

Calculating potential network savings through employing rainwater and greywater systems

Amber Garnett and Lee Bint





1222 Moonshine Rd
RD1, Porirua 5381
Private Bag 50 908
Porirua 5240
New Zealand
branz.nz



Funded from the
Building Research Levy

The work reported here was funded by BRANZ from the
Building Research Levy.

Acknowledgements

This 3-year research project was funded by the Building Research Levy.

We would like to thank the project Advisory Panel for their contribution in guiding and supporting the project throughout the past 3 years. Andrew Pollard (BRANZ Ltd) was key in the early development and analysis framework for this research and his contribution is highly valued.

Roman Jaques and Lee Bint (BRANZ Ltd) have also enthusiastically contributed to the two other research streams, which are reported in SR382 (Bint & Jaques, 2017) and SR383 (Bint, 2017).

Last, but certainly not least, are the owners and managers of the eight case study buildings detailed throughout this report. Their interest, willingness to participate, answer our (very) many questions and receive us on site over the last 3 years has been a really rewarding and enlightening experience. The information from these buildings is the basis of this research, which could not be conducted without their support.

Note

This report is intended for dissemination as a publicly available BRANZ study report. It is based on the research undertaken under Commercial Rainwater & Greywater Feasibility (ER0845) research between 1 April 2014 and 31 March 2017.

Calculating potential network savings through employing rainwater and greywater systems

BRANZ Study Report SR384

Authors

Amber Garnett and Lee Bint

Reference

Garnett, A. & Bint, L. (2017). *Calculating potential network savings through employing rainwater and greywater systems*. BRANZ Study Report SR384. Judgeford, New Zealand: BRANZ Ltd.

Abstract

Strain on New Zealand's water networks is forecast into the future as populations continue to increase alongside rates of urbanisation and per capita water use. Compounded by climate change, the stability of the freshwater resource in New Zealand in future years is an issue of growing concern.

Adoption of rainwater and greywater technologies could help to alleviate that burden to water networks around the country.

Eight commercial buildings were monitored during the 2015/16 period. This found rainwater use ranged from 45 to 1,147 kL per month in summer, 22 to 1,039 kL per month in winter and an annual water use of 309 to 23,525 kL/year. The average proportion of total water use that comprised of non-potable, non-contact end uses (i.e. toilets and urinals) was 23%. Assuming that this non-potable water could all be sourced from rainwater, this indicates a potential optimistic saving of 23% of total water from the water network under optimistic conditions. This also equates to a financial saving for both the building owner and the water service provider. Rainfall used for non-potable purposes is not required to be treated, thus saving the water service provider the energy and financial cost of treating and transporting the water. Similarly, this results in financial savings for the building owner by reducing their volumetric water charge. However, when aggregated regionally, the proportion of non-potable supply actually met by the buildings ranged from 4% in the Bay of Plenty region to 38% in the Canterbury region. These observed supply rates provided the basis for extrapolation of current impacts to the water networks in 50 years, alongside the optimistic scenario.

Non-potable uses were extrapolated for the building stock and projected to the year 2066 across the four regions (Canterbury, Auckland, Wellington and Bay of Plenty). This enables an indication of the potential volumetric savings to the network in a range of uptake scenarios in 50 years' time.

Under an optimistic supply scenario:

- a low building uptake is estimated at 109,859 to 585,814 kL/year savings
- a medium uptake saves 235,462 to 1.5 million kL/year
- a high uptake saves 580,782 to 3.6 million kL/year.

When the observed supply scenario is used:

- for the low uptake scenario, the forecast savings across all four regions ranged from 199,743 kL/year in the Bay of Plenty region to 925,170 kL/year in the Canterbury region
- for the medium uptake scenario, volumes saved ranged from 428,112 kL/year in the Bay of Plenty region to 2.6 million kL/year in the Canterbury region
- for the high uptake scenario, the volume ranged from 1 million kL/year in the Bay of Plenty region to 6.2 million kL/year in the Canterbury region.

Keywords

Rainwater harvesting, greywater recycling, water network, future water savings

Contents

GLOSSARY	VI
1. INTRODUCTION	1
1.1 Rainwater harvesting and greywater recycling	2
1.2 Research approach and aims.....	3
1.3 Structure of report	3
2. CALCULATION METHOD	5
3. ESTIMATED CURRENT SAVINGS (2016).....	6
3.1 Building information	6
3.2 Water use.....	7
3.3 Regional water demand	10
3.4 Rainfall.....	10
3.5 Current savings to the potable water network.....	11
4. ESTIMATED FUTURE SAVINGS (2066)	13
4.1 Uptake	14
4.2 Climate projected rainfall	14
4.3 Projected commercial building stock.....	16
4.4 Regional water demand forecast.....	17
4.5 Estimated future savings.....	17
4.5.1 Optimistic scenario.....	19
4.5.2 Observed scenario	20
5. CONCLUSIONS	21
5.1 Future considerations	21
REFERENCES	23

Figures

Figure 1. New Zealand average annual rainfall 1972–2013.....	1
Figure 2. Example of a greywater recycling system.	3
Figure 3. Process involved in the impact assessment.	5
Figure 4. Building WUI by size strata.	8
Figure 5. Mains supply, rainwater and greywater demand as an annual average.....	8
Figure 6. Mains supply, rainwater and greywater demand during summer.....	9
Figure 7. Mains supply, rainwater and greywater demand during winter.	9
Figure 8. Annual water supply for 2015/16 and number of commercial buildings.	10
Figure 9. Monitored rainfall data by season.	11
Figure 10. Summary of approach taken in Auckland study (Klein et al., 2015).	13
Figure 11. Observed and projected rainfall.	15
Figure 12. Current and future estimates of non-residential building stock.....	16
Figure 13. Current and future water demand.....	17
Figure 14. Annual proportion of potable and non-potable water demand.....	18
Figure 15. Optimistic savings to the water networks.....	19
Figure 16. Observed savings to the water networks.	20

Tables

Table 1. Estimated number of commercial buildings by case study region.	6
Table 2. Description of the eight case study buildings.....	7
Table 3. Total annual water use (Bint, 2017).	7
Table 4. Basic extrapolation of rainwater and greywater opportunity.	11
Table 5. Uptake scenarios.....	14
Table 6. Projected rainfall according to representative concentration pathways in 2066.	15
Table 7. Projected commercial building stock.....	16
Table 8. Regional proportion of non-potable demand and supply (2015/16).....	18

Glossary

blackwater	Wastewater containing biological waste, as from toilets, dishwashers or kitchen sinks.
freshwater	Defined as having a low salt content, usually less than 1%.
functional unit	A quantified level of functionality or service that is provided. For example, a comparative assessment of various water technologies might use a functional unit of 1 m ³ over the period of a year.
GHG	Greenhouse gas emissions.
greywater recycling	The reuse of wastewater originating from wash hand basins, showers, washing machines and dishwashers. For the purposes of this study, only greywater recycled from wash hand basins is used.
non-potable water	Sources include rainwater, reclaimed/recycled water and greywater. While non-potable water is not appropriate for human consumption, it can be used in a myriad of other applications, such as toilets and irrigation.
potable water	Water that is suitable to meet drinking water standards.
rainwater harvesting	The collection of precipitation for use on site, as opposed to allowing this precipitation to form stormwater run-off.
size strata	The stratification of New Zealand's commercial building stock in BEES by gross floor area (Amitrano et al., 2014): <ul style="list-style-type: none"> • S1: ≤649 m² • S2: 650–1,499 m² • S3: 1,500–3,499 m² • S4: 3,500–8,999 m² • S5: ≥9,000 m²
water scarcity	The lack of available freshwater required to meet water usage demands of a region. This can occur in the form of physical scarcity (not enough freshwater available to meet demand) or economic scarcity (there is a lack of infrastructure and/or mismanagement of the freshwater resource).
water stress	The ability or lack thereof of water to meet human and ecological demands.
WUI	Water use intensity.

1. Introduction

Freshwater is essential to many of the primary industries that earn New Zealand its wealth. It is also heavily valued for recreation and cultural significance, and freshwater has been described as New Zealand's greatest natural asset (Ministry for the Environment, 2014).

A series of mountain chains span the length of New Zealand, providing a barrier to prevailing westerly winds and essentially dividing the country into different climatic regions. Nationally, the climate ranges from warm subtropical in the far north to cool temperate in the far south, with severe alpine conditions in the mountain ranges (NIWA, 2001). It is due to these vastly differing climatic conditions that the abundance of freshwater across New Zealand can differ drastically, in accordance with topography and regional characteristics (Figure 1).

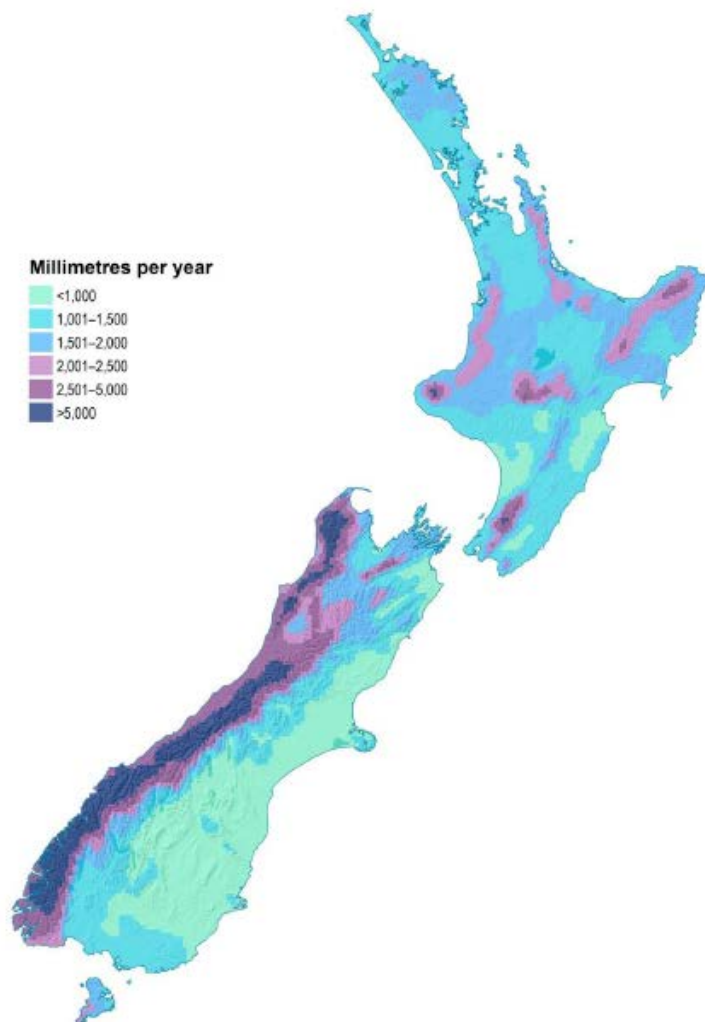


Figure 1. New Zealand average annual rainfall 1972–2013.

