WATER PERFORMANCE BENCHMARKS FOR NEW ZEALAND

Understanding water consumption in commercial office buildings

By Lee Ellen Bint

A thesis submitted to the Victoria University of Wellington in fulfilment of the requirements for the degree of Doctor of Philosophy in Architecture (Building Science)

Victoria University of Wellington
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PREFACE

This research thesis was submitted in fulfilment of the requirements for the degree of Doctor of Philosophy in Architecture at the School of Architecture, Victoria University of Wellington, New Zealand.

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ABSTRACT

There is an increasing amount of literature outlining the issues underlying water shortages and restrictions to come in most regions of New Zealand. The problem is not helped by rising demands and climatic changes, as well as both a lack of measured data, and a lack of any demand-side incentives. No attempt has been made to assess how the users of commercial buildings are consuming potable water. There are no benchmarks for water performance in buildings, hindering attempts to improve water efficiency.

This study investigated the water use in 93 Auckland and Wellington commercial office buildings. The data collected from both survey level water audits (on-site investigations, historic billing analysis) and full water audits (water monitoring), were used to develop market-based water performance benchmarks, and a Water Efficiency Rating Tool (WERT). This was done to understand water consumption in these buildings, and to determine the feasibility of using performance based data for the development of a water benchmarking system.

The principal results were in the form of both a benchmarking index system, and the WERT. The benchmarking study found that Net Lettable Area (NLA) was the most statistically and pragmatically appropriate driver for water use. It also found that, due to the distinct difference in tariff structures and incentives between Auckland and Wellington, different benchmarks for the two regions (Auckland 'Typical' use $0.76m^3/m^2$/year, and Wellington 'Typical' use $1.03m^3/m^2$/year) were required.

The WERT calculates a building Water Use Index (WUI – m^3/m^2/year), estimates its end-use disaggregation, and provides recommendations through outlining the financial viability of implementing specific water efficiency measures. This tool utilised six design criteria to ensure target market usability: accuracy (demonstrated at ±8.5%); relevance and realism; practicality; promotion of understanding and action; objectivity; and effective communication.

Further recommendations included satisfying some of the many knowledge gaps present in the New Zealand water industry concerning office building water use. These included: introducing a national legislative or standard document providing guidelines on demand-side management of water; investigation into changing tariff structures to include a volumetric charge for all building types to increase individual awareness and education of water use; research into the durability of water meters; and expanding the research to include other New Zealand regions.

EXECUTIVE SUMMARY

In New Zealand there are no indicators for performance in terms of water consumption or water efficiency in commercial buildings. The delivery of potable water to buildings is paramount for the main reasons of human health and hygiene. However, with increasing water shortages around the country, and around the world, during peak summer demand periods for example, potable water supply to buildings could be compromised.

The aim of this research was to understand the water performance of New Zealand's commercial office buildings, by testing the below outlined methodologies as a means of establishing suitable performance benchmarks for commercial office buildings.

To do this, a literature review was conducted to determine a number of things, including: the current water supply and demand situation for New Zealand; water consumption studies from around the world on similar types of buildings; water allocation and measurement techniques and strategies; and existing benchmarking studies and tools available from around the world.

This information was used to develop the empirical methods of collecting data from 93 commercial office buildings studied across Wellington and Auckland. Two methods were included: a Survey Level Water Audit (SLWA); and a Full Water Audit (FWA). Current water consumption in commercial office buildings was investigated in order to develop measurable performance values and averages which can be compared with other buildings in New Zealand, and around the world; and, in turn, define New Zealand's place on the world map in terms of water performance in buildings.

This allowed data to be obtained whereby performance could be assessed. An analysis took place to measure any specific attributes resulting in statistically significant differences or similarities.

Using the collected data, and international examples, a water benchmark index system was formulated and tested. This piloted the water benchmark index method, outlining the viability of using the building and water data obtained in this study for the development of an official New Zealand benchmarking system. These benchmarking results, together with the data collected from the 93 office buildings studied, were then used to develop a Water Efficient Rating Tool (WERT). The WERT is proposed to be implemented in the industry at a later date.

Net Lettable Area (NLA – m^2) was found to be the most statistically and pragmatically appropriate driver to be used for normalisation of the buildings. This is also suitable for other reasons, such as providing an accurate value for describing the building, which is consistent (as opposed to occupants) as it is a figure known for most buildings. It also offers comparability with other Built Sustainability Rating Tools (BSRTs), such as the New Zealand Energy Use Indices (EUIs) which are normalised by NLA in commercial office buildings.

The Table below demonstrates the proposed market-based benchmarks for commercial office buildings in both Auckland and Wellington. Based on this data, it was determined that if a statistically representative trial were to take place on a national scale at a 95% confidence probability level, then 260 buildings would need to be selected at random.

AUCKLAND (m^3/m^2/year)	MARKET-BASED BENCHMARK (percentile)	WELLINGTON (m^3/m^2/year)
0.57	Best Case (25%)	0.73
0.76	Typical (50%)	1.03
0.97	Excessive Use (75%)	1.33

Table 0.1: Proposed Benchmarks

These data showed statistically significant differences between Auckland and Wellington, hence the two benchmarks. This separation is hypothesised to be due to tariff structures providing water reduction incentives in Auckland, and not in Wellington, as well as residential water metering and direct billing educating users at home.

The WERT was developed with five main design criteria: accuracy; relevance & realism; practicality; promotion of understanding and action; and objectivity. Also, one other overlying criterion was applied, which aids in achieving the above design criteria – effective communication.

The WERT has three levels, plus implementation: WUI calculation; end-use estimator; and Financial Cost-Benefit Advisor (FCBA) tool. Below in Figure 0.1 is a demonstration of the results screen-grab from the end-use estimator.

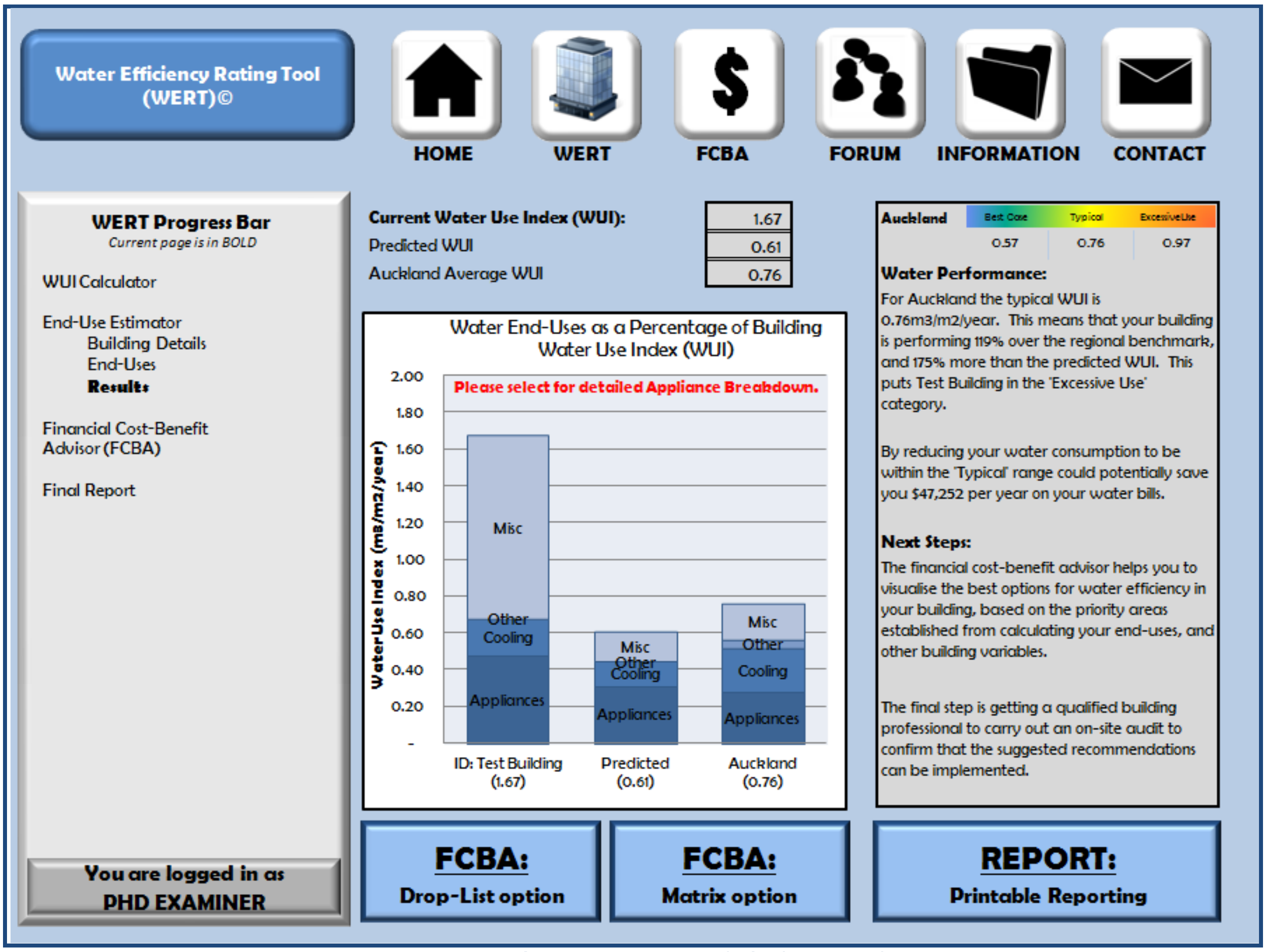

Figure 0.1: End-Use Estimator (Stacked-Chart) Results

The implementation environment and strategy were also considered for benchmarking systems, and such a tool as the WERT, and found that the biggest demand from the industry is 'environmental and cost-benefit evidence and case-studies', which is an output from this tool for each building specifically.

Both the industry interest and the evidence surrounding the argument on whether or not a water performance benchmarking system can be developed using performance based data obtained from water auditing a number of New Zealand commercial office buildings, suggest that it is very much possible.

ACKNOWLEDGEMENTS

In acknowledgement of my research co-supervisors; Professor Robert Vale (*Victoria University of Wellington*) and Nigel Isaacs (*Victoria University of Wellington* and *BRANZ*), and with support from Johannes (Hans) Roberti (*BRANZ*), I would like to thank you for your honest advice, motivation, academic support, and information given throughout this period. I could not have asked for better mentorship.

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- Water New Zealand's Annual Conference & Expo: Water 2020 From Fragmentation to Efficiency, in Rotorua, New Zealand (September 2009);
- New Zealand Sustainable Building Conference SB10: Innovation and Transformation, in Wellington, New Zealand (May 2010);
- Water New Zealand's Annual Conference & Expo: Water Our Key Strategic Resource, in Christchurch, New Zealand (September 2010);
- 37th International Symposium of CIB W062 on Water Supply and Drainage in Buildings, in Aveiro, Portugal (September 2011);
- Water @ Exeter in Exeter, United Kingdom (October 2011); and
- Water New Zealand's Annual Conference & Expo: Advancing Water Reform, in Rotorua, New Zealand (November, 2011).

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To Sophie Howard of *VicLink*, for helping me realise the potential of a business case in the WERT, for her continuous assistance, support, and advice. To *VicLink* for funding me through *Grow Wellington*'s *Activate* course. And to *Grow Wellington* (through the *Bright Ideas Challenge* and *Activate* course) for their advice and genuine interest in supporting this business case. Through the *Bright Ideas Challenge*, this business case was awarded the 'Wellington Regional Council' award.

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SECTION ONE: INTRODUCTION

This is the introductory section, which aims to provide the groundwork for this research on "*Water Performance Benchmarks for New Zealand*."

Chapter 1. Introduction introduces the topic and problem questions, outlines the research aims, and provides a description of the research approach.

1. INTRODUCTION

Inadequate consideration has been given to water use in buildings in New Zealand. Cessation of the delivery of clean (colourless, odourless, and tasteless) potable water into our buildings would result in reduced hygiene (for showering, bathing, washing), and reduced environmental control (heating, ventilating, and air-conditioning). Just as water makes life possible in the natural environment, in the built environment it makes buildings habitable.

Water is 'integral to the health, well-being, livelihood, and culture of all New Zealanders' (Stewart, 2009), and is one of the primary resource inputs into a building. However this resource seems to be simply expected, exploited, and then forgotten. New Zealand has always been seen as a "water-rich" country, and therefore water's true uniqueness and necessity to both human and all other environmental features is not yet understood (McGregor, 2007).

The dependence on the presence of this resource in buildings is significant, yet there is little understanding of its end-uses, and what constitutes good or bad performance. Demand management, as a method of water efficiency or water conservation, cannot be approached without the primary determination of how our buildings consume the purchased and supplied water. This is required for educated decision making and implementation of water efficient design.

A number of recent studies have been conducted on residential water use, as will be discussed, however no studies have been undertaken on commercial, or non-residential, building water use in New Zealand.

The overall aim of this study is to investigate and understand the water consumption of a selection of commercial office buildings in Auckland and Wellington, in order to develop water performance benchmarks and provide them in an easily usable form.

This is demonstrated through the development and validation of a Water Efficiency Rating Tool (WERT), developed using this performance and benchmarking data.

1.1. BACKGROUND

The demand for potable water in New Zealand is rapidly increasing, not only for domestic purposes, but also for industrial, commercial, irrigation, and recreational uses (Stewart, 2009). As Stewart (2009) points out, "there is no longer sufficient water to meet all our needs, in all places and at all times." This means that during times when water is less abundant, i.e. during the dry seasons (summer), increased water shortages, and in turn restrictions will be imposed in certain regions. Stewart (2009) notes this is directly influenced by the increasing variability in climates (increasing temperatures, and decrease in rainfall patterns), and population growth.

1.1.1. CLIMATE VARIABILITY & POPULATION GROWTH

Many water catchments are already over allocated or are approaching full allocation. Water scarcity is an increasing problem in some areas, and may be worsened by changing weather patterns, but our current system of allocating water does not encourage efficient use or easily allow transfer to best use (Land & Water Forum, 2010).

Climate change has the possibility of increasing water supply issues. In order to discuss the effects of climate change, one must first understand the basic chemistry and physics behind the definitions of climate change and global warming (Climate Change Information New Zealand [CCINZ], 2008).

Climate change is a combination of variations in the Earth's orbital characteristics, variations in solar output, and an increase and variation in certain gases (Carbon Dioxide (CO_2), Methane (NH_4), Nitrous Oxide (N_2O) and water vapour) in the Earth's atmosphere (Dorfman, 2008). It is this layer [of gases] that retains the Earth's water in its current form, and as the ratios of these gases change the layer's ability to trap heat changes (Dorfman, 2008).

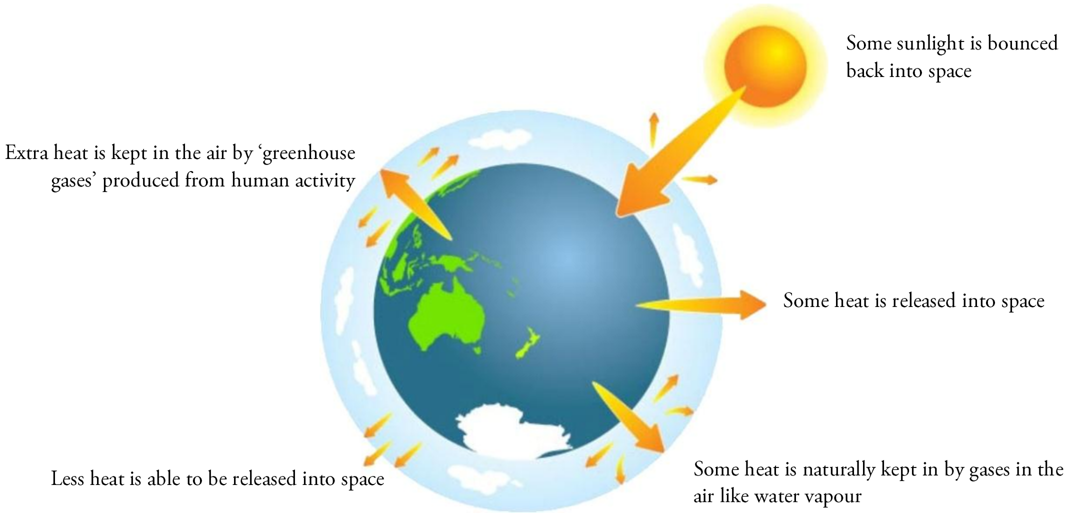

Figure 1.1: Atmospheric Climate Change (Source: CCINZ, 2008)

However, it is the rapid growth in population and the impacts of human activities such as driving cars, burning fossil fuels, and other processes which cause this increase in gases in the atmosphere, and of which the effect is significant in comparison to those of natural variations (CCINZ, 2008).

