of GI devices and evaluating wider social and environmental outcomes. These studies need to be appropriately supported and resourced to enable them to be of sufficient duration and spatial extent to generate meaningful datasets to build the WSUD evidence base. Multi-party collaborations (central government, local government, iwi, research organisations etc) are likely to be the most effective way of supporting and steering these studies to maximise their value.
- Conduct modelling studies of the potential effectiveness of WSUD in the delivery of climate change adaptation and mitigation, relative to conventional stormwater management.

4.7 Governance and funding

With the aim of improving the governance and funding of WSUD in New Zealand, the following research activities are recommended:

- Investigate pathways for the implementation of suitable funding systems and incentive mechanisms in New Zealand, including assessing:
 - the current state of three waters funding by local authorities;
 - opportunities to identify and resource common toolbox mixes of solutions;
 - opportunities for co-benefit based funding; and
 - gaps in capacities to pursue the opportunities afforded by alternative potential funding regimes.
- Investigate the development of transitioning strategies, institutional and governance arrangements and methods for promoting behaviour change in the NZ context. This applies to both the public and private development and water management sectors.

4.7 Closing comments

In June 2017 the Activating WSUD research team made its case for funding to the National Science Challenge for Building Better Homes, Towns and Cities on the grounds that WSUD has the potential to deliver:

- Better environmental outcomes, for instance better water quality in rivers and harbours, flood resilience and moderating climate extremes;
- Better social outcomes, including through its influence on sense of place, connectedness with nature and amenity values; and
- Better economic outcomes, through the avoidance of upfront infrastructure costs and avoided costs of environmental remediation associated with conventional development.

In the relatively short time since being awarded funding we have been able to deliver research that provides support for this value proposition, building an evidence base to help activate the implementation of WSUD in New Zealand.

There is a strong signal from WSUD's community of practice that New Zealand needs to continue investing in research in this field to ensure that wide-spread implementation of WSUD becomes

mainstream, contributing to the building of resilient, sustainable and culturally-connected cities and towns areas for the future wellbeing of our urban communities. Currently New Zealand is grappling with the need to efficiently and cost-effectively house a projected boom in our urban population. WSUD provides us with an opportunity to meet these development needs without needing to compromise the environmental goals and objectives set through the National Policy Statement for Freshwater Management. The timing is right to continue a research and capacity building effort that will support the implementation of WSUD reaching a critical mass.