© Copyright NIWA

By international standards, freshwater availability in New Zealand is abundant due to plentiful rainfall and comparatively low population densities. However, at the same

time, New Zealanders are reported to use two to three times more freshwater per person than most other OECD countries (Ministry for the Environment, 2014).

1.1 Rainwater harvesting and greywater recycling

Rainwater harvesting refers to the accumulation and deposition of precipitation for reuse on site as opposed to allowing this precipitation to form run-off. There are approximately 370 rainwater harvesting systems throughout New Zealand. Large-scale feasibility research of the use of rainwater tanks as an alternative to an additional river take in Auckland has been previously modelled (Klein et al., 2015).

Internationally, a life cycle assessment conducted by Ghimire et al. (2017) compared a commercial rainwater harvesting system with a municipal mains supply for 11 life cycle assessment parameters. The parameters were acidification, energy demand, eutrophication, fossil depletion, freshwater withdrawal, human health, metal depletion, ozone depletion, smog, evaporative water consumption and global warming. Rainwater used for toilets and urinals in a 4-storey office building was assessed, with the functional unit 1 m³ of rainwater and municipal supply. The study concluded that, for all 11 parameters (minus ozone depletion), the rainwater harvesting system outperformed the municipal mains supply by 45–55%.

Greywater recycling systems refer to the reuse of wastewater originating from wash hand basins, showers, washing machines and dishwashers. It is important to note the distinction between greywater and blackwater. The main difference between greywater and blackwater is the presence of faecal matter.

Typically, greywater and blackwater are combined and discharged as wastewater. However, there is increasing interest in separating greywater for reuse in non-potable demands (Siggins et al., 2016). This has been found to reduce water requirements of new potable supplies by up to 50% (Maimon, Friedler & Gross, 2014). A schematic of a residential greywater recycling system can be seen in Figure 2. This shows that, of the total 305 L of ingoing potable water, 150 L is reused for toilet, garden and cleaning uses supplied by water used in the hand basin, bath tub and shower.

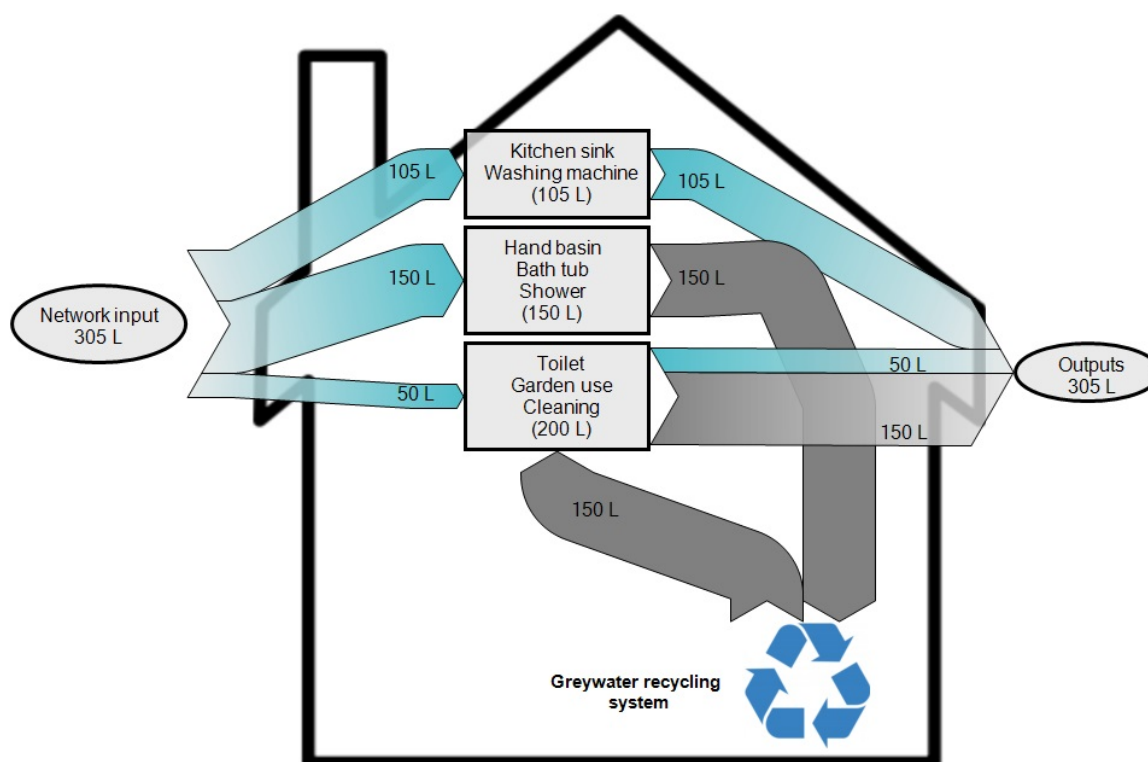


Figure 2. Example of a greywater recycling system.

Greywater recycling systems appear to be less common in New Zealand compared to rainwater harvesting systems. There is little published literature regarding the impacts of using recycled greywater on the water networks, both in New Zealand and internationally. Compounding this, the term 'greywater' in New Zealand is often mistakenly used to refer to rainwater.

1.2 Research approach and aims

To create a holistic overview of rainwater and greywater system feasibilities, a multi-disciplinary team has explored three research streams:

- Social and regulatory drivers and barriers to uptake.
- Investigations of buildings with rainwater harvesting and/or greywater recycling systems in operation.
- Impacts on the potable water network from uptake.

The work reported herein represents the third research stream – impacts on the water networks. The network impacts were estimated for both current and future scenarios.

This work also uses results from the Social & Policy and Buildings research streams, which developed a feasibility model for rainwater and greywater systems in New Zealand commercial buildings.

1.3 Structure of report

The intent of this study report is to calculate the impacts on the water supply, stormwater and wastewater networks from rainwater harvesting and greywater

recycling systems. This is calculated using eight case study buildings across New Zealand represented in SR383 (Bint, 2017). The following structure is used:

- Section 1 sets the research aim and objectives for this report. A New Zealand background discusses the freshwater, demographic, building stock and rainwater and greywater systems in the New Zealand context.
- Section 2 outlines the method used to calculate the current and future impacts on the water networks from eight case study buildings.
- Section 3 highlights the results of the current and future analyses.
- Section 4 steps through the key findings of the current and future analyses.
- Section 5 makes conclusions on the study.

2. Calculation method

Prominent findings from the social report in this series (SR382) found the largest barriers to uptake of rainwater harvesting and greywater recycling systems. These were cost and space (i.e. loss of car park and lettable area). The biggest drivers to uptake were again cost (savings) and environmental reasons. A primary concern was the health implications of using recycled water. Thus, water quality testing was conducted to assess the risk to human health.

Findings from SR383 found that tariff structures of the majority of water service providers were acting as a barrier to uptake by masking the potential financial benefits of installing these systems. The Auckland-based tariff structure was found to incentivise alternative technologies through clearer cost savings and could result in a shorter pay-back period when applied to other regions.

Leading on from the previous two study reports, the network impacts were estimated for both current and future scenarios (Figure 3):

- Current impacts were calculated in both summer and winter months to gain a better appreciation for seasonal variations in water use impacts to the network, using the eight case study buildings.
- Future projections were calculated as an estimated annual average, using the commercial building stock and uptake scenarios.