Climate change not only affects variations in climate and weather systems, but it also affects the function and operation of existing water infrastructure in more than one way, as well as current water management practices (Bates et al, 2008). According to many experts, including the *Intergovernmental Panel on Climate Change (IPCC)*, water and its availability and quality will be "the main pressures on, and issue for, societies and the environment under climate change" (Bates et al, 2008). As these issues have not been addressed under climate change analyses (OECD, 2006), it is therefore important to make preliminary assessment of how severely it is expected to effect the water supplies in New Zealand.

1.1.2. WATER AND BUILDINGS

The energy used in the supply and delivery of water is high (Lawton et al, 2010), and the treatments used to make water of a clean, drinking standard, increase this. A full list of chemicals found in and added to water sources is given in Appendix B3. In addition to this, the projected rise in population, and increased variability in the climate are primary constituents of water demand pressures (Bates et al, 2008).

While increasing demands push harder and harder on the water infrastructure, in New Zealand there is a shortage of both technical and practical information available with regard to water consumption in buildings, other than the recent studies conducted by the *Building Research Association of New Zealand (BRANZ)*, which were for residential buildings only.

- *Water Efficiency and End-Use Project (WEEP)* (Heinrich, 2007); and

- *Auckland Water Use Study (AWUS)* (Heinrich, 2008) studies.

There currently appears to be no strategies in place, no targets set for water reduction, and no performance levels outlining consumption benchmarks in New Zealand.

1.1.3. DEMAND-SIDE MANAGEMENT – AN APPROACH

Demand management, i.e. the reduction of consumption through the users, can be introduced through providing performance benchmarks, guidelines, and/or incentives. Water benchmarks are indicators of performance, and in the context of this research, it is the performance of water consumption and efficiency in commercial office buildings that is the focus. The primary purpose of a benchmarking measure is to 'normalise' water use with respect to the size and type of the building (Waggett et al, 2006a), which enables a method of comparison relative to other similar buildings.

Recent Australian research efforts have demonstrated that there is little to no knowledge as to what denotes good or bad performance with regard to water (Bannister et al, 2006). With this lack of knowledge and information on water consumption in buildings, it can be found that, both in New Zealand and internationally, benchmarking needs to be undertaken. This could allow the barrier currently preventing the market from responding to poor performance, to be overcome (Bannister et al, 2005).

There is a lack of suitable benchmarking information facilitating a simple method of comparing the water consumption of a particular property with other similar buildings and with national trends. There are a few international examples of water performance benchmarking, such as:

- *Water Efficiency Guide: Office and Public Buildings* by the *Australian Government: Department of Environment and Heritage (DEH)* in Australia (Quinn et al, 2006);

- *Commercial and Institutional End Uses of Water Study* (*CIEUWS*) by the *American Water Works Association (AWWA)* in the United States of America (Dziegielewski et al, 2000);

- *Practice Guidelines: for water conservation in commercial office buildings and shopping centres* by *Sydney Water Corporation (SWC)* (SWC, 2007);

- *Watermark* project by *OGCbuying.solutions* in the United Kingdom (Kitchen et al, 2003);

- *Water Key Performance Indicators and Benchmarks for Offices and Hotels* (*CIRIA C657*) by the *Construction Industry Research and Information Association (CIRIA)* study in the United Kingdom (Waggett et al, 2006b); and

- *Water Benchmarks for Office and Public Buildings* study by *Exergy* for the *Australian Government Department of Energy and Climate Change (DECC)* (Bannister et al, 2005).

These studies are classed as leaders in the field of water consumption research in the commercial building sector, as they have shown strong analysis and statistical methodologies for determining appropriate benchmarks for their regions, and have provided the basis for international comparisons to be made. These studies have been referred to throughout this research for guidance, when needed. On publication of a benchmark index system, building managers and owners will be able to determine how well their buildings are performing. This method will provide quick and simple results, enabling savings opportunities and areas of concern to be determined.

The creation of a water benchmark index system for commercial office buildings in New Zealand is just the beginning of implementing demand side management, gauging where efficiency levels lie, and identifying the scope for possible improvements. The next step includes implementing this data as an effective and informative model. A Water Efficiency Rating Tool (WERT) has been developed providing performance rating, end-use disaggregation, and financial cost-benefit analysis to meet this need.

1.2. SCOPE

Potable water is generally defined as 'water which is suitable for human consumption' (Corr et al, 2008), and is commonly referred to as drinking water. The scope of this research is to investigate and normalise the demand for potable water from commercial office buildings within Central Business District (CBD) locations only, throughout New Zealand. This research covers the assessment of commercial office buildings within both Auckland and Wellington CBD locations, as a starting point.

This research does not look at any buildings other than commercial office buildings. Also it will not discuss grey-water, wastewater, stormwater, or their related issues, even if links present themselves, unless otherwise stated.

The results of this work are used to establish measurable performance benchmarks and average consumption values as a starting point for introducing demand-side management in the commercial office building sector. This is demonstrated through the implementation of a WERT.

1.2.1. PROBLEM STATEMENT

There is an increasing amount of literature outlining the issues underlying water shortages and restrictions to come in most regions throughout New Zealand (Bates et al, 2008), especially during the drier summer months.

However, no attempt has been made in New Zealand to assess how the users of commercial office buildings, are consuming potable water. There are no benchmarks for water performance in buildings, thus disadvantaging any attempts made in improving water efficiency in New Zealand. There are a few international examples of water consumption in these types of buildings, but these may not be accurate for New Zealand buildings due to climatic, technical, and behavioural differences.

1.2.2. AIM & HYPOTHESIS

The overall aim of this research ***'Water Performance Benchmarks for New Zealand: understanding water consumption in commercial office buildings'***, is to understand the water performance of New Zealand's commercial office buildings, by testing the methodology (refer Chapter 1.2.3.) as a means of setting suitable performance benchmarks for commercial office buildings. This has been performed by attempting to answer the following research questions:

- How is water used in New Zealand office buildings?
- What determines water use efficiency?
- How do New Zealand office buildings compare internationally?
- What is needed to provide the support for higher levels of water efficiency and conservation?

The specific objectives were to understand the water using systems in existing office buildings, establishing implementable water performance benchmarks, and developing a Water Efficiency Rating Tool (WERT) which allows building owners, managers, and users to improve their building performance.

The hypothesis is that *'a water performance benchmarking index system can be developed using performance based water consumption data obtained from water auditing a number of New Zealand commercial office buildings'*.

1.2.3. METHODOLOGY OVERVIEW

A basic Survey Level Water Audit (SLWA) has been conducted on 93 commercially defined office buildings within the Auckland and Wellington CBDs. The data gathered from these water audits, and the historical water billing data for each building, form the basis for water performance benchmarks established through statistical and comparative analyses.

A SLWA involves identifying key building and user characteristics, as well as visiting the site to inspect visually and record all water consuming equipment/appliances within the building and its physical site. An analysis of water meter readings over the past five years together with key variables identified from the site surveys enables analysis to take place in forming appropriate water performance benchmarks from this study.

A Full Water Audit (FWA) was then undertaken in a smaller sub-portion (3 buildings) of the study. This involved installing monitoring equipment onto the main water meter(s), and collecting time-of-use water data. This helped in determining how and when water is being used within each building. The results from these audits were then used to develop appropriate benchmarks and a tool to assist building owners, managers, and users to use water more efficiently.

1.2.4. ETHICAL CONSENT

As the bulk of this study did not involve a questionnaire of personality, perception, or opinion, and only water and building data collection was required, ethical approval was not required. For the WERT trials and industry workshops (which were undertaken during August 2011, refer Chapter 13.1.3), ethical consent was gained through the *Victoria University Human Ethics Committee* (approval 18557). Please refer to Appendix C1 for the approval memorandum.

As this project was run concurrently with the *Building Energy End-Use Study (BEES)*, ethical advice was sought from contributing members of this study. All documents obtained from or containing data on individual buildings were kept confidential and secure for the duration of the study, and returned to the corresponding building management or destroyed upon completion of the research.

1.3. PROFESSIONAL SIGNIFICANCE

Firstly, this research provides an introduction to understanding water consumption in the New Zealand context; however, it is just the beginning of an attempt to fill in the voids in the New Zealand literature. This benchmark index system provides commercial office buildings in New Zealand with a baseline for water performance and rated levels of water efficiency. It will support the setting of both policy and individual water use targets for commercial users, as well as building performance rating tools, including the WERT and the *Green Star New Zealand (GSNZ) Office tool*. Although based on Auckland and Wellington CBD the methodology is applicable to other locations, requiring the future collection of appropriate data.

Determining this method as both statistically and pragmatically appropriate for New Zealand buildings, also enables replication of this methodology for other types of buildings, in other categories. Thus, establishing the method for determining water performance benchmarks will also create the beginnings of the development of a useful database for further establishing water efficiency strategies in New Zealand.

1.4. RESEARCH APPROACH

The following research approach was undertaken which gives the thesis its structure. This thesis is broken up into six sections to allow a clear and concise picture to be formed:

- *Section 1*: Introduction;
- *Section 2*: Literature review, industry identification of potential efficiency measures and empirical research into factors with measurable impact on building water efficiency;

- *Section 3*: Sampling Approach and Methodology;
- *Section 4*: Field Study Analysis;
- *Section 5*: Tool Development; and
- *Section 6*: Discussion.

The first section is the introductory section, ***Chapter 1. Introduction*** introduces the topic and problem questions, outlines the research aims, and provides this description of the research approach.

The second section is a review based on the existing literature, which outlines issues within the New Zealand context, and determines the necessity of this research. ***Chapter 2. Water Supply for New Zealand*** introduces the underlying supply issues within New Zealand. These issues are outlined in terms of both increasing climate variability and population growth, and the current state of supply side infrastructure and management systems.

Chapter 3. Water Consumption discusses water consumption, which in the context of this research focuses upon the consumption within commercial buildings, as this is where current literature seems to be lacking the most. ***Chapter 4. Water Allocation & Measurement*** outlines the selected allocation strategies, measuring devices, and auditing techniques of water. Then in ***Chapter 5. Benchmarking & Tools***, the purpose and types of performance based benchmarks and analysis tools are introduced as a solution to the issues outlined in the previous three chapters. However, it has been identified by the number of case studies internationally, that this technique is still in the early stages; nevertheless, examples from the energy sector can also be adapted.

The third section is the methodology outline; where ***Chapter 6. Building Selection & Sampling Approach*** outlines the method and criteria for selecting the sample and its size. ***Chapter 7. Water Auditing Methods*** describes the survey phase strategies, while ***Chapter 8. Data Analysis Methods*** summarises the analysis and benchmarking techniques for the water benchmarking index system. This chapter does not outline any results; its sole purpose is to define the methodology to be tested under this study.

The results, analytical discussions, and benchmarking development form the basis of the fourth section. The results are given in ***Chapter 9. Field Observations***. This discusses the observations made through the data collection phase; from building management knowledge, and through site surveys for each of the buildings. Identification of demand drivers for water are determined. This chapter forms the basis for the benchmark analyses.

Chapter 10. Detailed Water Analysis discusses the results from the FWA, displaying the time-of-use water analysis from the monitored buildings. Then, under ***Chapter 11. Benchmark Analysis***, statistical techniques outline the most statistically and pragmatically appropriate normalisation measures to be used under this dataset. From here, the statistical methods and processes adapted from previous international studies have been used to determine two distinct performance benchmarks. These performance benchmarks are then tested by analysing the normalised levels of water use between published international literature, and discussing the similarities of current New Zealand energy performance benchmarks.

The fifth section provides a discussion on the reality of implementing these changes into the New Zealand market environment. The design and development of the WERT are discussed in ***Chapter 12. Database/Tool Design***. Strategies and issues are discussed within ***Chapter 13. Implementation***. This also includes possible collaboration techniques with current Built Sustainability Rating Tools (BSRT), such as the *GSNZ* rating tool.

Key findings and discussion, which lead to future recommendations are then outlined within the sixth and final section. ***Chapter 14. Discussion*** provides a reflection of the research in the context of the research and specific aims and questions posed in Chapter 1.2.2. ***Chapter 15. Conclusions*** is where the significance of these key findings can be found, along with future research avenues which should be sought.

The appendices for this research are to be found at the rear of this thesis, and provide additional and/or supporting information relating to the study discussed in the text.

SECTION TWO: LITERATURE REVIEW

This section is a review based on existing literature. This section aims to outline any issues relating to water supply, water consumption, water demand (allocation), and benchmarking n the New Zealand context. This section determines the necessity of this research, and provides a theoretical support to a number of the research questions posed in Chapter 1.2.2, which will be answered later in the thesis:

- What determines water use efficiency?
- How do New Zealand office buildings compare internationally?

Chapter 2. Water Supply for New Zealand introduces the underlying supply issues within New Zealand. These issues are outlined in terms of both increasing climate variability and population growth, and the current state of the supply side infrastructure and management systems.

Chapter 3. Water Consumption discusses water consumption, which in the context of this research focuses upon the consumption within commercial office buildings, as this is where the current literature seems to be lacking the most.

Chapter 4. Water Allocation & Measurement outlines the selected allocation strategies, measuring devices, and auditing techniques of water.

Then in Chapter 5. Benchmarking & Tools, the purpose and types of performance based benchmarks and analysis tools are introduced as a solution to the issues outline in the previous three chapters. However, it has been identified by the number of case studies internationally, that this technique is still in the early stages; nevertheless, examples from the energy sector can also be adapted.

2. WATER SUPPLY IN NEW ZEALAND

This chapter discusses the background to the current water supply issues in the New Zealand context, and outlines the underlying issues which contribute toward the need for sustainable water development. How water is supplied and delivered, and current and predicted future water shares in New Zealand will be described. It also shows that historically the ideology behind water supply is to ensure the supply can meet the demand, whereas, as outlined here, this may not be a possibility in the near future without further action.

2.1. DISTRIBUTION SYSTEMS & INFRASTRUCTURE

Water in New Zealand is typically sourced from either ground water or surface water systems. Ground water systems are known as aquifers, and are below the Earth's surface. Surface water refers to the collection of water from rivers, lakes, and dams.

Surface water availability and quality is affected primarily by the climatic conditions. Figure 2.1 below demonstrates the current percentage of surface water allocation; showing that the major centres of Auckland, Hamilton, and Christchurch are already approaching or are at full allocation.

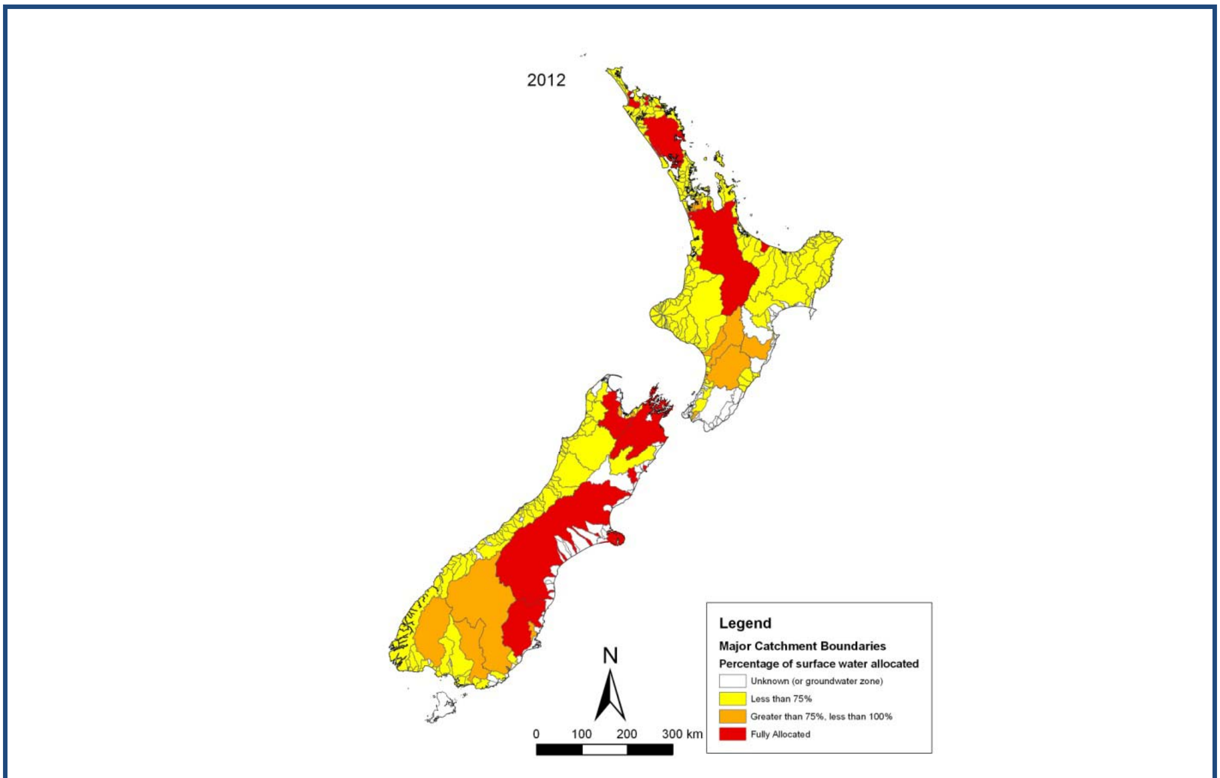

Figure 2.1: Major Catchment Boundaries (Source: Gudgeon, 2004)

Although the majority of water supplies appear to be from surface water sources, water is supplied 41.3% from groundwater sources, and the remaining 58.7% is supplied from surface water sources. These figures are based on the number of allocation consents issued (Gudgeon, 2004).

2.1.1. WATER SUPPLY

Throughout New Zealand water is typically sourced by Regional Councils, and delivered to service plants for treatment and monitoring, before being on-sold to billing utilities in each region. Infrastructure is also referred to as 'the built system' (Williams, 2001a), and includes the network of water supply reservoirs, water supply plants, pipes, concrete channels, drains, wastewater treatment plants and outfalls (Williams, 2001a).

Figure 2.2 and Figure 2.3 show the Auckland and Wellington supply areas. The water supplier for the Wellington region is the *Greater Wellington Regional Council (GWRC)*. *Capacity Ltd* is the company which delivers the water to each building in the Wellington City area, and monitors the distribution network within Wellington City, while *Wellington City Council (WCC)* are the water billers.

Figure 2.3 demonstrates the number of sources and water treatment plants servicing the *GWRC*. The *GWRC* sources water supply from five sources from around the region: the Hutt River and Stuart Macaskill Lakes in Upper Hutt; Wainuiomata and Orongorongo Rivers in Wainuiomata; and the Waiwhetu Aquifer. Water is then transported to one of four water treatment plants. The *WCC* buys water each year from the *GWRC.*

The water suppliers for the Auckland region are *Watercare Services Ltd*. As shown in Figure 2.2, the water is sourced from ten dams, one river, and one underground aquifer, over four regions: Hunua Ranges (Mangatangi Dam, Upper Mantawhiri, Cosseys Dam, Wairoa Dam, and Hays Creek); Waitakere Ranges (Waitakere Dam, Nihotupu Dam, and Huia Dam); Waikato River; and Ohehunga Aquifer.

The treated water is then distributed to one of the seven regions throughout Auckland. As of 1 November 2010 Auckland merged to become one super-city. *Watercare Services Ltd* is the primary distributor under the new *Auckland Council (AC)*.

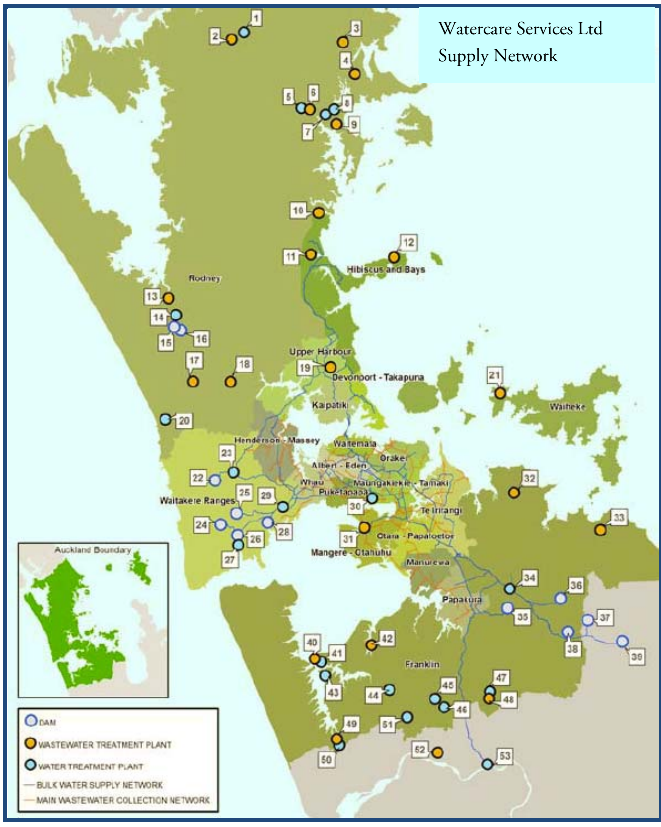

Figure 2.2: Auckland Water Supply Network (Source: Watercare Services Ltd, 2010)

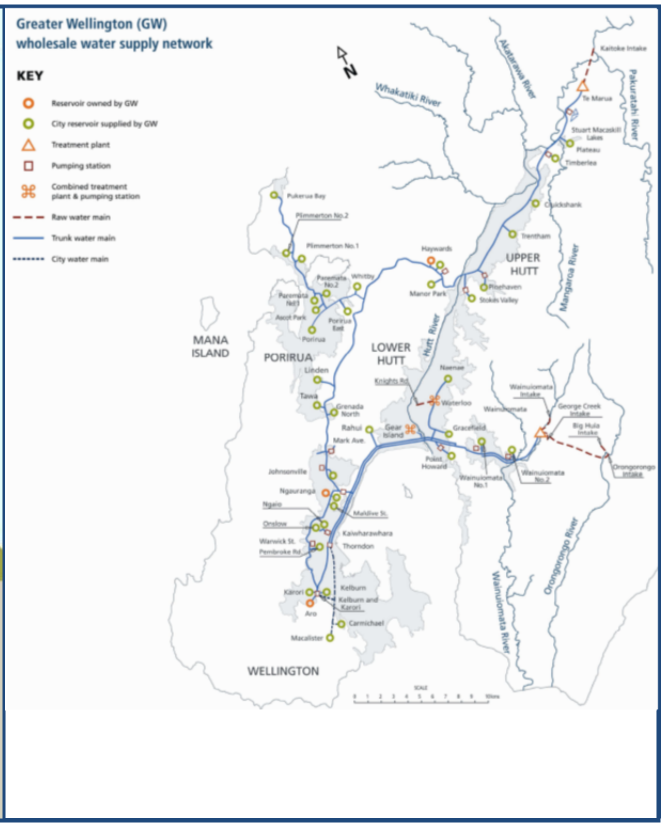

Figure 2.3: GWRC Wholesale Water Supply Network (Source: GWRC, 2012)

Current water suppliers for all of New Zealand are listed in Appendix B2. Within each of the outlined cities, water is delivered to reservoirs.

It has been identified that access to safe drinking water depends more on the level of water supply infrastructure, than on the quantity of runoff from precipitation (Bates et al, 2008). The level of New Zealand's infrastructure is said to be in need of improvement in most areas (OECD, 2006). It has been estimated that approximately NZD$5 billion of investment will be required over the next twenty years to upgrade water related infrastructure (Williams, 2001a). It is the infrastructure that enables the delivery of safe drinking water to buildings.

2.1.2. WATER TREATMENT & QUALITY

The water treatment requirement is different for each region, and is sometimes even different for zones within regions, for example in *GWRC*, Wellington requires fluoride, while the other three areas (Upper Hutt, Lower Hutt, and Kapiti) do not. The image below displays the flowchart of water treatment for the *GWRC* (WRC, 2001):

1- Creating the right water pH for the treatment chemical to attract dirt and impurities.
2- Coagulation: mixing the treatment chemical into the water.
3- Flocculation: allowing time for impurities to attach to the treatment chemicals.
4- Separation: concentrating the blobs (flocculation) formed by the chemicals and impurities, into a thick layer and removing it.
5- Filtration: catching any remaining flocculation.
6- Adding disinfection to the clean water to kill any bacteria within the distribution pipes.
A- Sand and other media in the bed of the filters trap flocculation as water flows down through it.
B- The filter media is cleaned regularly to stop it from becoming clogged with flocculation. First, water flow into the top of the filter is shut off. Second, a combination of air and water is forced up through the filter bed to loosen the flocculation and float it to the surface of the filter, from where it is flushed away to waste. The solid material is separated out and disposal of at a landfill. The retrieved water is recycled through the treatment process. Third, the filter material settles down again, and the filter is returned to use.

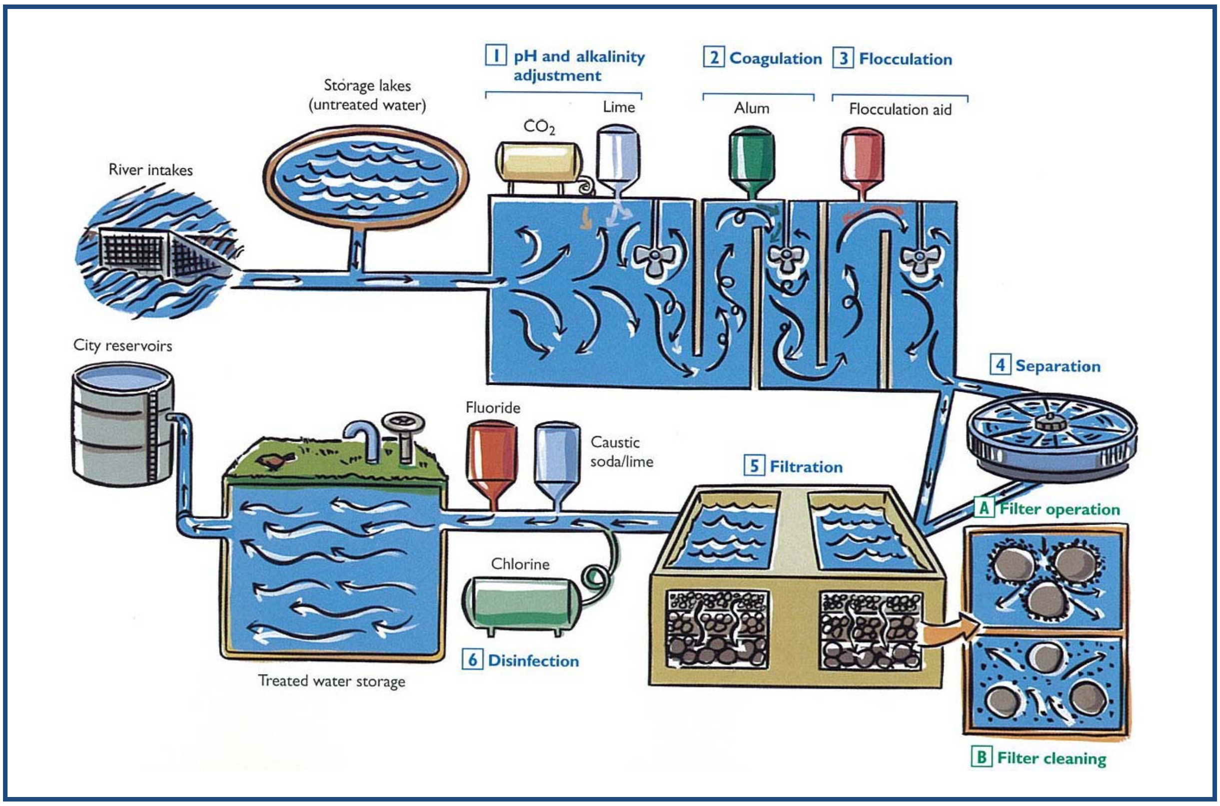

Figure 2.4: Water Treatment flowchart for the Greater Wellington Region (Source: WRC, 2001)

From here, the water is delivered to a number of reservoirs within each of the defined regions, the water entering each reservoir is monitored and metered by the *GWRC*, and/or the relevant supplier for that region.

2.1.3. CONSUMER DISTRIBUTION

The distributors for each region are also responsible for water meters at each commercial (and/or residential/other) property supplied. However, the water supply is the property owner's responsibility once it reaches the point of supply, as shown below in Figure 2.5.

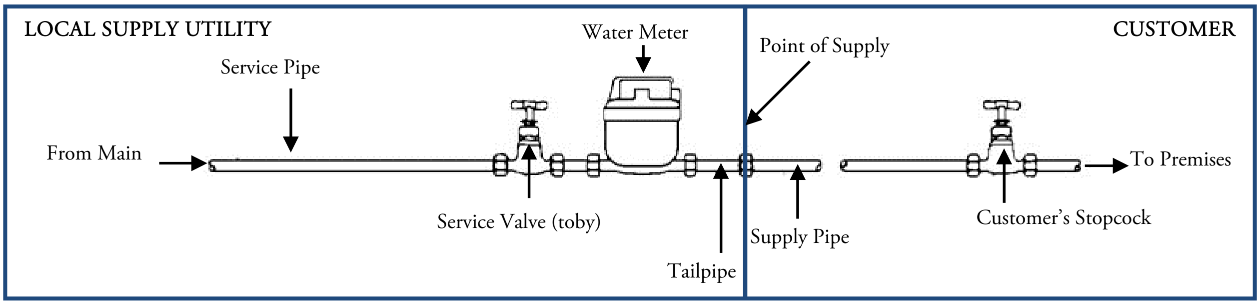

Figure 2.5: Ownership and Responsibilities (Source: WCC, 2009)

Once the water reaches the point of supply (for both metered and non-metered water supply), the delivery system (pipe work) then becomes the customer's responsibility to maintain. This typically means that the water meter is controlled and maintained by the local supply utility, as it is in their best interest to ensure accuracy of their readings.

Current consumption data, for differing regions of New Zealand, appears to be extremely vague. In some parts metering is mandatory for both residential and commercial users, and in others, only commercial users are metered and charged on a per consumption basis. This has formed the basis of many disagreements when comparing regions' per capita water consumption for example (Chipp, 2009).

If water metering is used for all consumers, then comparisons can be accurately made, and leaks within infrastructure and distribution systems can be more easily identified. Tariffs can more adequately meet the needs of environmental and management systems, and customers who have to pay for how much water they consume are likely to become more water conscious. There are many examples of effective water meter implementations around New Zealand, including in Tasman, Tauranga, and Auckland regions (Jaduram, 2009).

2.2. THE CHANGING CLIMATE

There have been two main causes of water shortages identified in recent literature, that is the limitations of quantity due to climatic conditions, and increased use linked to population growth (Bate, 2006). As the *IPCC* point out, "water resource issues have not been adequately addressed in climate change analyses" (Bates et al, 2008), yet it has also been stated that water will be most largely influenced by the changing climate (OECD, 2006), as identified in Chapter 1.1.1. Therefore it is important to make preliminary assessment of what this means, and how severely it is expected to influence the water supplies for New Zealand.

New Zealand has a rather moderate climate, whereby the majority of the precipitation is found during the winter and spring months. The total annual volume of precipitation varies between 300,000 million and 600,000 million cubic metres (Gudgeon, 2004). However, as this naturally varies in each location, urbanised areas have been found to be less abundant in water than those more rural locations (Gudgeon, 2004).

It is believed that New Zealand is already beginning to see the effects of climate change, as many countries have done in recent years. New Zealand specifically is displaying an overall warming trend, over the past century ambient temperatures have risen by approximately 0.9°C on average (NIWA, 2008). Water supply impacts are directly influenced by these recent changes, which are due to natural variability in climate induced patterns, and human activity (Bates et al, 2008).