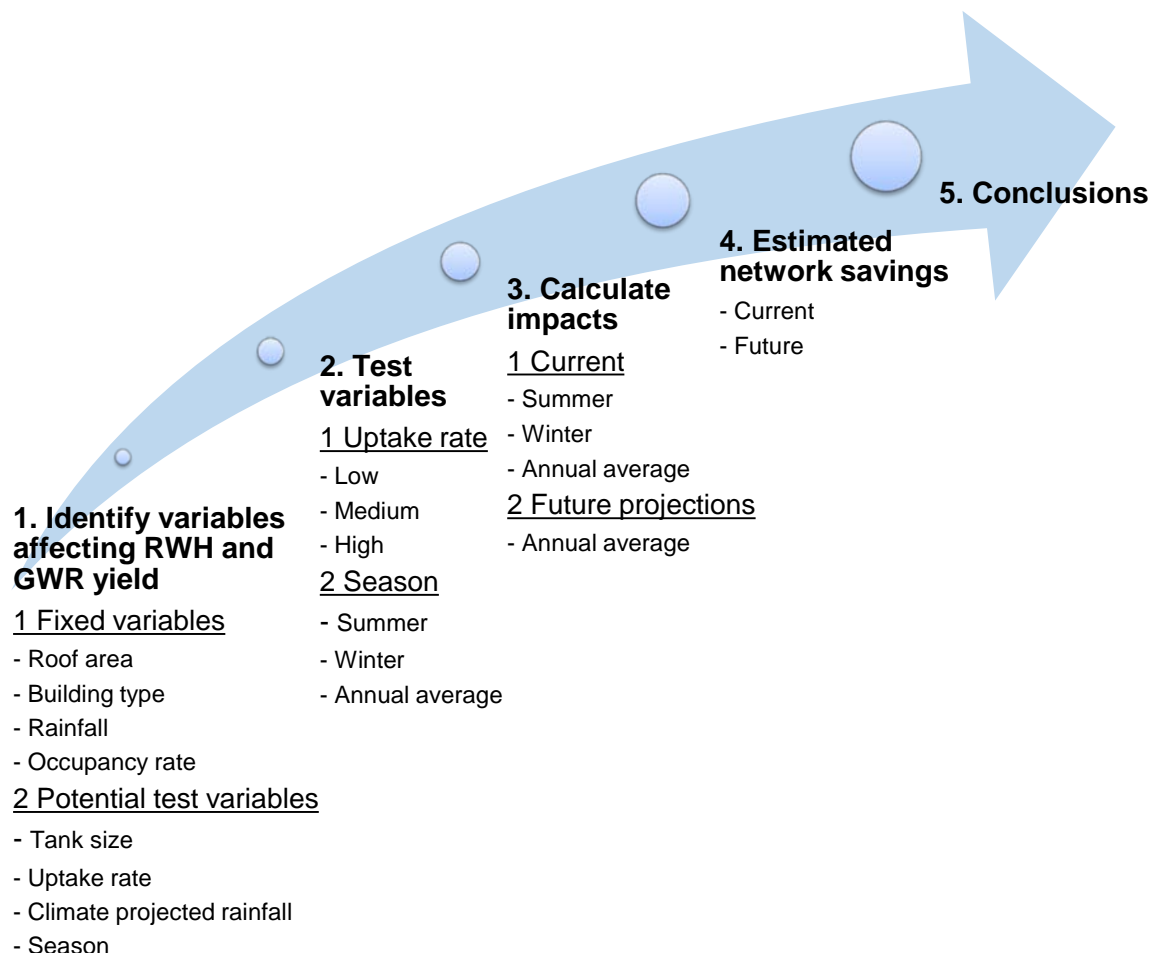


Figure 3. Process involved in the impact assessment.

3. Estimated current savings (2016)

The current impacts of the eight case study buildings on the water networks were calculated. Metered mains water, rainwater and greywater inputs to the system were monitored for the 2015/16 period. The volumetric saving from installing rainwater harvesting and greywater recycling systems to the water network is assessed.

Rainfall was multiplied by each building (roof) catchment area to get the volume of water available for rainwater seasonally. This also takes into consideration efficiency and losses from the roofing materials. No first-flush diversion or treatment systems were present in the case study buildings other than in building B1 (for greywater purposes).

For more information on the performance of case study system, please refer to SR383 (Bint, 2017).

3.1 Building information

Most of the commercial building stock is made up of smaller buildings (Table 1), with an estimated average floor area of 970 m² across all 41,154 buildings (Amitrano et al., 2014). The Building Energy End-use Study (BEES) disaggregated the commercial building stock based on gross building floor area (refer to the glossary for more information).

Table 1. Estimated number of commercial buildings by case study region.

Size strata	Auckland		Bay of Plenty		Canterbury		Wellington	
	No.	000 m ²	No.	000 m ²	No.	000 m ²	No.	000 m ²
S1	5,303	1,947	644	225	2,819	1,132	956	345
S2	2,177	2,136	223	312	891	792	288	262
S3	1,405	2,962	67	179	399	890	215	534
S4	701	3,322	28	119	140	682	163	970
S5	177	2,784	12	89	43	653	103	1,500
Total	9,763	13,151	973	924	4,292	4,150	1,725	3,611

Size S1 and S2 buildings can be described as smaller-scale non-residential buildings and comprise 86% of the commercial building stock. Larger buildings (S3, S4 and S5) make up only 14% of the commercial building stock.

At least 370 of the commercial building stock has a rainwater system, and at least one has a greywater recycling system (Bint, 2017). Water use in eight of these commercial buildings was assessed over 2015 and 2016 (Bint, 2017). These buildings were spread across four New Zealand regions: Auckland, Bay of Plenty, Canterbury and Wellington. For these regions, an estimate of the total number of commercial buildings and their associated gross floor area was determined using the BEES database.

Table 2 shows the size classification, tank information and location of the eight case study buildings. Their floor areas ranged between 2,333 m² and 35,367 m², or S3 and S5 in accordance with the BEES size strata.

Table 2. Description of the eight case study buildings.

Building	Size strata (BEES)	Rainwater tank	Greywater tank	Mixer tank	Region
A1	S5	24 kL			Auckland
A2	S3	7 kL			Auckland
A5	S5	38 kL			Auckland
B1	S5	20 kL	300 L	5 kL	Bay of Plenty
C1	S3	20 kL			Canterbury
C2	S4	20 kL			Canterbury
C3	S5	185 kL			Canterbury
W1	S5	40 kL			Wellington
Average	S3	13.5 kL			
	S4	20 kL			
	S5	61.4 kL	300 L	5 kL	

The size of the rainwater and greywater tanks is an important consideration when accounting for the potential impacts that rainwater harvesting and greywater recycling might have on water networks. The larger the tank, the greater capacity to store rainwater and reduce the amount of potable water consumed for non-potable purposes. Furthermore, reducing potable water demand may result in delaying the need for infrastructure development.

3.2 Water use

The current water savings of each rainwater harvesting and greywater recycling system to the potable water network was assessed. However, it was first necessary to gain an understanding of the total volume of water used by each building for the 2015/16 monitoring period (Table 3).

Table 3. Total annual water use (Bint, 2017).

Type	Water use (kL/year)							
	A1	A2	A5	B1	C1	C2*	C3	W1
Size strata	S5	S3	S5	S5	S3	S4	S5	S5
Mains	9,275	194	3,249	22,659	237	6,605	11,727	6,833
Rainwater	2,661	113	682	695	394	1,780	5,372	641
Greywater	-	-	-	171	-	-	-	-
TOTAL	11,935	307	3,931	23,526	631	8,385	17,099	7,474

*Mains water data was not recorded and is not monitored – this is a predicted number only.

Building B1 has the greatest water use and is amongst the largest 1% of the New Zealand commercial building stock. Those buildings with a floor area of between 1,500 m² and 3,499 m² (S3) appear to use less water than their larger counterparts.

To remove the influence that the building size has on total water use, the water use intensity (WUI) was calculated (Figure 4). The WUI removes the impact of building size to enable a comparison of building water consumption. This uses kilolitres of water per square metre of net lettable floor area per year (kL/m²/year).

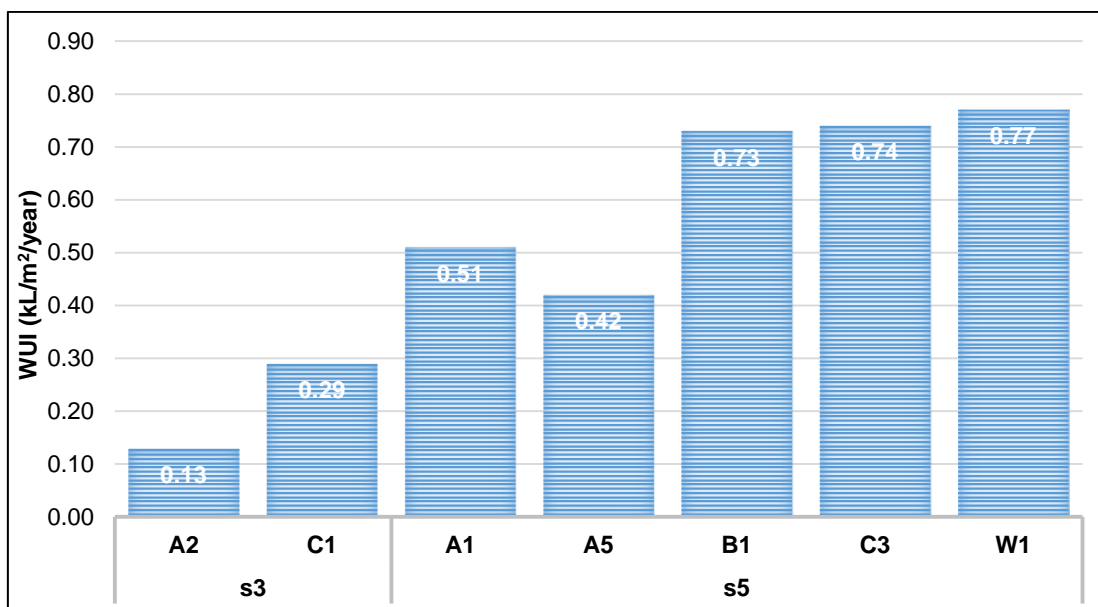


Figure 4. Building WUI by size strata.

The WUI is useful in comparing buildings regardless of size. However, it does not consider that a proportion of the total water use of the buildings is comprised of mains water, rainwater and/or greywater.

This is an important consideration as the opportunity cost of water supplied by the mains or recycled and reused water differs greatly. Rainwater harvesting and greywater recycling systems do not negatively contribute towards overallocation problems or stress on the water network. This differentiation between water types is important and not captured by the WUI.

The annualised average proportion of mains supply, rainwater and greywater demand can be seen in Figure 5. The average proportion of non-potable water used by the case study buildings was calculated to be 23%. Non-potable uses in the case study buildings were toilet and urinal flushing, irrigation or miscellaneous uses (such as for chemistry laboratory uses).