The *National Institute for Water and Atmospheric research (NIWA)* publishes computer simulated projections of the New Zealand climate regularly via its climate database and climate modelling scenarios. Current predictions include an increase in mean ambient temperatures by approximately 1°C by 2040, and 2°C by 2090; for a mid-range scenario (NIWA, 2008), this doubles the temperature increase measured over the last 100 years. Not only is this temperature increase expected but less rain along the eastern parts of the country is predicted, while more rain is expected on the western and more southern parts (NIWA, 2008); as shown in Figure 2.6 and Figure 2.7 below.

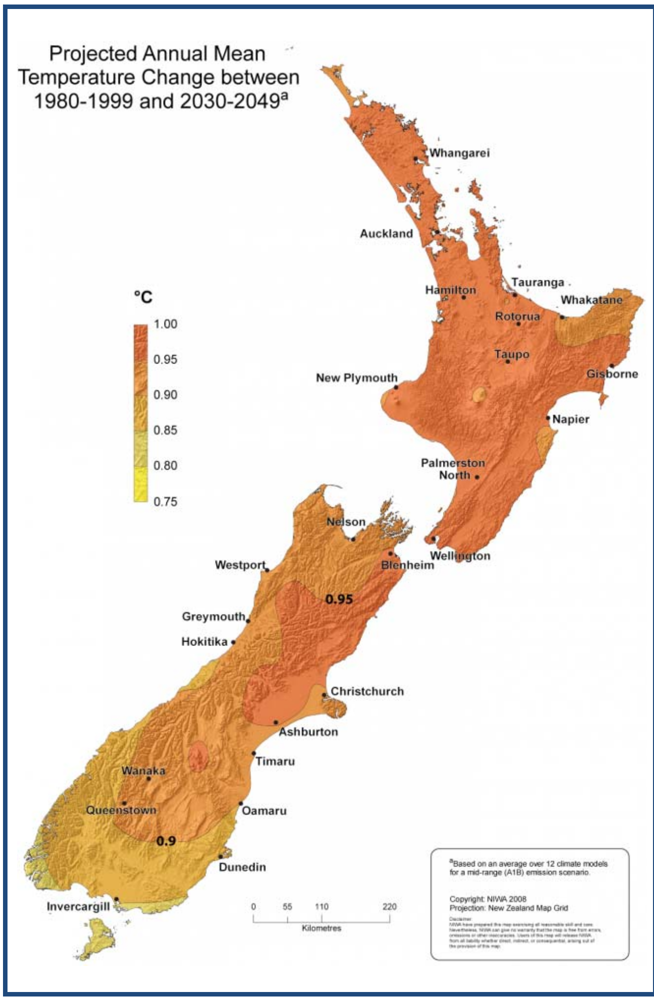

Figure 2.6: Projected Annual Mean Temperature (Source: NIWA, 2009)

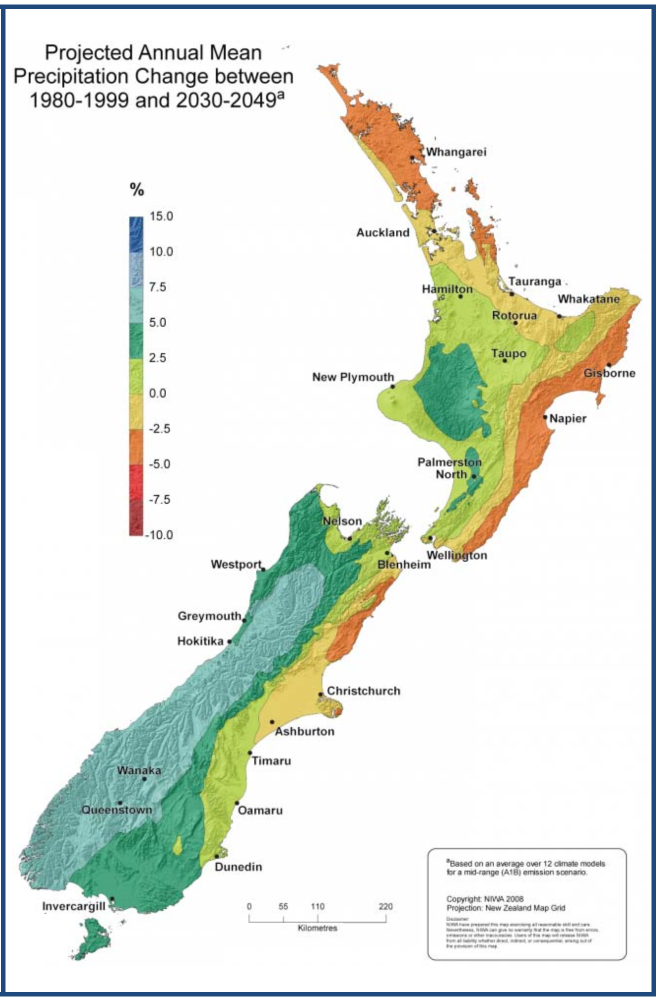

Figure 2.7: Projected Annual Mean Precipitation (Source: NIWA, 2009)

Although Figure 2.7 above shows an overall increase in rainfall in the western parts of the country, it is the average annual precipitation changes, e.g. does not relate to peak demand (summer) periods when there is likely to be less precipitation. This indicates that even though rainfall in the west is predicted to increase during the winter and spring months, an overall decrease is predicted for most eastern parts of the country.

Currently the already drought prone areas are also covering these eastern parts of the country, and as can be seen in Figure 2.7, these areas are also where the highest demands are to be found (PricewaterhouseCoopers, 2005), such as the most urbanised locations of Auckland, Hamilton, Wellington, and Christchurch, among others. And it is these areas in which the *IPCC* has stated 'ongoing water security problems are very likely to increase in the near future' (OECD, 2006).

2.3. WATER SHARES

As population continues to rise, the share of water available to each person is reduced, unless more supplies are sourced or overall per person demands are reduced. Not only this, but increases in population can typically mean increases in water pollution, which in turn affects the availability of freshwater and levels of treatment and energy required to maintain a safe drinking standard for the delivery of water.

The estimated increase in population in New Zealand by 2031 is 18%, bringing the national total up to approximately 5,148,500 residents, with Auckland alone to have approximately 1,944,700 residents and Wellington 541,200 residents (Statistics New Zealand, 2012). As defined by the *Ministry of Economic Development (MED)*, future water demand trends can be estimated by applying *Statistics New Zealand* projections of population change in the period of 2010 to 2031 to the water use from 2010 consent allocations.

$$E_{2031} = E_{2010} \times G$$

Equation 2.1: Estimating Future Water Use (Source: PricewaterhouseCoopers, 2004)

Where: E_{2031} is the estimated water use in 2031, E_{2010} is the estimated water use in 2010, G is the regional population growth (PricewaterhouseCoopers, 2004).

Region	Population[1]			Potable Water Demand[2]	
	2010	2031	G	E_{2010}	E_{2031}
Northland Region	157,400	171,300	9%	57,000	62,034
Auckland Region	**1,461,900**	**1,944,700**	**33%**	**134,600**	**179,052**
Waikato Region	409,300	468,200	14%	313,000	358,042
Bay of Plenty Region	275,100	323,400	18%	200,000	235,115
Gisborne Region	46,600	45,900	-2%	61,000	60,084
Hawke' s Bay Region	154,800	158,300	2%	164,000	167,708
Taranaki Region	109,100	108,500	-1%	73,000	72,599
Manawatu-Wanganui	231,500	236,900	2%	79,000	80,843
Wellington Region	**483,300**	**541,200**	**12%**	**52,777**	**59,486**
Tasman Region	47,300	53,200	12%	52,000	58,486
Nelson Region	45,500	49,900	10%	8,000	8,774
Marlborough Region	45,300	48,700	8%	100,000	107,506
West Coast Region	32,700	31,300	-4%	116,000	111,034
Canterbury Region	565,700	652,400	15%	2,830,000	3,263,730
Otago Region	207,400	225,900	9%	1,063,000	1,157,819
Southland Region	94,200	87,900	-7%	11,913,000	11,116,271
New Zealand	4,367,800	5,148,500	18%	17,386,000	20,293,571

Table 2.1: Projected Growth in Population and Water Demand Allocation (Source: Statistics New Zealand, 2011; MfE, 2010)

Thus Table 2.1 shows the overall demand for water is expected to rise by at least 18% over the period (from 2010 to 2031) due to population growth.

2.3.1. BALANCING THE FUTURE

[1] Numbers derived from Statistics New Zealand (Statistics New Zealand, 2011).

[2] Potable Water Demand measured as ML per year, E_{2010} sourced from MfE (MfE, 2010).

Using the information from Table 2.1, and the per capita water consumption as obtained from the individual water suppliers, current consumption can be measured against the supply of potable water available through present infrastructure.

The capacity of the water supply system is determined by a wide range of factors, including pumping station capacity, storage facility capacity (dams or reservoirs), and resource consent water-take limits.

Region	2010 Demand	2010 Capacity	2031 Demand	Year Capacity Limit Reached
Auckland Region	134,600 ML	196,288 ML	179,052 ML	2039
Wellington Region	52,777 ML	76,833 ML	58,486 ML	2090

Table 2.2: Difference in 2031 Projected Demand and Current 2010 Capacity

As noted above, no additional capacity seems to be required by 2031, however, it should be noted that this is only based on the annual demands, and does not consider any peak demands during drier seasons; which in some cases can reach as high as twice the average daily load (SWC, 2002).

2.4. SUMMARY OF WATER SUPPLY IN NEW ZEALAND

Sources of information on the supply of water in New Zealand have proved to be minimal. However, the sources that are present are explicitly there for the purpose of ensuring demand consumptions are met. What the majority of the literature has failed to recognise is that water availability is limited, and the focus must now be turned to finding ways to reduce demands rather than trying to increase supply to meet these rising demands. At current population growth, these limits will be met in the Auckland region in 27 years and in Wellington in 78 years.

The *Parliamentary Commissioner for the Environment (PCE)* has outlined through a number of reports, the effects demand management and water efficiency strategies can play on the supply-side. “Solutions are needed to support more efficient water use and to recognise the important linkages between the different water services components of water supply, treatment, use, and disposal of wastewater, and stormwater" (Williams, 2001a).

The *PCE* also goes on to state that “progress could be made in the area of demand management and least cost planning. In practice this will involve a package of measures including regulation, economic instruments, information, and education, along with measures which directly address production as well as consumption patterns” (Williams, 2001a).

3. WATER CONSUMPTION

In the frame of this research, water consumption refers to the demand for potable water, and the volume of this water purchased for differing uses. In order to understand the process of designing water benchmarking systems the water consumption must firstly be understood.

This chapter sets out the background knowledge of how commercial buildings and their users consume potable water, in the New Zealand context. Where New Zealand literature has been found to be lacking, those international studies which are considered in this research to be leaders in this field (*SWC*, *Exergy*, *Watermark*, and *CIEUWS*), have been used to provide the best available knowledge.

This chapter explains the reasons behind the selection of commercial office buildings as the area of study within the industrial & commercial user category, and discusses the issues and the differences in water-use between both categories and regions. It then outlines the details of how purchased water is consumed in a typical commercial office building, and describes a selection of specific demand drivers.

3.1. CATEGORY DESIGNATION

In order to compare the consumption and use of water in buildings, a like-for-like comparison must be made. This means that only buildings that are similar in their activities and their function can be compared against each other. This is easiest done by assigning categories and using these to determine similarities.

As a large proportion of buildings in New Zealand are not metered for their water consumption, Regional Councils commonly combine a whole regions' worth of water use into a per capita figure (Chipp, 2009). However the differing number and types of establishments within that region may skew these figures between, for example, residential and commercial users. Therefore, building category designation needs firstly to be determined, followed by the water use for each of those categories.

3.1.1. BUILDING CATEGORIES

The *Building Energy End-use Study (BEES)* project, which is currently being led by *BRANZ*, is a nationwide study looking at resource use within non-residential buildings. One of the first issues they encountered was the lack of information on the number and types of buildings in New Zealand, in absolute figures.

BEES research found that, in New Zealand, there are 50,539 non-residential buildings (including commercial and industrial classifications). Up to 13,669 buildings, or 27% of the total, may contain commercial 'Office' space (along with other 'Mixed Use' space), while there are 7,133 (14%) buildings which are solely used as commercial 'Office' buildings (Isaacs et al, 2009).

User Category	Number of Buildings			
	Auckland	Wellington	Christchurch	New Zealand
Commercial:	**7,907**	**3,445**	**4,340**	**34,473**
- Mixed Use[1]	2,327	838	691	7,133
- Office Only	1,791	553	850	6,536
- Retail Types	3,789	2,054	2,799	20,804
Industrial:	**3,410**	**1,713**	**3,068**	**16,066**
- Service	1,388	1,225	1,062	9,625
- Warehouse	2,022	488	2,006	6,441

Table 3.1: Building Energy End-Use Study (BEES) Category Disaggregation (Source: Isaacs et al, 2009)

The main centres are outlined above, with Auckland having up to 36% of non-residential buildings being classified as partially or fully occupied by office type tenants, Wellington up to 27%, and Christchurch up to 21% (Isaacs et al, 2009). It should be noted that these figures were representative prior to the Christchurch earthquakes, and will have changed. Due to severity of the Christchurch situation, no further comment can be made.

For ease of access and comparability, as a starting point the sub-category group of commercial office buildings was selected for this investigation. Within the most densely populated urban areas, office building floor area is predominantly the majority of the total building stock by floor area (TelferYoung (Wellington) Limited, 2009).

Total office space, by floor area, in Wellington's CBD as at December 2008 was 1,461,776m^2 (TelferYoung (Wellington) Limited, 2009). Since the early 2000s there has been a significant rise in the amount of office floor area, but with variations as shown in Figure 3.1. This is partially due to the fluctuations in demolition and construction of office buildings within the area.

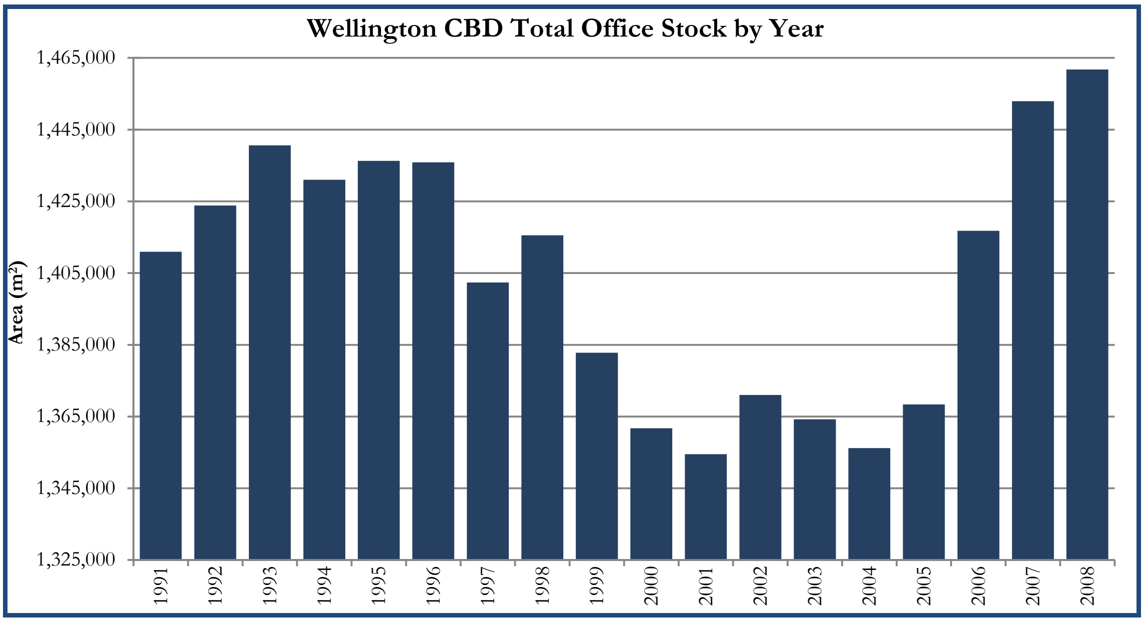

Figure 3.1: Wellington CBD Total Office Floor Area by Year (Source: TelferYoung (Wellington) Limited, 2009)

[1] It should be noted, that 'Mixed Use' buildings, may also fall under the 'Office' building typology, as the ground floor for these buildings have been found to be occupied by some form of retail, food, or other mixed use occupancies.

The forecast is that commercial building floor area is set to increase by 3% [or less] nationally. When compared to trends over recent years, this is a low increase (Bishop, 2001; Denne et al, 2007). However, as seen in Figure 3.1 (please note the suppressed x-axis scale) above, the area of Wellington office buildings has increased by more than 7% since the year 2000, and the floor area is the greatest it has been over at least the previous seventeen years (to 2008). This indicates there is still a rising demand for commercial office buildings.

3.1.2. WATER USE BY CATEGORY

Within New Zealand, each Regional Council divides their buildings into water use categories differently, for example some use 'metered' and 'non-metered' categories, while others use 'residential', 'industrial and commercial', and 'other' users.

This is also the case internationally, and 'somewhat frustrates efforts to compare water use for individual categories among regions' (Dziegielewski et al, 2000), and discourages comparisons being made between regions and countries. Two examples of detailed separation are displayed below in Figure 3.2 and Figure 3.3, where the differing categories listed have been identified as the most informative titles throughout New Zealand. This outlines the average percentages of total annual water use by category for Auckland (2010) and Christchurch (2008).

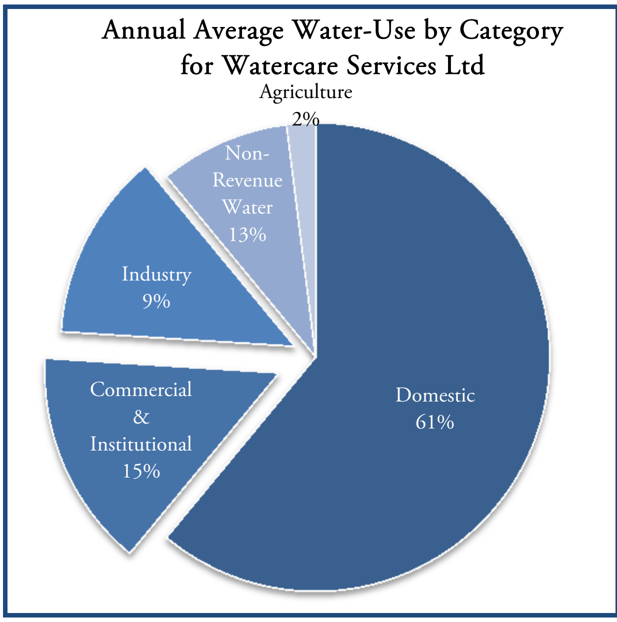

Figure 3.2: Estimated Water-Use Percentages for Auckland (Source: Watercare Services Ltd, 2010)

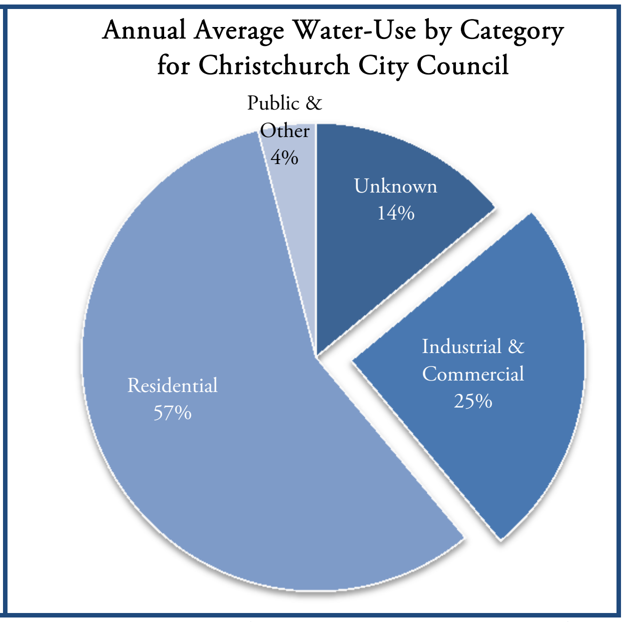

Figure 3.3: Estimated Average Water-Use Percentages for Christchurch (Source: CCC, 2008)

Figure 3.2 and Figure 3.3 show that industrial and commercial consumption accounted for approximately 25% of the annual average total water use in Christchurch during 2008, and 24% in Auckland during 2009/2010 financial year. As residential water consumption has been the subject of recent investigation in New Zealand (Heinrich, 2007), the next biggest category for investigating water use in the built environment is that of users within the industrial & commercial sector.

As this category covers a varied range of industrial and commercial building types, ranging from production, manufacturing, and processing factories, to retail outlets and commercial offices, this category needs to be broken down further into sub-categories. Some of these sub-categories have already been identified by the *Australia and New Zealand Standard Industrial Classification (ANZSIC)* codes (Trewin et al, 2006), although in some cases the breakdown is still very broad; refer to Appendix B6 for more details on *ANZSIC* categories and codes.

As water use within further sub-categories is not known or not documented in New Zealand, further comment can only be made on the Industrial & Commercial water use in Sydney. Figure 3.4 below shows the water used by commercial buildings in Sydney as a proportion of total business water use.

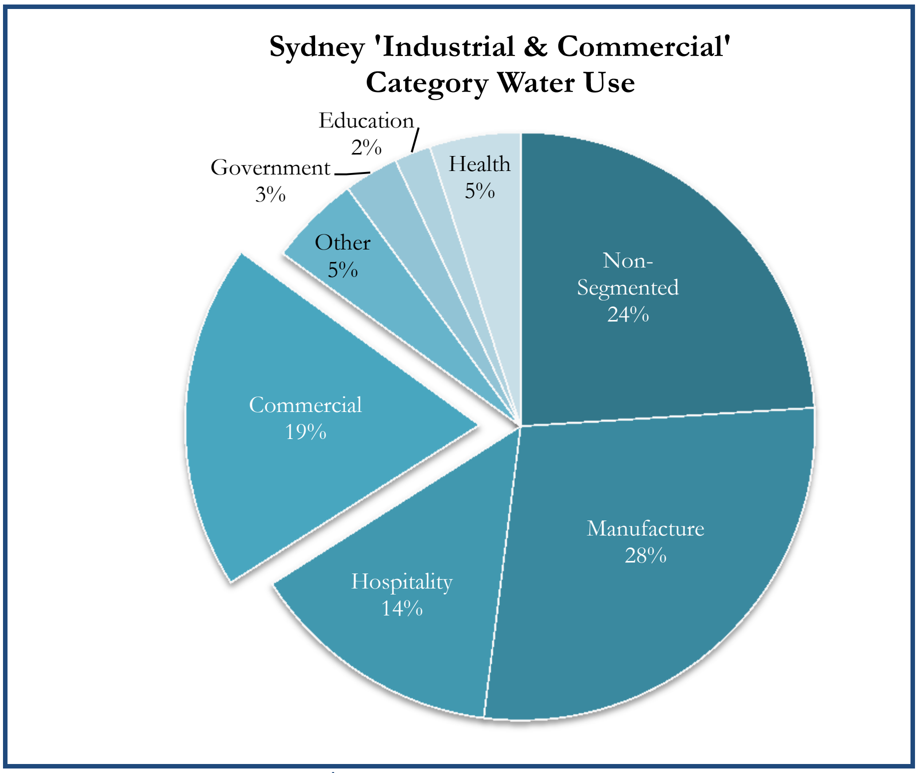

Figure 3.4: Sydney Industrial & Commercial Category Breakdown by Water-Use (Source: SWC, 2007)

Figure 3.4 shows that the commercial building sector uses approximately 19% of total annual water use in Sydney, across all commercial and industrial sector building types. A recent national study in Australia suggests that approximately 10% of total urban water supply can be accounted for by offices alone (Quinn et al, 2006).

3.2. OFFICE BUILDING WATER USE

Mains pressure water is normally delivered to a building through one or more water meters. From the point of supply (refer Figure 2.5), it is then either directed through sub-meters, or directly to the building's storage tanks, which are usually located on the upper or mid levels of the building.

Within the Wellington region mains pressure ranges from 600 to 700 kPa (Gribble, 2009). Where this is insufficient to deliver water to storage tanks, pneumatic water-pressure-booster pumps are used. The storage tanks provide supply for both cold (flusher or domestic water tanks) and hot (hot water cylinders) water for domestic supply, and to plant and equipment for heating and cooling requirements.

Figure 3.5 shows a typical water reticulation layout in a commercial office building. High-rise buildings of this nature can also incorporate a secondary staged cistern or tank supply system, as shown in Figure 3.6.

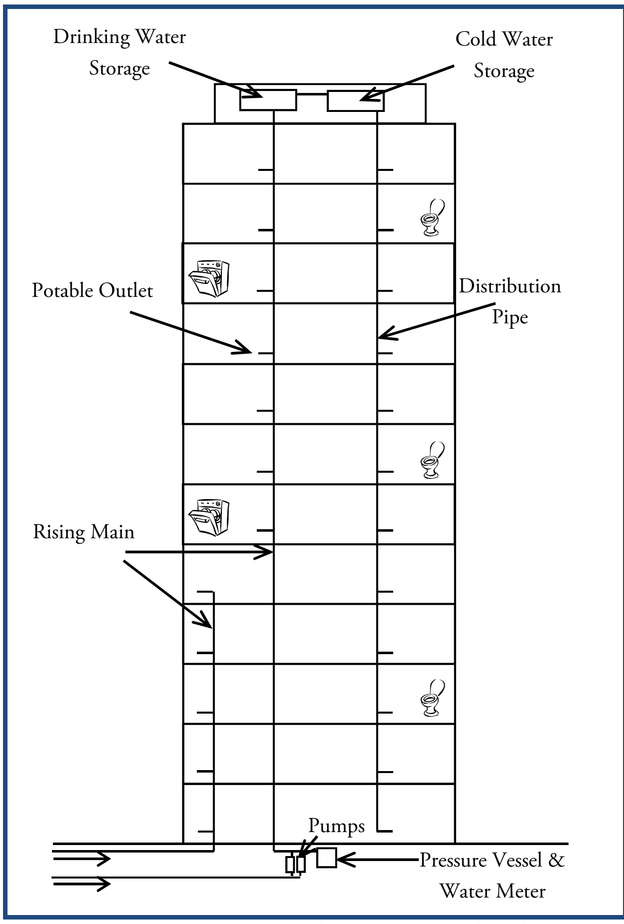

Figure 3.5: Water Reticulation using Flush Valve (Source: Wise et al, 1995)

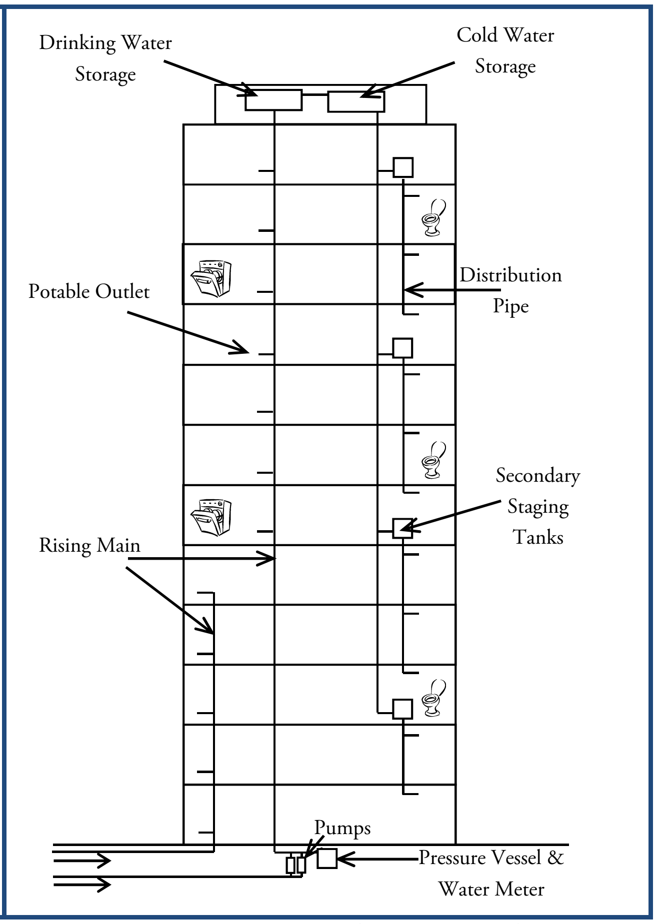

Figure 3.6: Water Reticulation using Tanks (Source: Wise et al, 1995)

A building's purchased water is consumed by varying types of equipment and the end-uses used by the occupants, each with a specific but different purpose. For a typical commercial office building international research suggests that the following are primary determinants of water demand in commercial office buildings:

- Heating, Ventilation, and Air-Conditioning (HVAC) Equipment;
- Domestic Amenities;
- Leakage; and
- Other.

Each of these are discussed below in greater depth in terms of their water consuming processes and estimated percentages of the total annual purchased water. Other drivers of water use are the way people use water, and the age, size, and physical condition of the installed appliances/equipment. Data gained from separating out the water end-uses in each building, will enable further analysis to take place. Typically most commercial office buildings will contain similar water using features, in order to provide the mandatory facilities for human sanitation and hygiene.

Below in Figure 3.7 is a breakdown of how the average commercial office building in Sydney (Australia) consumes its purchased water, based on research undertaken for *DEH* (Quinn et al, 2006).

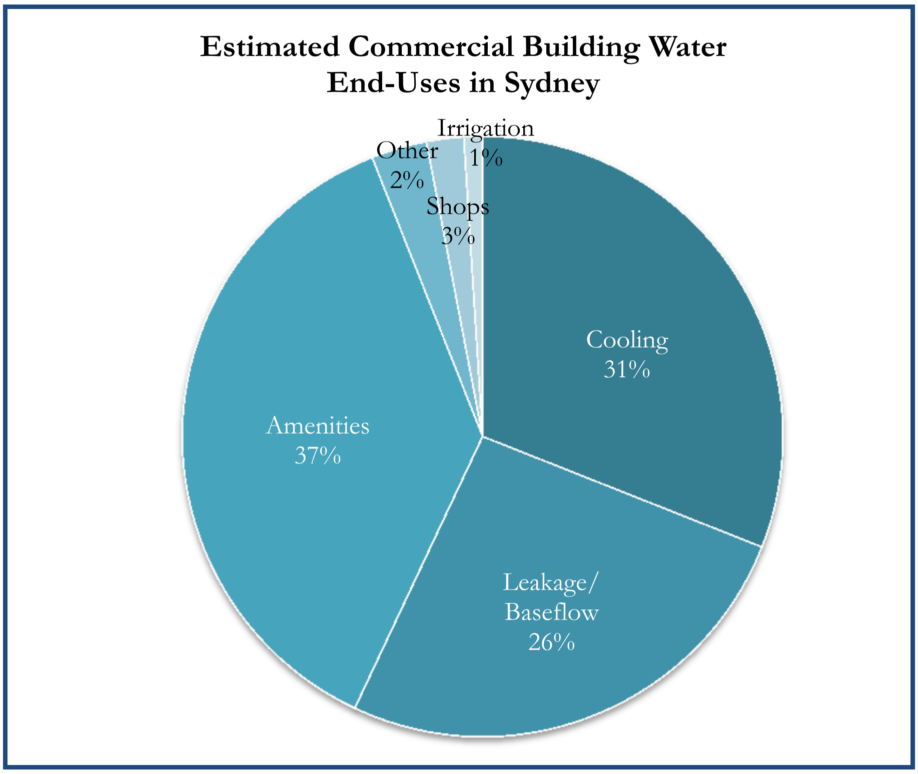

Figure 3.7: Sydney Commercial Building Water End-Uses (Source: Quinn et al, 2006)

It has been found in the Sydney buildings sampled by the *DEH* that the domestic amenities of office buildings, including restrooms, kitchens, and shower facilities, consumed approximately 37% of the total annual water use, although this ranged between 30% and 40% (Quinn et al, 2006).

The cooling functions of the building represent a similar portion (31%), also ranging between 30% and 40% of the total annual water use (Quinn et al, 2006). Other water uses include garden irrigation, cleaning, and/or ground level retail or food outlets. Food outlets often require water on a different scale to that of a typical office space. Leakage and baseflow (i.e. when no one is using the building, and the amount exceeded 80% of the time), typically occurring from taps, urinals, cisterns, piping, valves, and pumps, represents approximately 26% of the total annual water consumption (Quinn et al, 2006).