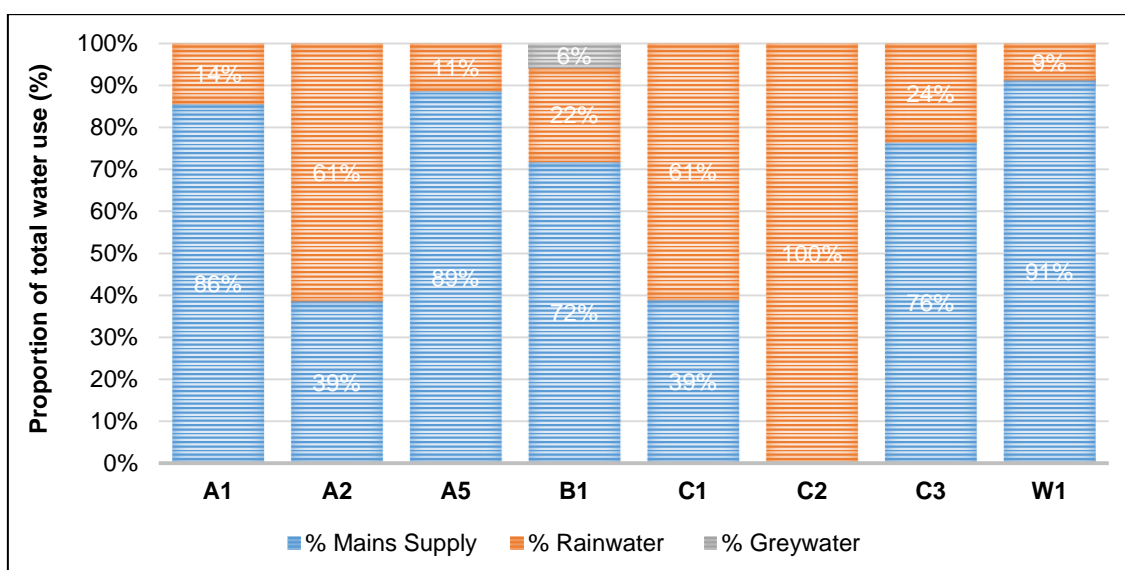


Figure 5. Mains supply, rainwater and greywater demand as an annual average.

To gain a better understanding of how water use alters seasonally between buildings, both the monitored mains water and rainwater/greywater were separated for the summer (December–February) and winter (June–August) months.

Figure 6 shows the proportion of mains water supply and the rainwater and/or greywater supply for each building during the summer months. This shows that, for all buildings except for C1, more mains water is supplied and used compared with rainwater and greywater.

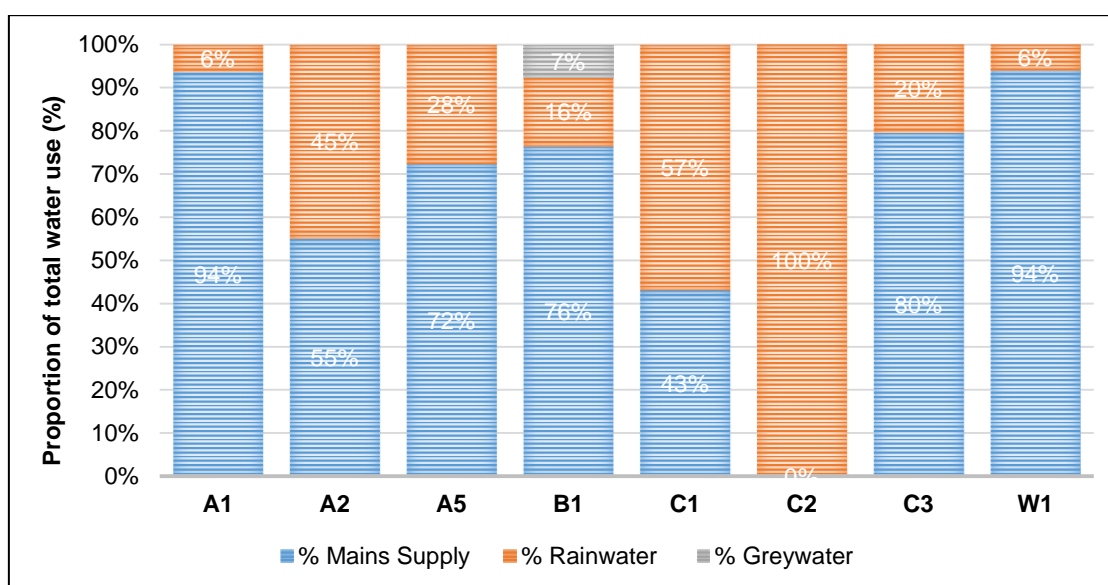


Figure 6. Mains supply, rainwater and greywater demand during summer.

When the summer water use (Figure 6) is compared to the winter water use (Figure 7), a similar trend can be seen. Mains water is consistently the largest water supplier to all buildings (except for building C1).

It should be noted that buildings A2 and C2 had some seasonal data missing and are therefore excluded from analysis from this point forward.

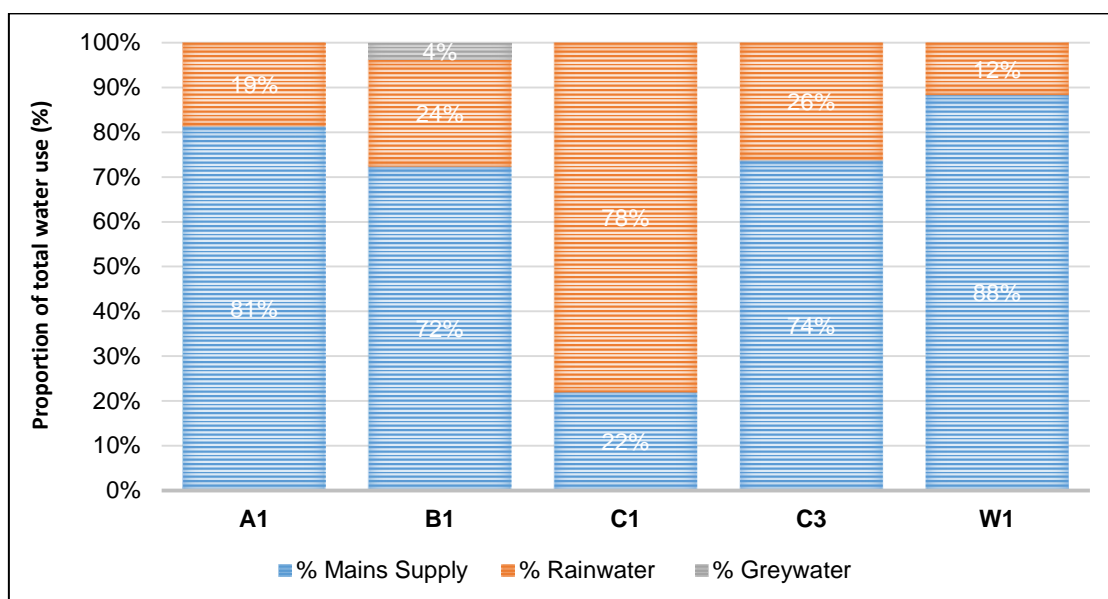


Figure 7. Mains supply, rainwater and greywater demand during winter.

Across the eight case study buildings, the total annual water use varies significantly, from 308 kL/year to 25,000 kL/year. This is a function of the building size, with S5 buildings having the highest total water use.

Those buildings with the greatest building floor area (S5) show a larger WUI than the smaller (S3 and S4) buildings. Previous assessment of WUI and building size found that a high WUI was likely related to industrial processes with a higher water use. It was further determined that 80% of water use was driven by occupancy rates (Roberti, 2014).

The relationship between floor area and water use is also relevant when comparing the rainwater volumes used in each building. Buildings with a larger floor/roof area have a larger catchment area and thus the opportunity for greater rainwater harvesting.

3.3 Regional water demand

Regional water demand for the 2015/16 period was provided by the respective water service providers. Figure 8 details the average annual water demand across the four regions studied, compared with the estimated commercial building stock for each region.

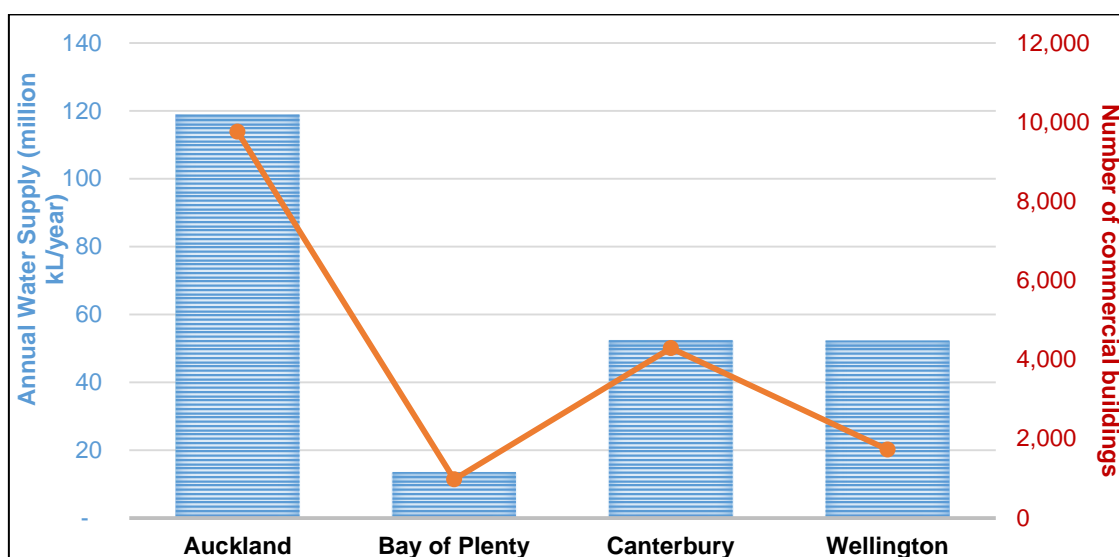


Figure 8. Annual water supply for 2015/16 and number of commercial buildings.

3.4 Rainfall

Rainfall data for the monitoring period was obtained through the CliFlo database (NIWA, 2017), using the monitoring station closest to each case study building.

All rainfall data is for January 2015 to December 2016, except building C3 (June 2014 to July 2015) and buildings A1 and A5 (January 2009 to December 2010), due to data availability.

A seasonal analysis was conducted and rainfall volumes for summer (December–February), winter (June–August) and an annual average were determined (Figure 9).

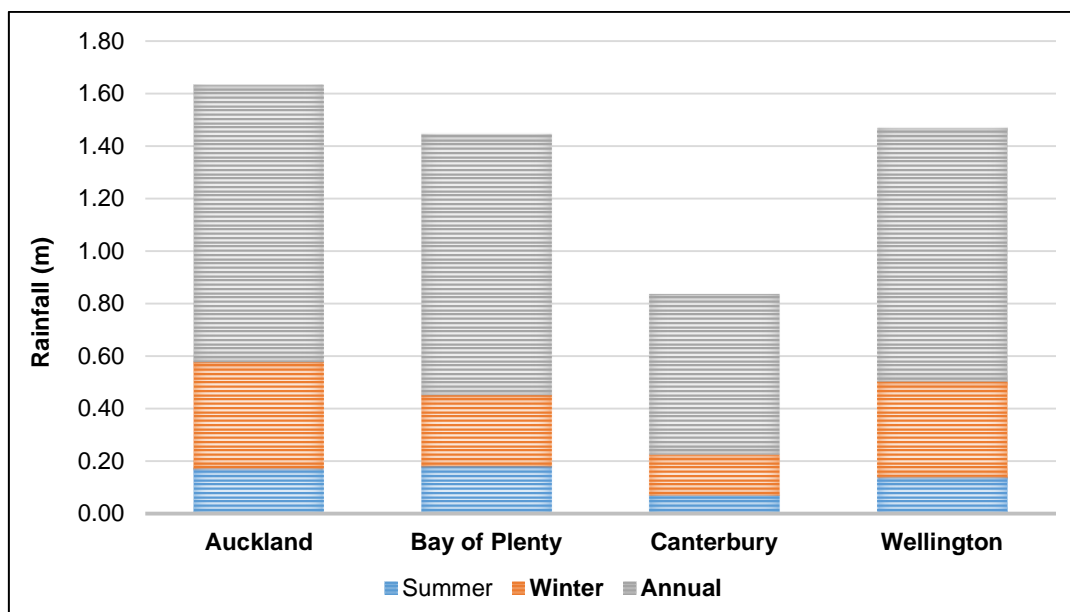


Figure 9. Monitored rainfall data by season.

3.5 Current savings to the potable water network

Based on the average of the eight case study buildings, the non-potable component of a building's water use is up to 23% of the total water use.

As the case study buildings were limited in frequency and regional range, their volumetric impact to the network is considered minor. The volume of rainwater and greywater used by the case study buildings ranged from:

- 45–1,147 kL during summer (December–February)
- 22–1,039 kL during winter (June–August)
- 309–23,525 kL per year.

However, with increased uptake, the capacity for these systems to reduce the network demand would increase. Hypothetically, if all S3, S4 and S5 buildings were to substitute 23% of their non-potable demand with rainwater and/or greywater, this could result in notable savings to the water networks.

Table 4. Basic extrapolation of rainwater and greywater opportunity.

Region	Floor area S3, S4, S5 (000 m ²)	Benchmark WUI (kL/m ² /yr)	Commercial demand (ML/yr)	Opportunity 23% supply (ML/yr)	Regional demand (ML/yr)
Auckland	9,068	0.76	6,892	1,585	118,990
Bay of Plenty	387	0.79	306	70	13,519
Canterbury	2,225	0.84	1,869	430	52,434
Wellington	3,004	0.45	1,352	311	52,317

Based on the information in Table 4, the maximum percentages of total regional demand that could be saved if applying today's case study building findings to the entire commercial building stock are:

- Auckland – 1.3%

- Bay of Plenty – 0.5%
- Canterbury – 0.8%
- Wellington – 0.6%.

It should be noted that this uses the benchmark WUI. The case study buildings, however, had an 8–65% lower WUI – combining mains water, rainwater and greywater. This indicates that the buildings were already designed with water efficiency in mind. Given the annual rainfall opportunity, this could be much greater in the future.

4. Estimated future savings (2066)

A 2015 Auckland study assessed whether residential rainwater harvesting was a viable option to meet future water demand needs (Klein et al., 2015). The methodology from the Auckland study (Figure 10) has informed aspects of this study – for example, the effect of various uptake scenarios for both existing and new builds.

There were certain variables that could not be accounted for in this study, such as an estimate of tank sizes across different building types. This was due to the diversity of the commercial building stock in New Zealand and the lack of clear standards and regulations surrounding rainwater tanks. Furthermore, an estimate of future building catchment size, building type or projected occupancy rate could not be attained for non-residential buildings, again due to variation in the building stock.

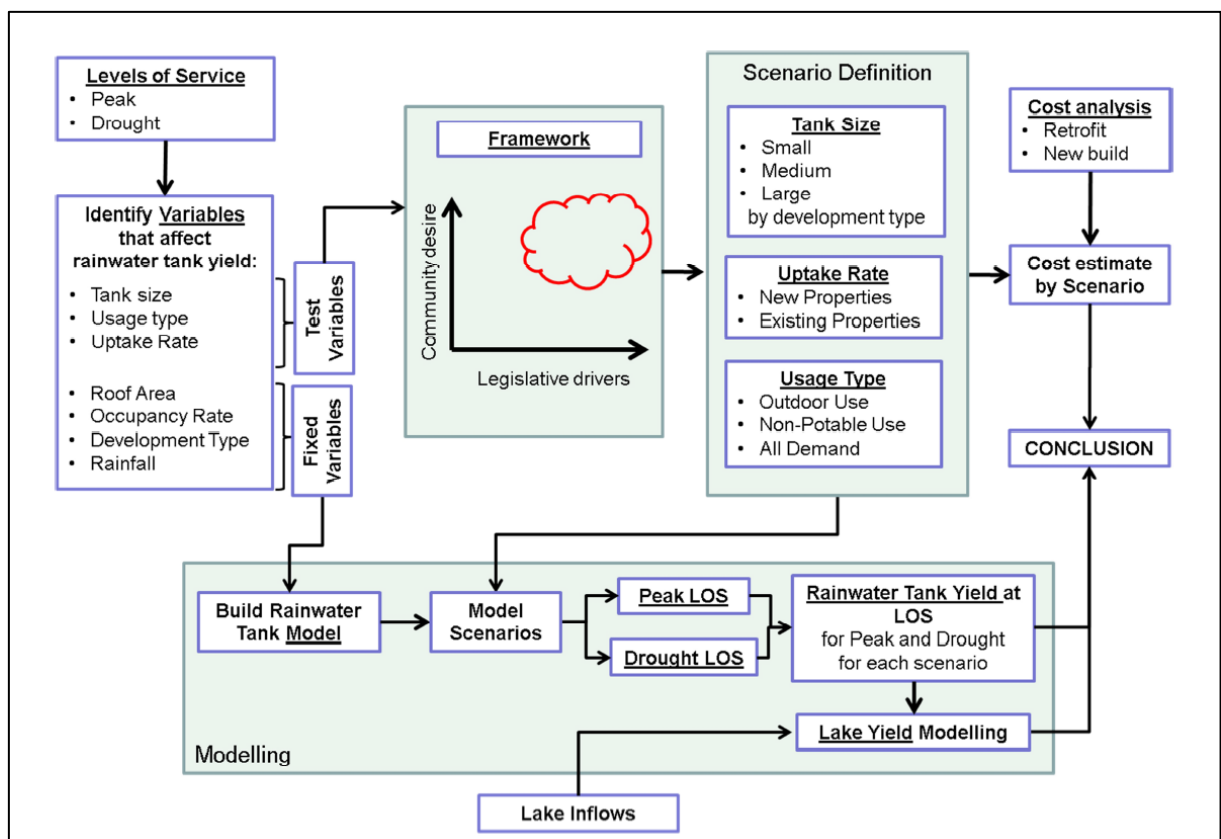


Figure 10. Summary of approach taken in Auckland study (Klein et al., 2015).

© Watercare Services Limited.

The Auckland study briefly investigated the impact of rainwater tank implementation on the non-residential building stock. It calculated the proportion of non-domestic end uses that could be supplied using rainwater tanks, both now and in the future. This was calculated as 12 ML/day based on all new commercial buildings and half of the existing buildings having rainwater tanks. As only a proportion of this could be supplied by rainwater tanks, this was not considered beneficial to the required levels of service.

The results of the eight case study buildings aim to contribute to New Zealand-focused research on alternative water sources in the non-residential sector.

Based on a range of uptake scenarios and seasonal variabilities, two water supply scenarios and three building uptake scenarios were modelled (Table 5):

Table 5. Uptake scenarios

Test variable		Scenarios (low <=> high)		
Uptake	New build	10%	20%	30%
	Retrofit	0%	10%	20%
Rainwater/greywater supply met		Regional average supply met – observed		Optimistic demand met

Ideally, an estimate of tank yield using average tank size and projected rainfall data would be conducted to assess the feasibility of future rainwater harvesting and greywater recycling uptake scenarios. Unfortunately in this instance, with limited data, it was determined that a meaningful estimate of the average tank yield in 50 years could not be estimated. Therefore, calculated future impacts are on the basis of the potential volumes that could be alleviated from the network if rainwater supply dictates. These volumes are based on three building uptake scenarios and two rainwater/greywater supply scenarios (Table 5) based on case study information. An indication of rainfall volumes in 2066 alongside rainfall for the period 2015/16 can be seen in Figure 11 and provides an indication of the future increase/decrease in expected rainfall. It can be seen that, for Auckland and Bay of Plenty, rainfall is expected to decrease by almost 1%, whilst in Canterbury and Wellington, this is expected to increase by almost 5%. The results of this analysis could benefit from a rainwater tank yield calculation with the addition of more case study buildings.

4.1 Uptake

Three uptake scenarios were modelled as outlined in Table 5:

- A low uptake scenario – 10% of new builds in 2050 install the systems.
- A medium uptake scenario – 20% of new builds and 10% of existing buildings (retrofits).
- A high uptake rate scenario – 30% of new builds and 20% existing builds install the systems.