However, as this end-use breakdown was derived for Australian commercial office buildings, it may not be realistic for New Zealand as behavioural, economic, building practices, and local climates may differ significantly between regions.

3.2.1. HEATING, VENTILATION AND AIR-CONDITIONING (HVAC) EQUIPMENT

HVAC refers to mechanically operated processes for conditioning and controlling the air and/or internal environment of specific spaces within the building to pre-determined comfort conditions. It is acknowledged that many commercial buildings utilise natural ventilation and/or mixed mode methods, however this chapter will only outline mechanical ventilation.

Typical features within the HVAC system of a commercial office building to complete this process may include a heating circuit, a cooling/refrigeration circuit (including heat rejection), humidification control, as well as Air-Handling Units (AHUs) for the distribution of conditioned air.

Water and refrigerant are the primary mediums used in the majority of buildings throughout the air-handling processes, due to their unique heat and carrying capacities. Depending on whether it is an open-loop (condenser water exposed to outside air) or a closed-loop system (cooling- or heating-system water does not come into contact with the outside air), determines the amount of water treatment, maintenance, and level of make-up water needed (Stanford, 2003).

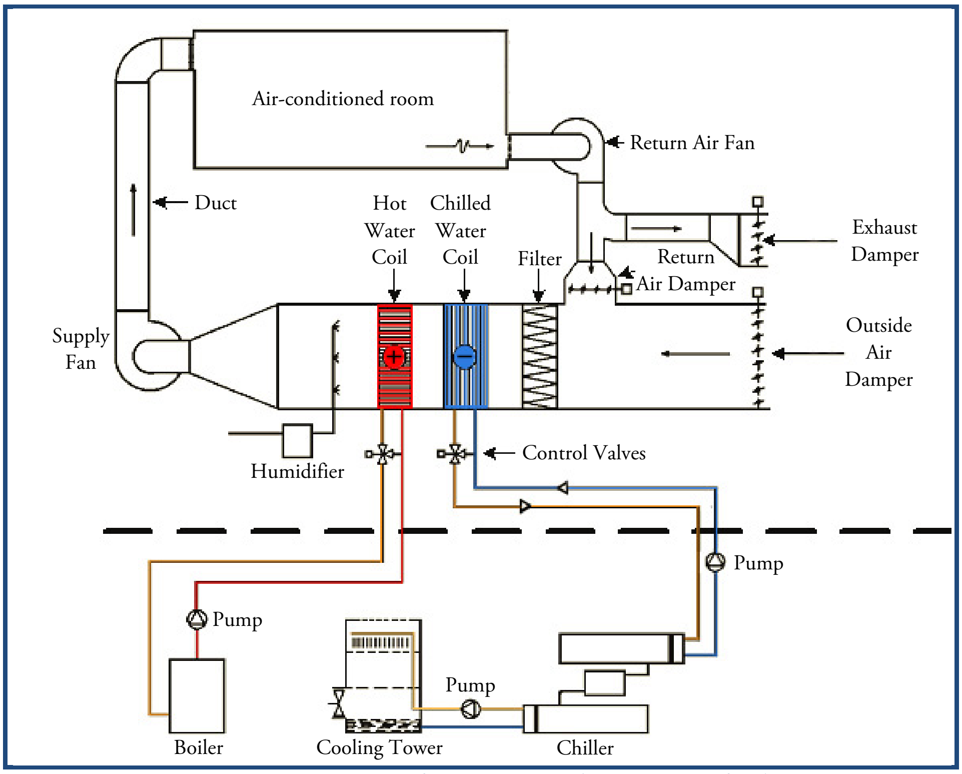

Figure 3.8: HVAC Water Distribution System Schematic (Betterbricks, 2010)

In order to transfer the heat from one medium (water or refrigerant) to another (air for circulation) a series of heating and/or cooling coils (also referred to as heat exchangers) are used. The water then circulates back (from the heating/cooling coils) through the relevant circuit(s).

3.2.1.1. HEATING CIRCUIT

The heating units within a building typically include gas fired boilers which supply the water for the heating coils or for radiant heaters (usually around the perimeter of each space) within the building (if any). However, this may not be the case where packaged units or other heating systems are installed.

Water is utilised in a boiler unit for its thermal ability and transportation properties. It enters the boiler chamber, passes through a flame, and is heated to a temperature just below boiling point (Kuehn et al, 2005). It should be noted that no water is actually being used/consumed in this process; rather it is circulated through the pipe-work as a closed-loop. However, as evaporation, leaks, and malfunction are possible, a small percentage of the water can sometimes be lost, and therefore a make-up supply must be enabled.

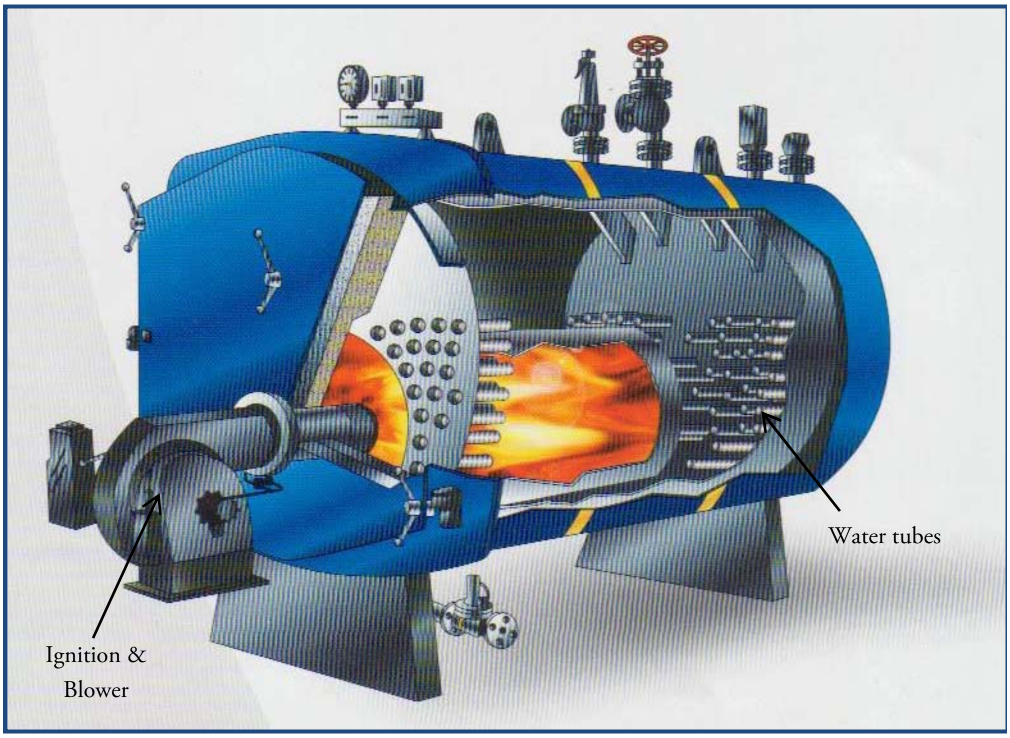

Figure 3.9: Boiler Water Use (Source: Water Tube Boiler, 2011)

Figure 3.9 shows a closed-loop example of how the water is heated inside the boiler. The water enters through the water tubes, and is then returned through the boiler again and transported back to the AHU heat exchangers.

Research found that an insignificant proportion of the total annual water bill will be used for HVAC heating purposes. The heating of water for domestic hot water uses will be discussed later in Chapter 3.2.2.

3.2.1.2. COOLING CIRCUIT

The cooling mechanisms for a building can include a unit for providing chilled water, which in turn is used to produce the cooled air for the air-conditioning system. As water is a key part in the method of cooling for HVAC, it can be said that buildings using mechanical cooling are expected to consume more water than a naturally ventilated (or non-mechanically cooled) building, however this is also suggested to be due to whether or not an open-loop is present (Stanford, 2003).

The way in which water is used within a refrigeration (chiller) unit is outlined below in Figure 3.10. There are five primary components to the cooling process:

- AHU;
- Evaporator;
- Compressor;
- Condenser; and
- Expansion Valve.

Each of which comes into contact with at least one of the following loops:

- Chilled Water Loop;
- Refrigerant Loop; and
- Heat Rejection Loop (cooling tower circuit or air-cooled condenser circuit).

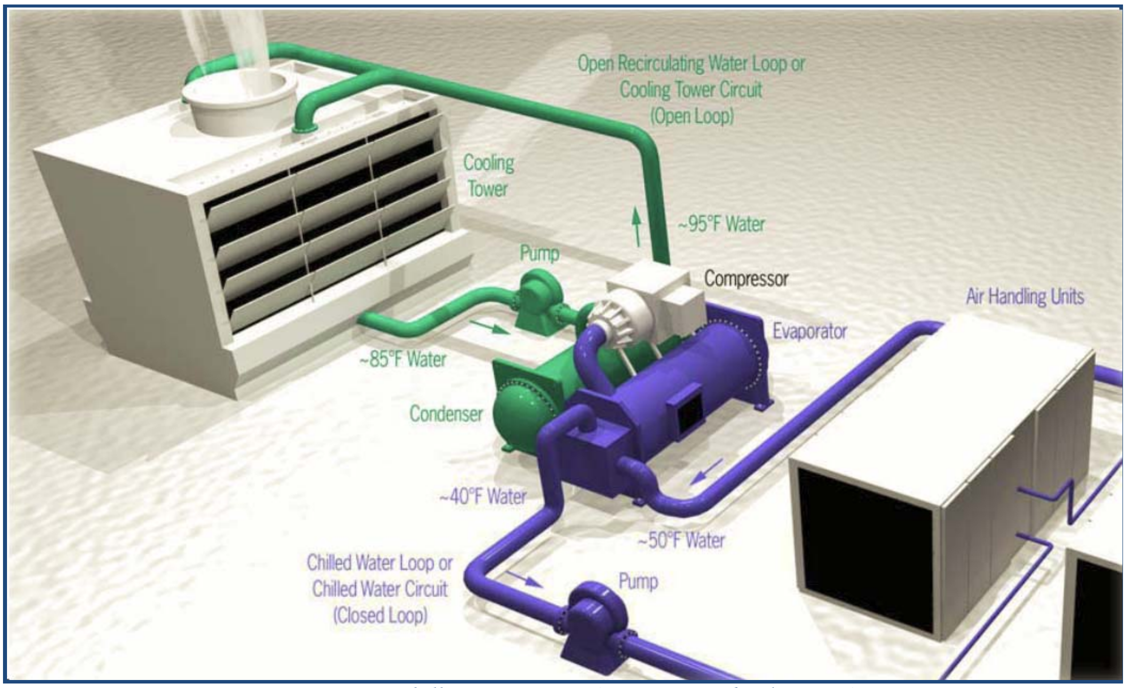

Figure 3.10: Chiller Water Loops (Source: Betterbricks, 2010)

3.2.1.2.1. Chilled Water Loop

The chilled water loop runs between the AHU and the evaporator. Within the evaporator, the chilled water loop passes the refrigerant loop where heat transfer takes place to cool the water (and heat the refrigerant).

The water then continues on to the cooling coils within the AHU. Here the air passes over the piped chilled water, cooling the air and in turn heating the water. The heated water then returns to the evaporator, and the cycle continues. This is a closed-loop circuit, as the water does not at any time come into direct contact with any other medium (air, refrigerant, etc) (Stanford, 2003).

3.2.1.2.2. Refrigerant Loop

The warmed refrigerant (from the evaporator) travels to the compressor, where it is mechanically compressed and therefore comes out at a higher pressure and higher temperature. The refrigerant then travels to the condenser where another heat transfer takes place to cool the refrigerant (heat the heat rejection loop water). The refrigerant is then cooled further by passing through the expansion valve. It then returns to the evaporator and the cycle continues.

This refrigerant closed-loop is all within the chiller unit. There are a few differing types of compressors (reciprocating, rotary screw, centrifugal, etc), however they all do the same thing – compress the refrigerant.

3.2.1.2.3. Heat Rejection Loop

Firstly, there is more than one method for rejecting waste heat to the atmosphere, two of which will be discussed here:

- Water Cooled (via a cooling tower); and
- Direct Air-Cooled (via roof-top condenser units).

Water Cooled: The water cooled heat rejection loop receives the heat transferred from the refrigerant loop within the condenser. This warmed water is then cooled via transferring its heat to the atmosphere through the use of a cooling tower.

A cooling tower is a heat rejection mechanism for the cooling of water by evaporation. This system, commonly situated on the roof top, utilises the outside air to reject heat to the atmosphere by maximising water and air contact through the fill material inside the tower (SWC, 2002). The water within the tower requires on-site treatment in order to prevent any transmission of airborne disease bacteria, such as Legionella.

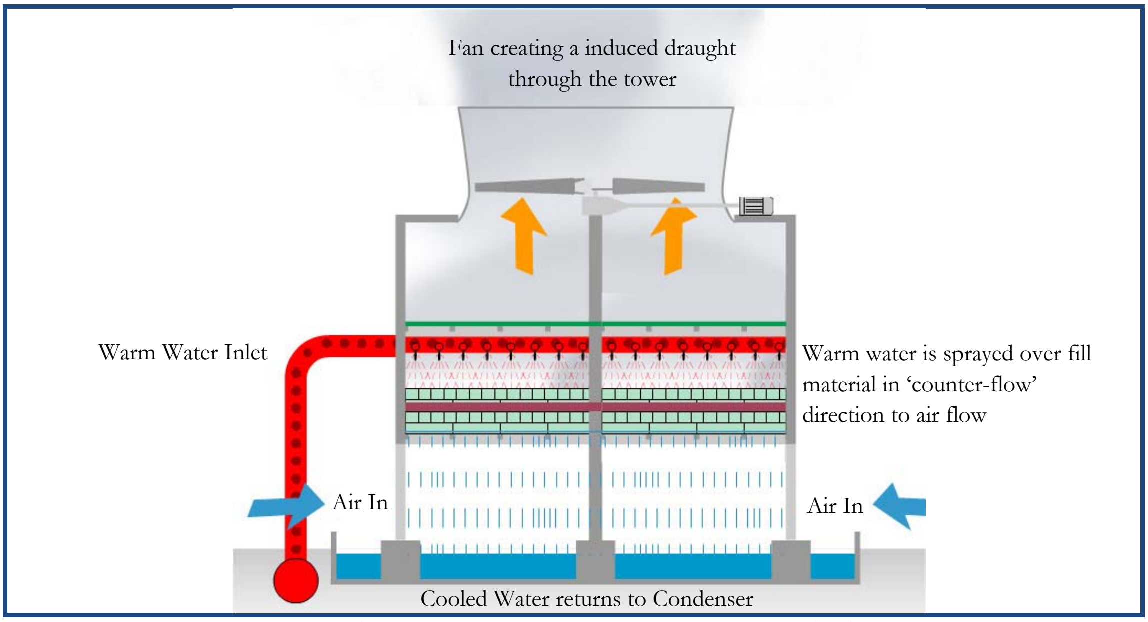

Figure 3.11: Cooling Tower Cut-Away (Source: GEA Energy Technology, 2010)

The water [that is not evaporated] is typically cooled to 5°C or 6°C cooler than the water inlet temperature. However, the cooling tower is unable to reduce the water temperature to less than the wet bulb temperature of the outside air (Stanford, 2003; Bureau of Energy Efficiency, 2005). Refer to Stanford (2003) for further details on the operation of a typical cooling tower for commercial buildings. The cooled water after evaporation is returned to a condenser, and the cycle continues.

The efficiency of the tower is dependent upon a number of factors including wet bulb temperature of the ambient air, the temperature of the inlet condenser water, the volume of fill material and the flow rates of air and water (SWC, 2002). This means that the summer peak water use in a cooling tower can often reach twice the average annual daily demand (SWC, 2002).

Direct Air-Cooled: The direct air-cooled heat rejection loop fulfils the same function as the water cooled option, but employs refrigerant as the heat transfer medium – not water.

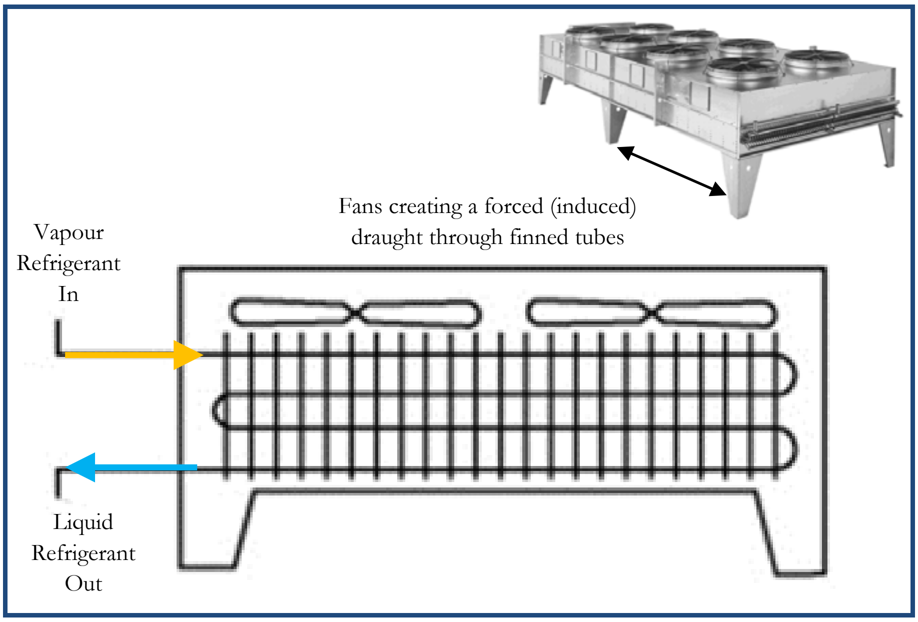

Figure 3.12: Air-Cooled Condenser Schematic (Source: GEA Energy Technology, 2010)

This heat rejection unit consists of an array of 'radiator' type units (similar to a motor-vehicle's radiator) where a forced draught over the refrigerant tubes is used to cool the refrigerant. No water is used in this system (apart from that in the chilled water loop – above).

3.2.2. DOMESTIC AMENITIES

The amenities of a building include domestic appliances, such as those found in typical kitchens and restrooms at home. However, commercial buildings normally also have urinals installed within male restrooms, and the domestic bath is generally not present in the commercial building.

Within these appliances there can be a wide range of performance in terms of water use, particularly in the case of toilets, urinals, faucets, showers, and dishwashers. The New Zealand *Water Efficiency and Labelling Scheme (WELS)* ratings can provide information of the efficiencies within appliance categories, a list of these *WELS* ratings can be found in *AS/NZS 6400:2005 WELS* (Standards New Zealand, 2005). The *WELS* ratings apply also to the amenities and facilities provided in a commercial building, and specification of appropriate appliances can greatly improve the efficiency in these areas.

RATING	SPECIFICATION (L/min)			
	Tap-ware	Toilet	Showerhead	Urinal
0 star	>16	N/A	>16	>2.5*, 4.0*
1 star	>12, <16	>4.5, <5.5	>12, <16	<4.0*
2 star	>9, >12	>4, <4.5	>9, <12	<2.5*
3 star	>7.5, <9	>3.5, <4	>7.5, <9	<2.0*
4 star	>6, <7.5	>3, <3.5	>6, <7.5	<1.5*
5 star	>4.5, <6	>2.5, <3	>4.5, <6	<1.0*
6 star	<4.5	<2.5	>4.5, <6*	<1.0*

*Please refer to AS/NZS 6400:2005 Water Efficiency Labelling Scheme for additional specifications.

Table 3.2: WELS Ratings for Domestic Appliances found in typical Commercial Office Buildings (Source: Standards New Zealand, 2005)

3.2.2.1. RESTROOMS

Restrooms within commercial office buildings will typically either be male, female, or unisex/disabled facilities. Typical office restrooms may include toilets, wash hand basins, cleaner's tubs, showers, and urinals in the males' restroom. The minimum number of appliances per building/restroom is dependent on the maximum number of occupants rated for fire safety or personal hygiene (NZBC Acceptable Solution G1/AS1, 2004), and therefore the size of the building.

Facility		Male		Female		Disabled	
		Design Occupancy	Number	Design Occupancy	Number	Design Occupancy	Number
Combination of Toilets & Urinals (Male Restroom)	Toilet	1-10 11-60 61-120 >120	1 2 3 +1 per 80				
	Urinal	1-150 151-550 >550	1 2 +1 per 450				
Toilets Only		1-10 11-50 51-110 >110	1 2 3 +1 per 70	1-10 11-50 51-90 >90	1 2 3 +1 per 60	1-300 >300	1 2
Wash Hand Basins		1-70 71-250 >250	1 2 +1 per 200	1-70 71-250 >250	1 2 +1 per 200	1-300 >300	1 2
Unisex Toilet Facilities		1-5 6-30 >30			1 2 +1 per 40		

Table 3.3: Staff Facilities for 'Offices' as per NZBC G1/AS1: Personal Hygiene

No baths or showers are required in commercial office buildings, with the exception of 'places of active recreation, swimming pools, squash courts, gymnasiums', where one is required for the first 30 persons, and another for every 50 persons after that.

A 1995 New Zealand study found that in a commercial office building, on average there can be expected to be 60% male and 40% female occupants. In this 1995 study, males used the urinal twice per day, and the toilet once per day. Females used the toilet three times per day. While, on average, the males used the wash hand basin on 90% of their visits to the restroom, for approximately 29 seconds (flow time), and the females used it on 100% of their visits to the restroom, for approximately 25 seconds (flow time) (Stewart, 1995).

Depending on the number of appliances, the type, and how many times per day each domestic appliance is used will determine how much water is consumed by these amenities.

3.2.2.1.1. Toilets

Toilets have two primary components, the cistern, and the pan. The pan is matched to the cistern desired for the level of flushing efficiency, in order for the waste to be carried away adequately.

There are several differing types of cisterns available for the flushing of waste via a toilet system. More common today are the dual flush systems, which offer both a half flush (~3L) and a full flush (~4.5L or 6L). Older style (single flush) toilets can use anywhere from 11L per flush (Quinn et al, 2006).

Figure 3.13: Dual Flush Toilet

Figure 3.14: Single Flush Toilet

Figure 3.15: Flush Valve Toilet

Replacing just one 11L single flush toilet with a 3/4.5L dual flush toilet can save approximately 140m^3 (140,000L) of water each year (Quinn et al, 2006). These can all be either cistern, or in-line flush valve operated. Also other types such as valve flush systems, vacuum systems, and even composting systems are found in some buildings (SWC, 2002).

3.2.2.1.2. Urinals

Urinals in the male restroom have a few differing types of flushing mechanisms available; cyclic (syphonic), sensor (motion (microwave or infrared) or urine), or manual flushing. Most are on an automated flushing system. Normally the urinal fixture will either be in the form of a multi-user trough (typically stainless steel), or an individual use wall pod fixture (typically porcelain). The flushing mechanism type and settings will determine the water consumption, this may vary from 50m^3 to 100m^3 per year (based on 30-70 flushes of 4L each per day) (Quinn et al, 2006).

Figure 3.16: Manual Flush Wall-Pod Urinal

Figure 3.17: Motion Sensor for Urinal

Figure 3.18: Cyclically Flushing Trough Urinal

Cyclic flushing urinals are very wasteful, as they are still flushing when no-one is using the appliance – 24 hours of the day, seven days a week. However, there are now timed flushing urinals with [enzyme or bacteria] cartridge inserts which treat the fluid as it goes through the insert and continues down the drain pipe. These inserts require less water than without one. They also require higher levels of maintenance, and the cartridge needs to be replaced every couple of months (re-filling is not yet an option in New Zealand), and then transported to landfill (Zygis, 2010).

Sensor (either by microwave or infrared technology) activated flushes only use water when motion is detected within the restroom, or when the motion of urine is detected through the cartridge. These systems also require maintenance and inspections to ensure they are working appropriately. These sensor activated systems generally use less water than a cyclically flushing system, if correctly maintained.

The manually flushing systems employ a pull-chain, or the more popular push-button flush method. Recent studies have shown that urinals have potential savings of up to 500m^3 per year (Quinn et al, 2006), compared with a worst case scenario – as they have the benefit of only being flushed once used.

It should be noted that most installed urinals will undertake a pre-programmed larger and longer flush once per day for hygiene reasons. Waterless urinals still use water, and are difficult and costly to maintain (Joseph, 2011).

3.2.2.1.3. Showers

Most commercial office buildings will have at least a few showers scattered somewhere throughout the building (although, as stated earlier, it is not always necessary). Shower with a *WELS* rated head can in turn reduce the amount of heating energy required (which is known as one of the bigger energy consumers – 29% of total energy in residential applications (Isaacs et al, 2010a)) as well as the water consumed. Older showerheads typically have a flow rate of 15L to 20L per minute (SWC, 2002), which according to the *WELS* ratings achieves between 0 and 1 stars out of the 6 stars available (Standards New Zealand, 2005), refer to Table 3.2, above for more details.

3.2.2.1.4. Wash Hand Basins (Faucets)

Wash hand basins usually contain either individual faucets for hot and cold water or both hot and cold water supplied via a mixer spout. In some buildings, water can flow from taps at a rate as high as 15L to 20L per minute, which is excessive for certain purposes; 6L per minute or even less has been found to be enough for the purposes of hand washing (Quinn et al, 2006).

Figure 3.19: Wash Hand Basin with Individual Faucets

Figure 3.20: Wash Hand Basin with Mixer Spout

Figure 3.21: Wash Hand Basin with Mechanically Timed Faucet

In other applications, timed (self-closing), and/or motion (infrared) sensor taps can be applied, where either temperature mixing is pre-set (away from the users' control), or is self-adjustable. These usually last for 30 seconds per push (timed applications) (Joseph, 2010).

3.2.2.1.5. Other
Within an office building, cleaning facilities will normally be provided. The most typical form is a cleaner's tub. Depending on each building, this can either be located within each level (either within male or female restrooms or separate cupboard), or there will be a few scattered around the building. Typically at least one or two are present.

3.2.2.2. KITCHENS
A kitchen (or kitchenette) can be found in varying sizes throughout an office building. In some cases, where one tenant occupies a large proportion of the building's lettable space, a large common area on one floor will be designated as a kitchen/staff room area, otherwise most buildings have either one small kitchen per tenancy, or per level.

Commercial scale kitchens are also commonly found in office buildings; either for catering purposes, or work-related purposes (i.e. within specific tenancy-use areas), or on ground floor tenancies of non-office use.

3.2.2.2.1. Dishwashers (Commercial & Domestic)
Dishwashers are generally only used for one cycle per day by the occupants of an office building, depending on the rate of occupants using the facility. However, where there are commercial kitchens (i.e. that of a cafe or catering facility), more industrial dishwashers will be found, and will be used on a more frequent basis.

3.2.2.2.2. Kitchen Sink (Faucets)
Sinks typically contain either individual faucets for hot and cold water supply or both [hot and cold water] supplied via a mixer spout (see Figure 3.19 and Figure 3.20). In some buildings, water can flow from taps at a rate as high as 45L per minute (Joseph, 2011). Kitchen taps may be desired to have a higher flow rate than that of the restroom wash hand basin faucets, due to the nature of use.

3.2.2.2.3. Instant Hot Water
Instant hot water can either supplied via an over-sink electric heated unit, usually called a 'zip' (because of its brand name), or via the newer 'billi' tap outlet – which has the ability to provide both instant hot water as well as chilled water from the same outlet. The 'billi' tap is fixed to the sink, as per the usual faucet, with a small electric heating/cooling box found underneath the sink, out of sight.

3.2.2.2.4. Other
Quite often there will be a number of various water using appliances within a kitchen environment. This is typically down to the type of tenants which occupy the building and/or the individual spaces within the building.

These can include, but are not limited to (depending on the type of tenancy):

- Ice machines;
- Coffee Machines:
  - Commercial (Espresso) Type,
  - Domestic Type,
- Washing Machines;
- Humidity Ovens; and
- Cooler Fountains/Filters (which may or may not be plumbed into the building water system).

3.2.3. LEAKAGE
In commercial buildings, Australian studies have shown leakage and base-flow can account for up to 30% of total water consumption. Leakage usually occurs from cooling towers, dripping taps, urinals, cistern flappers

and filler ball valves, fire hose reels, underground pipes, and control valves (Quinn et al, 2006). The research suggested that a single dripping tap can waste more than 24,000L (24m^3) per year (Quinn et al, 2006).

3.2.4. OTHER

Other covers the categories of irrigation, water use features (both internal and external), and other ground floor spaces if tenanted differently (i.e. retail/restaurant) (Quinn et al, 2006). This can account for between 11% and 15% of the total annual water consumption (SWC, 2007) of an office building.

3.3. DEMAND DRIVERS

From several similar studies conducted internationally, the potential explanatory variables and demand indicators for commercial office buildings are outlined below under the headings of building, occupant, appliance, and other drivers.

3.3.1. BUILDING DRIVERS

Building drivers could include such building characteristics as building age, the size and scale of the building (i.e. Net Lettable floor Area (NLA), Gross Floor Area (GFA), number of storeys, materiality, and so on). Basically it is the drivers that cannot be influenced by the tenants or for any other reason besides the fact that the building is what it is.

The size of floor area in each building is usually a good determinant for consumption intensity (Waggett et al, 2006b). In most studies it is the NLA (and/or occupancy) that is referred to for consumption intensities in office buildings. NLA is a measure of the lettable space within the building excluding services and circulation areas as defined by the *Guide for the Measurement of Rentable Areas* (Building Owners and Managers Association [BOMA] et al, 1996), also detailed in Appendix A. The HVAC system in a building is selected by the size of the building; therefore water use is expected to be proportionally higher for larger sized buildings.

The location of the prospective building site determines the building's maximum height and footprint areas – either by the land size restriction, or by the regional and zoning/planning bylaws.

3.3.2. OCCUPANT DRIVERS

Occupant drivers are those determined or influenced by occupant use, timing, and patterns. There are several legislative requirements which specify maximum limits of these.

The number of tenants within a building will have an effect on the water consumption. Each tenancy will be occupied differently, contain differing activities, and have different in-house water use practices. However, as offices are generally used for the same purposes, a reduced effect is likely to be apparent here.

The ground floor business of a large commercial building is typically very different to the floors above. In most cases either a retail outlet or a restaurant type facility will tenant the ground floor space. As these differences are identified, it becomes obvious that there may well be specific requirements for water use. For example within a restaurant type facility, water is used for cooking and for hygiene on a much larger and more frequent scale than that of an office space. And retail outlets may use no water apart from that used in maintaining a comfortable level of indoor environmental quality, and in domestic appliances (if any), making their water use potentially comparable to an office space with the same number of staff.

It has been found that the definition of 'water consumption per occupant' varies depending on the study. As the number of visitors to a building varies dramatically, and their effects on water consumption can be minimal, only the Full Time Equivalent (FTE) employees/occupants should be measured.

Occupant density is a measure of NLA per FTE occupant. This covers both consumption per FTE occupant and NLA, and could be a useful way of normalising water consumption. The estimated design occupancy of typical buildings as stated by the *GSNZ Office Design rating tool* is 15m^2 per person (GSNZ, 2009). Different occupancy rates have been found by the *Property Council of New Zealand* (BOMA et al, 1996), which can be calculated using the *NZBC Acceptable Solution G1/AS1* values against the NLA for each space.

The number of hours per day, week, or annually the building is fully occupied may have a large impact in terms of the amount of water consumed, when compared to a building that is fully occupied all hours of the day. This is due mainly to amenity and heating/cooling use influences. However, the number of hours per day in which the HVAC equipment is running may differ from the hours during which the building is fully occupied, and is not relevant to those buildings utilising natural ventilation.

3.3.3. APPLIANCE DRIVERS

This comes down to the type of activities and functions within each building. For office buildings only, it can be approximately determined by the presence of three influencing factors: kitchen and restroom amenities; HVAC equipment; and use of irrigation and other water feature purposes, and will have the greatest impact on the demand for water.

From previous studies conducted on water consumption in commercial office buildings, particularly of interest are the *SWC* studies, where the type of heating and cooling equipment used is shown to dramatically alter the amount of water consumed annually. Cooling towers are known to use between 20% and 50% of the total annual water bill (Quinn et al, 2006), as discussed earlier.