The number of new builds expected in 2050 was calculated using past building consent data for each region concerned. Consent data was averaged between 1991–2016 to give the average number of new building consents per year. This was extrapolated to the year 2066, accounting for 0.2% loss per year due to natural building degradation.

4.2 Climate projected rainfall

Climate projected rainfall data was acquired through the Our Future Climate database for the period 2016–2066 (NIWA, 2016). Climate projected rainfall is provided as modelled by six international climate models. For the purposes of this research, a six-model average was recommended (A. Tait, personal communication, 21 February 2017). Furthermore, climate projections have been produced for several plausible greenhouse gas emission pathways over the next 100 years. These are called representative concentration pathways. It is acknowledged that the four representative concentration pathways provided by NIWA and used in this study do not represent the full range of pathways possible. However, they do represent a good span. They have been used by all the global models that contributed to the global climate model of the

fifth assessment report of the Intergovernmental Panel on Climate Change (Stocker et al., 2013). The four representative concentration pathways used to project future precipitation across New Zealand can be seen in Table 6.

As can be seen in Table 6, the projected rainfall volumes for Auckland, Bay of Plenty, Canterbury and Wellington vary as a function of the representative concentration pathway (i.e. greenhouse gas emissions). Across all climate scenarios, Canterbury can be seen to receive notably less annual rainfall than all other cities. Under a high representative concentration pathway, Wellington and Tauranga will receive the most rainfall, and this will be an increase on the volume predicted if there are low greenhouse gas emissions.

Table 6. Projected rainfall according to representative concentration pathways in 2066.

Representative concentration pathway	Projected rainfall (mm/year)			
	Auckland	Bay of Plenty	Canterbury	Wellington
Low (2.6)	1,178	1,169	610	1,334
Low-medium (4.5)	1,219	1,265	632	1,134
Medium-high (6.0)	1,306	1,481	656	1,252
High (8.5)	1,142	1,243	622	1,254

Although it varies naturally, the climate across the Earth is changing because of anthropogenic activity (Vitousek et al., 1977). The biggest driver of change is the increase in greenhouse gas emissions, causing temperatures across the world to increase.

Climate change affects New Zealand's weather, especially precipitation and temperature patterns. Figure 11 shows a comparison of observed rainfall data (1972–2015) with the average projected rainfall data (2016–2100) assuming a low-to-medium increase in greenhouse gas emissions for New Zealand. Auckland and Bay of Plenty regions are projected to see a 1% decrease in rainfall, whilst Canterbury and Wellington are projected to see an increase of just under 5%.

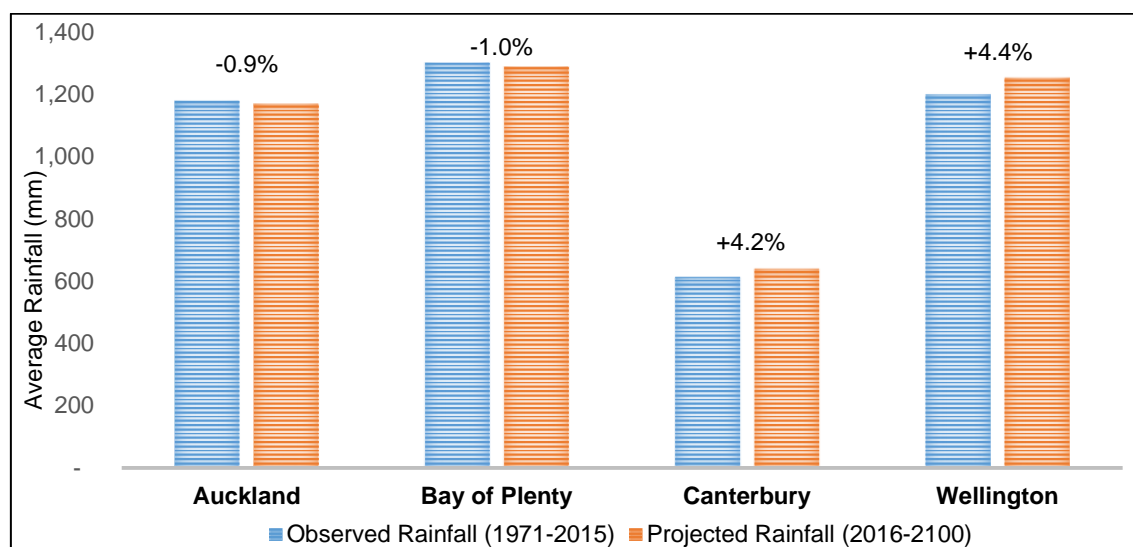


Figure 11. Observed and projected rainfall.

Forecast climate scenarios for Auckland, Canterbury, Wellington and Bay of Plenty suggest that rainfall will vary locally, with the largest variations seasonal, as opposed to annual. The capacity of stormwater systems may be exceeded more frequently due to heavy rainfall events, which could lead to surface flooding. River flooding and hill country erosion events may also become more frequent, particularly in low-lying areas. Floods are likely to become more intense (Ministry for the Environment, 2016).

4.3 Projected commercial building stock

The projected growth in the commercial sector was estimated for the year 2066 for each region (Figure 12 and Table 7). This was based on building consent data between 1991 and 2016 (Statistics New Zealand, 2017). As it is not possible to predict the number of new commercial buildings that will be built over the next 50 years, the number of new building consents for the commercial, industrial and education sectors were averaged to give growth in the commercial sector over the previous 25 years.

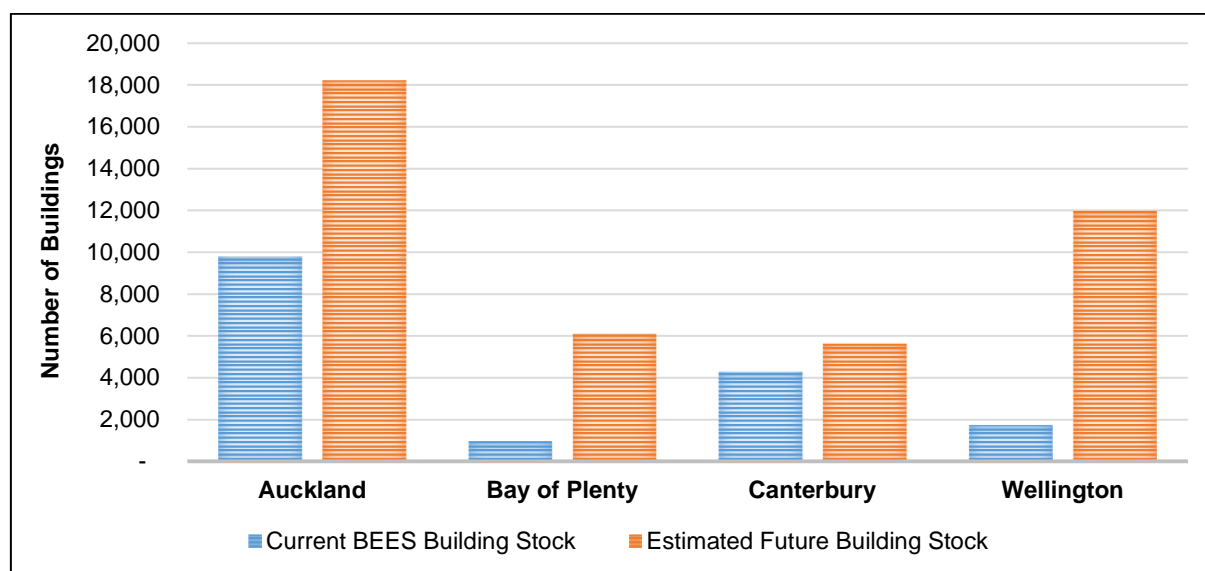


Figure 12. Current and future estimates of non-residential building stock.

The education sector was included, as three of the case study buildings are educational buildings. For these buildings, the average growth over the previous 25 years was halved to account for the increase in single and/or double classrooms required to meet roll growth. These classrooms were subsequently removed some years later (I. Page, personal communication, 21 March 2017). It was assumed there would be a 0.2% decrease in the existing building stock per region per year due to building age and related parameters.

Table 7. Projected commercial building stock

Size strata	Auckland		Bay of Plenty		Canterbury		Wellington	
	2016	2066	2016	2066	2016	2066	2016	2066
S1	5,303	-	644	-	2,819	-	956	-
S2	2,177	-	223	-	891	-	288	-
S3	1,405	-	67	-	399	-	215	-
S4	701	-	28	-	140	-	163	-
S5	177	-	12	-	43	-	103	-
Total	9,763	18,228	973	6,113	4,292	5,635	1,725	11,988

It is important to note that these estimates do not account for occurrences of natural disasters such as earthquakes. These have proven to negatively impact on the commercial building stock in previous years through earthquake damage and subsequent demolition.

4.4 Regional water demand forecast

Every water service provider is required to have a long-term plan. This plan must include a forecast on future demand to the water supply network. The four water service providers were approached to provide future water supply forecasts for their region. Most providers had water supply forecasts to approximately 2050. These estimates were used to predict the future impacts to the networks in 50 years' time or 2066.

Figure 13 shows the 2015/16 demand compared to the projected future demand. In terms of future demand, the Auckland region is projected to have the greatest demand of all regions, followed by Canterbury, Wellington and Bay of Plenty. However, in terms of the increase as a percentage over the next 50 years, Bay of Plenty has by far the greatest increase in demand.

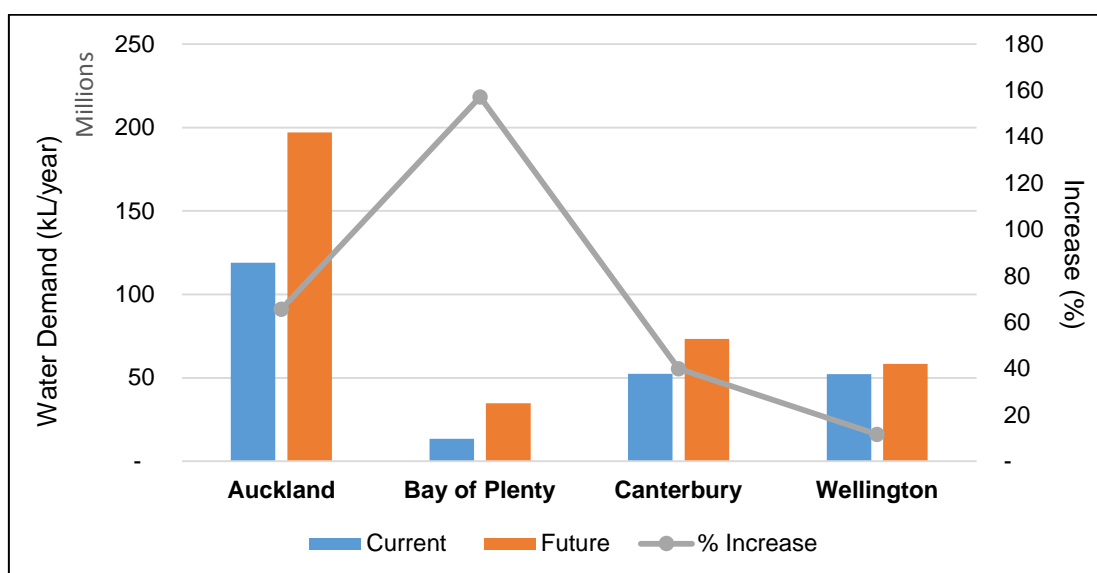


Figure 13. Current and future water demand.

4.5 Estimated future savings

A broad estimate of the volume of potable water that could be saved by implementing rainwater harvesting or greywater recycling systems in commercial buildings was conducted. This was based on three building uptake scenarios and two supply/demand scenarios (Table 5). It should be stressed that the calculated volumes are based on case study data only and as such provide an indication of the methodology used and should not be taken as absolute. Results would be more robust if the sample size were increased.

The average annual percentages of non-potable demand for each of the eight case study buildings were calculated. These were used to estimate the volume of rainwater and greywater that could be used in place of treated potable water under an optimistic scenario. When aggregated at the regional level, it was found that not all regions were meeting 23% of total water demand with rainwater and/or greywater (Table 8).

Therefore, an observed supply scenario is also used. Of the eight case study buildings, only five had complete datasets. Therefore, the following demonstration of impact assessment is based on five buildings only.

Table 8. Regional proportion of non-potable demand and supply (2015/16).

Region	Optimistic scenario	Observed scenario
Auckland	14%	25%
Bay of Plenty	28%	4%
Canterbury	42%	38%
Wellington	9%	9%
AVERAGE	23%	19%

The proportion of potable and non-potable water used per region was aggregated, as opposed to the proportion per building. This was in order to take a snapshot of the future impact that rainwater harvesting and greywater recycling systems could have to the water network based on case study examples. The average annual proportion of potable and non-potable water per region can be seen in Figure 5 alongside the average over the five case study buildings used for impact assessment.

The average proportion of total water use that is comprised of non-potable demand is 23%. For the optimistic scenario, this assumes that 23% of total building water use can be met with rainwater and/or greywater and is not required to be abstracted from the network. Potable water can be seen to be the dominant source of water for all regions, based on the five case study buildings (Figure 14). Canterbury has a slightly higher ratio of non-potable water use due to the greater proportion of non-potable water use found in building C1.

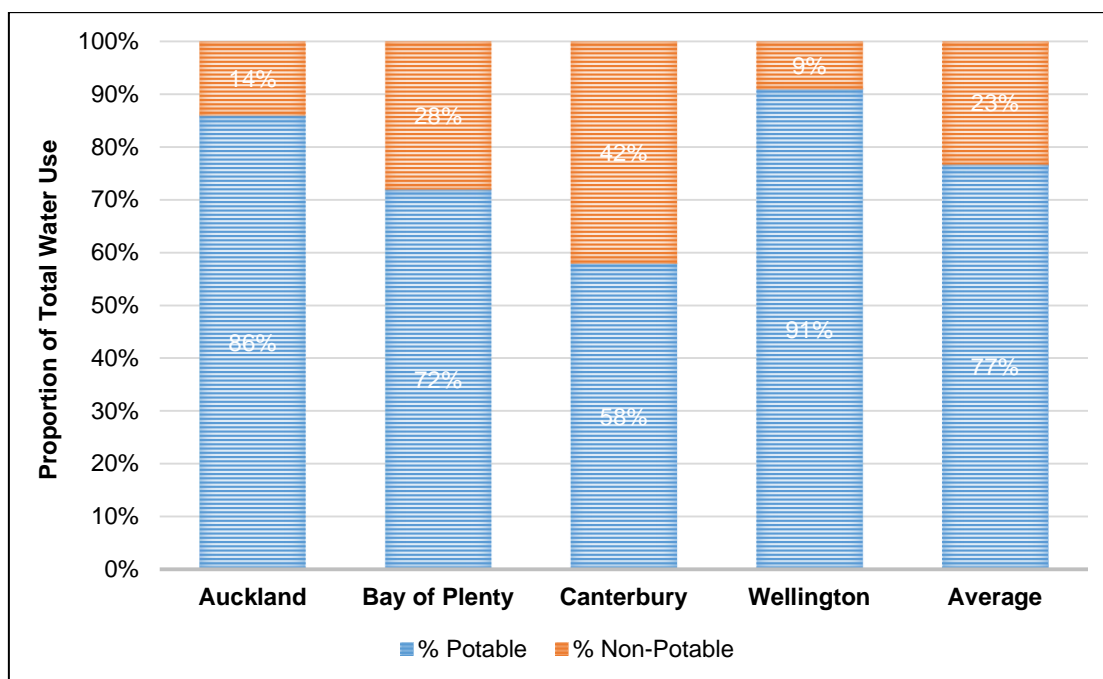


Figure 14. Annual proportion of potable and non-potable water demand.

Buildings were grouped by region for impact assessment due to the differences in variables such as rainfall and the projected number of new builds across regions.

The volume of potential potable water that could be saved from the network in 50 years (based on case study data) was roughly estimated. To do this, it was necessary to determine the number of buildings that would adopt rainwater harvesting and/or greywater recycling based on the previously defined uptake scenarios. It is important to note that the existing building stock was reduced by 10% over the 50 years to account for natural degradation in the current stock (of around 0.2% per annum).

The numbers of both current and projected buildings (Figure 12) to adopt the systems were then multiplied by the average total non-potable water use of the buildings (per region). First, the average percentage of non-potable waters across the five case study buildings (23%) was used. This allowed an indication of the optimistic potential volume of potable water to be saved to be determined for three building uptake scenarios (Table 5). As this information is based on five case study buildings only, it should be considered indicative. Second, an observed scenario was calculated based on the regional averages of non-potable supply met within each building and for the three building uptake scenarios.

4.5.1 Optimistic scenario

Based on the limited number of case study buildings, Figure 15 shows the potential volume of mains water that could be alleviated from the water network. This assumes an average total water use (as per the case study buildings) and an optimistic supply of 23% non-potable usage.

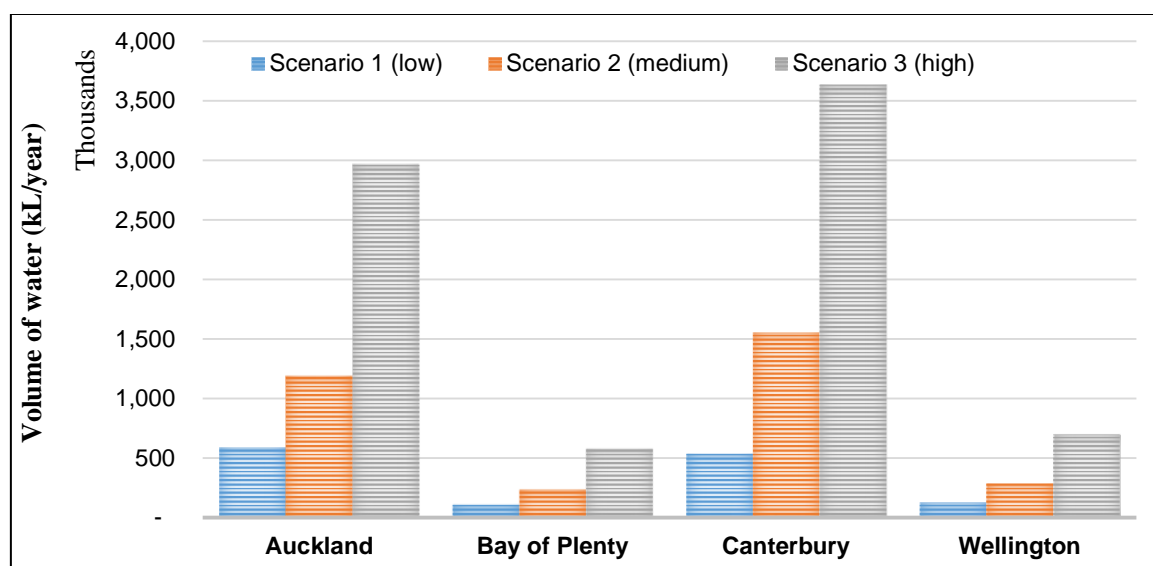


Figure 15. Optimistic savings to the water networks.

Using an optimistic scenario of 23% total water demand being supplied by rainwater and/or greywater sources, the forecast savings across all four regions ranged from:

- 109,859 kL/year in the Bay of Plenty region to 585,814 kL/year in the Auckland region for the low uptake scenario
- 235,462 kL/year in the Bay of Plenty region to 1.5 million kL/year in the Canterbury region for the medium uptake scenario
- 580,782 kL/year in the Bay of Plenty region to 3.6 million kL/year in the Canterbury region for the high uptake scenario.

4.5.2 Observed scenario

Referring to Table 8, when the buildings were aggregated per region, the volume of non-potable demand that is actually able to be supplied varies. Accordingly, a second supply scenario was used to project future impacts to the water networks based on observed supply at the regional scale.

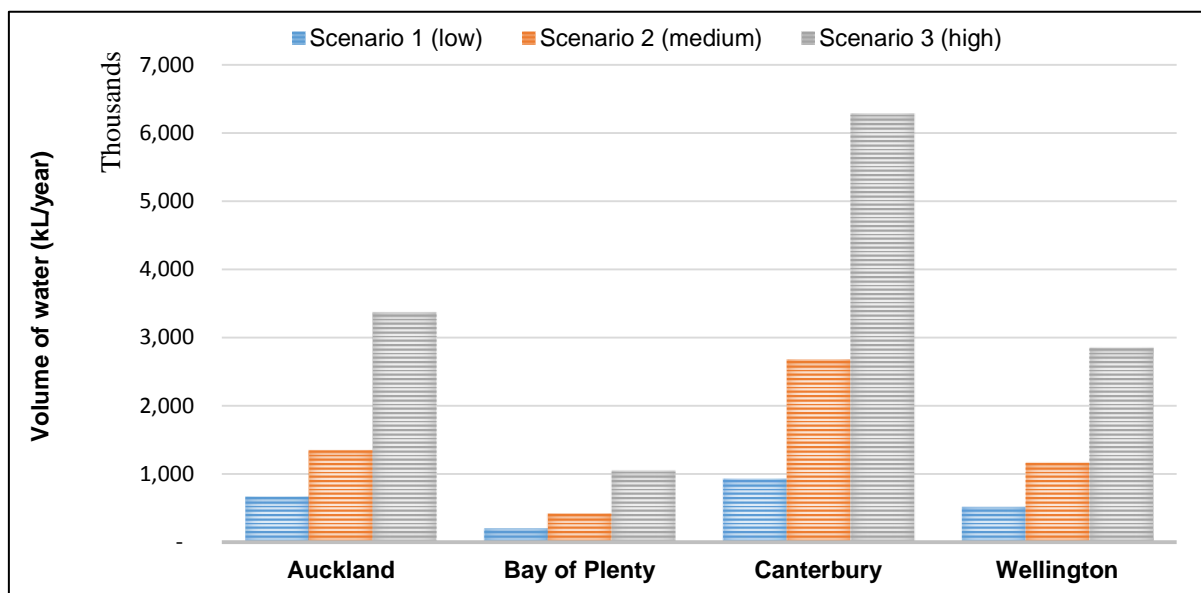


Figure 16. Observed savings to the water networks.

Using an observed scenario per region, the forecast savings across all four regions ranged from:

- 199,743 kL/year in the Bay of Plenty region to 925,170 kL/year in the Canterbury region for the low uptake scenario
- 428,112 kL/year in the Bay of Plenty region to 2.6 million kL/year in the Canterbury region for the medium uptake scenario
- 1 million kL/year in the Bay of Plenty region to 6.2 million kL/year in the Canterbury region for the high uptake scenario.

The greatest potential for volumetric savings occurs in the Canterbury region under the high uptake scenario. Canterbury has the greatest potential savings in part due to the high rainwater-to-mains ratio of the C1 building.

When compared to the forecasted water demand in 2066, the volumes of potential water that can be saved under the optimistic and observed scenarios are comparatively low. Alongside a residential rainwater and greywater scheme, the savings could increase. Furthermore, increasing the water end uses for non-potable water would increase the potential water savings to the networks into the future. Whilst rainwater/greywater systems can contribute to a reduction in network demand, they are unlikely to ever replace traditional sources. The Auckland residential study found that rainwater tanks were unable to meet even half of the expected future demand, even under a high uptake scenario (Klein et al., 2015)

5. Conclusions

The current and future impacts to the water networks are somewhat limited due to the number of available study buildings. However, they do provide an insight into the proportions of total water use that are comprised of non-potable demand. For the 2015/16 period, it was found that only three of the buildings were utilising the full potential of their rainwater and/or greywater systems (Bint, 2017). This is an important consideration when estimating any potential future impacts to the water networks when using the eight case study buildings as a basis. If the buildings were better utilising the existing systems during the monitoring period (2015/16), future extrapolations in terms of volume of water saved from the water networks would undoubtedly increase. This highlights the importance of a large case study database when making future assumptions. It further highlights a potential knowledge gap to how these systems are best maintained to get the optimum usage.

To counter the underutilised rainwater and/or greywater systems of some of the case study buildings, an optimistic scenario based on the average non-potable proportion of all eight case study buildings was calculated. At the regional scale, the observed supply of non-potable sources was assessed, as this varies in some instances from the optimistic average of 23%. Observed non-potable supply was found to range from 4% in the Bay of Plenty region to 38% in the Canterbury region based on the case study buildings data.

Projecting the result from the 2015/16 case study data with specific uptake and supply scenarios shows the potential volumetric savings possible for the water network in the future. This is based on estimated new builds and uptake scenarios. The addition of more commercial buildings data to this analysis would help build a more comprehensive picture of potential future impacts of using rainwater harvesting and greywater recycling technologies across New Zealand.

It is important to note the impacts of rainwater and greywater systems were calculated for non-potable water uses only (for example, toilets and irrigation), based on previous research (Klein et al., 2015).

5.1 Future considerations

Perhaps a large and somewhat overlooked advantage of using rainwater harvesting and/or greywater recycling systems is the capacity to maintain supply given conditions in which the reticulated network is constrained. For example, flood events can overwhelm the network and cause reduced water availability due to water treatment facilities becoming overwhelmed by increased flows and sediment content. Whilst rainwater and/or greywater would be used for non-potable uses only, reducing the demand for treated water during these events would be beneficial. Therefore, as a resilience measure, rainwater and greywater could be an advantageous development in future years.

Moreover, a common consequence of urban development is increased peak discharges and flood frequencies. Urban streams have been found to rise more rapidly than their rural counterparts (Konrad, 2003). In part, this is due to the modification of the landscape required for urban settlement. Removing vegetation from the landscape and replacing it with buildings and roads reduced the imperviousness of the surface and its attenuation capability. These surfaces store little water and accelerate run-off (Konrad, 2003). A solution to this increase in run-off is increasing the capacity to detain rainfall

before it becomes surface run-off. The wide-scale adoption of rainwater tanks could help attenuate stormwater run-off contributing to large flood events.

Water demand forecasts are set to increase – in some cases substantially over the next 50 years. The move to alternative water sources can provide relief to an increasingly pressured resource and is a large driver for continued research and uptake of alternative water sources such as rainwater and greywater in New Zealand

References

- Amitrano, L., Isaacs, N., Saville-Smith, K., Donn, M., Camilleri, M., Pollard, A., Babylon, M., Bishop, R., Roberti, J., Burrough, L., Au, P., Bint, L., Jowett, J., Hills, A. & Cory, S. (2014). *Building Energy End-use Study (BEES) Part 1: Final Report*. BRANZ Study Report SR297/1. Judgeford, New Zealand: BRANZ Ltd.
- Bint, L. (2017). *Performance of commercial building rainwater and greywater systems*. BRANZ Study Report SR383. Judgeford, New Zealand: BRANZ Ltd.
- Bint, L. & Jaques, R. (2017). *Drivers and barriers to rainwater and greywater uptake in New Zealand*. BRANZ Study Report SR382. Judgeford, New Zealand: BRANZ Ltd.
- Ghimire, S. R., Johnston, J. M., Ingwersen, W. W. & Sojka, S. (2017). Life cycle assessment of a commercial rainwater harvesting system compared with a municipal water supply system. *Journal of Cleaner Production*, 151, 74–86.
- Klein, R., Lester, A., Reed, C. J. & Reed, J. P. (2015). *Impact of rainwater tanks on the level of service for water supply in Auckland*. Auckland, New Zealand: CH2M Beca and Tonkin & Taylor for Watercare Services Ltd.
- Konrad, C. (2003). *Effects of urban development on floods*. Fact Sheet 076-03. Tacoma, United States of America: US Geological Survey.
- Maimon, A., Friedler, E. & Gross, A.. (2014). Parameters affecting greywater quality and its safety for reuse. *Science of the Total Environment*, 487, 20–25.
- Ministry for the Environment. (2014). *Delivering fresh water reform: A high level overview*. Wellington, New Zealand: Author. Retrieved from <http://www.mfe.govt.nz/sites/default/files/media/Fresh%20water/Delivering%20freshwater%20reform.pdf>
- Ministry for the Environment. (2016). *How could climate change affect my region?* Retrieved from <http://www.mfe.govt.nz/climate-change/how-climate-change-affects-nz/how-might-climate-change-affect-my-region>
- NIWA. (2001). *Overview of New Zealand's climate*. Retrieved from <https://www.niwa.co.nz/education-and-training/schools/resources/climate/overview>
- NIWA. (2016). *Our future climate New Zealand*. Retrieved from <https://ofcnz.niwa.co.nz/#/home>
- NIWA. (2017). The national climate database. Retrieved from <https://cliflo.niwa.co.nz/pls/niwp/wgenf.genform1>
- Roberti, H. (2014). *Building Energy End-use Study (BEES) Year 5: Auckland's water use*. BRANZ Study Report SR277/8. Judgeford, New Zealand: BRANZ Ltd.
- Siggins, A., Burton, V., Ross, C., Lowe, H. & Horswell, J. (2016). Effects of long-term greywater disposal on soil: A case study. *Science of the Total Environment*, 557–558, 627–635.
- Statistics New Zealand. (2017). *Construction*. Retrieved from http://stats.govt.nz/browse_for_stats/industry_sectors/Construction.aspx

Stocker, T. et al. (Eds.). (2014). *Climate change 2013: The physical science basis: Working Group I contribution to the fifth assessment report of the Intergovernmental Panel on Climate Change*. Cambridge, UK, and New York, USA: Cambridge University Press.

Vitousek, P. M., Mooney, H. A., Lubchenco, J. & Melillo, J. M. (1977). Human domination of Earth's ecosystems. *Science*, 277(5325), 494–499.