3.4. SUMMARY OF WATER CONSUMPTION

Commercial office buildings in particularly account for up to 27% of the non-residential building stock in New Zealand, yet very little work has been done to understand the water performance in these buildings. From investigating the consumption of water, both in New Zealand and internationally, there does not appear to be a coherent method of reporting and/or evaluating performance within specific building types.

The primary water end-uses in comparable Australian buildings were in the HVAC, primarily through the use of evaporative cooling, and the domestic amenities, with a similar proportion being lost through leakage. To understand water use, the drivers of water demand first needed to be determined in the New Zealand context. This has been enabled through categorising the drivers into: building influenced; people influenced; and equipment influenced drivers.

4. WATER ALLOCATION & MEASUREMENT

Water has been the subject of many disputes, even wars, since the beginning of human civilisation on Earth, influencing the subject of allocation, and therefore methods of delivery and measurement. However, measurement not only refers to the measurement of the amount supplied for cost-recovery, but also for the determination of efficiency and conservation monitoring.

The measurement of water can be discussed under many fields; however, this chapter will discuss the different methods for cost-recovery, and the varying legislation controlling water use. Also covered are the types of water meters found within many New Zealand buildings today, and their characteristics. These topics are used to cover the way in which water is allocated, controlled, and measured, both in New Zealand and internationally.

The way in which water is monitored and/or audited for performance or efficiency within a building is then discussed, and which types of sensory and logging equipment are needed, and their characteristics. This has been done to prepare the most suitable methodologies, to be covered in Section Three.

4.1. WATER SUPPLY & BILLING UTILITY

"During the twentieth century the allocation, management and distribution of water was largely brought under the control of governments. Political scientists regarded the resource as a good that had to be provided by government since water was too precious a resource to be left to the whims of the open market" (Bate, 2006). This meant government controls were put into effect, tariff charges for customers were made payable, and certain legislative controls had to be developed to ensure safe and efficient shares were allocated to all. However, this has not always made for the allocations necessary to ensure environmental and wildlife protection, as well as water security for future demands and generations.

4.1.1. TARIFFS

Current market based instruments such as tariffs and water rates do not sustainably cover environmental and management expenses, which in turn influence poor demand side behavioural management. Many people are not aware of the actual costs and the difficulties to supply safe water (OECD, 2006), which also wrongfully implies a lesser importance on water as a resource.

Current tariffs barely include, or cover, actual costs inflicted on the environment, and the cost to maintain and upgrade the system infrastructure, let alone the costs of sourcing, treating, and delivering clean high quality drinking water to customers (Bate et al, 2008).

Most tariffs are expected to rise as the stresses outlined within the previous chapters increase and the delivery of water to buildings becomes more difficult, and as suppliers eventually need to invest in new supply and infrastructure systems to cope with the rising demands (OECD, 2006). There are a few differing types of tariff structures used around the world; four of the more common are outlined below:

- Fixed Charge;
- Fixed Charge + Uniform Rate;
- Fixed Charge + Block Rate; and
- Variable Type Rates.

4.1.1.1. FIXED CHARGE

This generally applies to buildings that are not charged based on consumption, and/or are not metered. Instead they pay an annual supply cost no matter how much water is taken from the system. An example of this is residential customers in Wellington who pay a fixed charge of NZD$112.50 per annum (as at 1 July 2009) for water (Fleet, 2009).

4.1.1.2. FIXED CHARGE + UNIFORM RATE

This charge is based on an annual service fee, which could be directed at several different costs (e.g. the number of water meters installed within the building site and the building itself). The current per cubic metre rate of water consumed is then added to this and billed usually on a monthly, bi-monthly, quarterly, half yearly, or yearly basis. This system is the most widely used, as it can be found both throughout New Zealand and internationally where commercial water metering exists (SWC, 2007).

Volume	Fixed Charge	Fixed Volume Rate
No Limit	NZD$7 / meter / month	NZD$1.715 / m^3

Table 4.1: Fixed Charge + Uniform Rate Tariff Structure (WCC, 2012)

Table 4.1 gives tariffs that are current for the *WCC* (as at 1 February 2012), with the last increase in July 2011. This fixed volume rate gives a limited incentive for higher water users to reduce or monitor their consumption. The charges for water going out (i.e. wastewater) of a building defined as commercial in Wellington are payable as a percentage of the subject buildings' capital value (WCC, 2012).

4.1.1.3. FIXED CHARGE + BLOCK RATE

This tariff system is also usually based on the number of water meters installed within the site and building, but instead of a fixed unit rate, as the consumption of water increases above a certain point, the rate either increases (increasing block rate), or decreases (declining block rate) for those higher volumes, as illustrated in Figure 4.1.

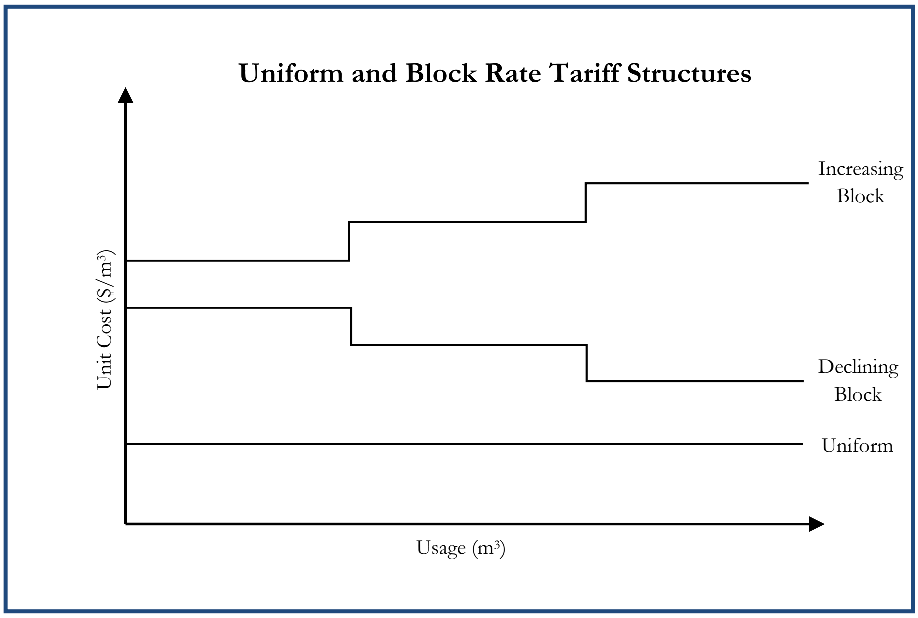

Figure 4.1: Examples of Block Rate Tariffs (Groves et al, 2007)

4.1.1.3.1. Increasing Block Rate

As this method is based on variation of use rather than having a single fixed volume rate, this provides some incentive for consumers to only use water within the lower brackets of the variable volume rate.

Variable volume pricing could reward water conservation. These pricing mechanisms have been introduced in some states of Australia, such as that of Victoria, for residential customers as shown in Table 4.2 below.

Volume	Fixed Charge	Variable Volume Rate
0-440 m^3/day	AUD$/meter	AUD$0.78 / m^3
441-880 m^3/day		AUD$0.92 / m^3
881+ m^3/day		AUD$1.36 / m^3

Table 4.2: Fixed Charge + Increasing Block Rate Tariff Structure Example (Corr et al, 2008)

However, it can be seen that the highest rate is only charged at a price comparable to that of the uniform rate for *WCC*, so as currently constituted this charging system sends a very weak signal to the consumer regarding water conservation.

4.1.1.3.2. Declining Block Rate

This method is used in some regions, whereas consumption increases, the volume rate decreases. This means that for the lower volume users, the average cost per unit of water may actually increase as water use decreases (Groves et al, 2007).

Volume	Fixed Charge	Variable Volume Rate
0-10,000 m^3/year	NZD$173.46/connection	NZD$1.914 / m^3
10,001-100,000 m^3/year		NZD$1.493 / m^3
100,001+ m^3/year		NZD$1.179 / m^3

Table 4.3: Fixed Charge + Declining Block Rate Tariff Structure Example (NCC, 2012)

As shown in Table 4.3, the *Nelson City Council (NCC)* employed, as at 1 July 2012, a declining block rate for all residential, commercial, and industrial users. This sends a message that decreasing block rate pricing could reward higher water users for using more water.

4.1.1.4. VARIABLE TYPE RATES

This charge is determined by the treatment level of water source, whether it be salt water used directly for toilet flushing, fire services water, or fully treated drinking water for domestic consumption purposes. Hong Kong water tariffs are an example of this, as shown below in Table 4.4.

Type	Volumes Charged 4-monthly	Variable Type Rate
Drinking Water	0-12m^3	FREE
	13-43 m^3	HK$4.16/ m^3
	44-62 m^3	HK$6.45/ m^3
	63+ m^3	HK$9.05/ m^3
Salt Water for Flushing		FREE
Fresh Water for Flushing	0-30 m^3	FREE
	31+ m^3	HK$4.58/ m^3
Non-Domestic Supply	Trade	HK$4.58/ m^3
	Construction	HK$7.14/ m^3
	Ocean Going Shipping	HK$10.93/ m^3
	Non-Ocean Going Shipping	HK$4.58/ m^3

Table 4.4: Variable Type Rate Tariff Structure (Source: Water Supplies Department, 2003)

It should also be noted that in Hong Kong these pricing mechanisms are strictly enforced, with fines payable by those who use levels of treatment incorrectly (Water Supplies Department, 2003).

See Appendix B2 for more information on tariff structures for the rest of New Zealand. The *Organisation for Economic Co-operation and Development (OECD)* recommended in 2006 that current tariffs in New Zealand should to be adjusted to include for operation, maintenance, and environmental costs (OECD, 2006).

4.1.2. LEGISLATION

It is noted that "concern has been expressed about the multiple and potentially conflicting roles of authorities" (Williams, 2001a). Legislation is required to ensure sustainable allocation and management strategies are enforced. In New Zealand there is no uniform national policy. Each regional council is required to develop their own bylaws, and therefore issues differ considerably within each regional council, and each water source. However, the most in-depth control of water falls under the *Resource Management Act 1991 (RMA)*, the *Local Government Act 2002*, and the *Health (Amendment) Act 2007*, with only a single statement found in the *Building Act 2004*.

4.1.2.1. RESOURCE MANAGEMENT ACT 1991

The *RMA* outlines any restrictions and rules relating to the taking (use, damming, and diversion) of any water or heat and energy from a water source. The *RMA* controls the discharge of wastage into, or near, any water source used for drinking purposes. Also laid out are the definitions and classifications of water uses. For this study 'Class WS Water' (being water managed for supply purposes) can be defined as the focal point (RMA, 1991). There are a set of rules which enable the water to be classed as 'WS', such as those found in Appendix B5.

4.1.2.2. LOCAL GOVERNMENT ACT 2002

The *Local Government Act 2002* outlines the powers of local authorities to create bylaws with regard to the supply of water, both generally and specifically (Local Government Act, 2002), while also discussing the local authorities rights and customer/public offences related to the supply of water.

4.1.2.3. HEALTH (AMENDMENT) ACT 2007

The *Health (Amendment) Act 2007* provides direction and promotion of "adequate supplies of safe and wholesome drinking water from all drinking water supplies" (Health (Amendment) Act, 2007). It also states that the *Director-General of Health* must retain a register of all suppliers within New Zealand, thus enabling individuals to access information regarding suppliers in their area, and information about the source and supply of water from that supplier (Health (Amendment) Act, 2007).

4.1.2.4. BUILDING ACT 2004

The *Building Act 2004* contains the only legislative statement specifically related to demand management or water efficiency by the users:

Part 1 Section 4: *"In achieving the purpose of this Act, a person to whom this section applies must take into account the following principles that are relevant to the performance of functions or duties imposed, or the exercise of powers conferred, on that person by this Act"*

Sub-Clause (o): *"the need to facilitate the efficient use of water and water conservation in buildings"* (Building Act, 2004).

Emerging from the above Acts are several New Zealand codes of practice and standard documents.

4.1.2.5. NEW ZEALAND STANDARDS

There are few standards relating directly to the supply of water, and those that are available refer primarily to the prevention of contamination of the water source and supply, which stem from the above Acts. A full list of these New Zealand Standards and other legislation can be viewed in Appendix B1.

The only New Zealand standard directly related to the consumption of water, is the *AS/NZS 6400: 2005 Water Efficiency Labelling Scheme (WELS)*, refer Table 3.2 (Standards New Zealand, 2005).

4.1.2.6. INTERNATIONAL STANDARDS
In some cases, international standards (such as *ISO 4064: 1993 Measurement of Water Flow in Closed Conduits – Meters for Cold Potable Water;* or the later revised *ISO 4064: 2005 Measurement of Water Flow in Fully Charged Closed Conduits – Meters for Cold Potable Water and Hot Water*) are used to validate certain practices and methods used in New Zealand, such as water meter accuracy, and so on.

4.1.2.7. LAND & WATER FORUM (2010)
The *Land & Water Forum* "brings together a range of industry groups, electricity generators, environmental and recreational national government organisations, iwi, scientists, and other organisations with a stake in freshwater and land management" (Land & Water Forum, 2011).

In 2010, the *Report of the Land & Water Forum: a Fresh Start for Fresh Water* was published. This document was the first complete document summarising both the issues in New Zealand (full- or over-allocation of supplies, lack of national policy for water management, infrastructure investment deferral, etc), and solutions for overcoming these issues, and/or transitioning to smarter water management. The report was established "in the belief that stakeholders needed to engage directly with each other if we are to find a way forwards." It highlights the ongoing disputes surrounding Water Conservation Orders, water infrastructure development, intensification of farming and run-off, water infrastructure and discharge in cities and towns, organisation, and management (Land & Water Forum, 2010).

Though the majority of the report focuses on supply, rural demand, and irrigation, it identifies that "good practice, adaptive management, and efficiency drivers can and must also be applied to urban water supply..", through a new charging system, whereby "efficiency and environmental gains will result from requiring utilities to meter and charge users for their services on a volume-related basis", resulting in "more efficient use of water" (Land & Water Forum, 2010).

4.2. WATER METERS
A water meter is an "instrument intended to measure continuously, memorise, and display the volume of water passing through the measurement transducer at metering conditions" (ISO, 2005). The availability, rating, and preference of water meter types, brands and models will determine which water meter is selected and/or installed into a building. Within New Zealand, the two main companies supplying water meters are *Arthur D. Riley & Co. Ltd*. who primarily supply *Elster* (previously known as *Kent*) water meters, and *Deeco Services*, who mainly deal with *Sensus* water meters and related equipment, as well as *Actaris*.

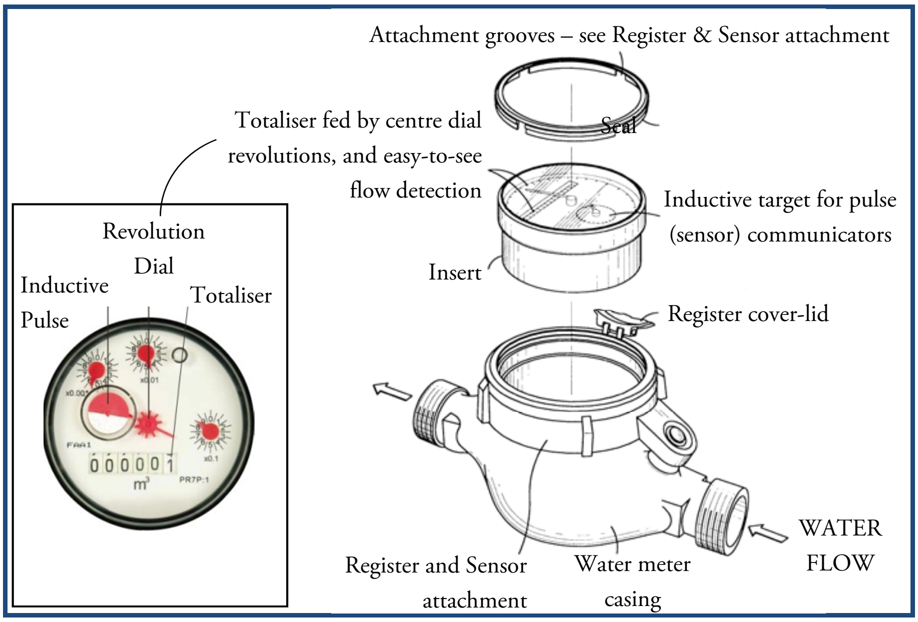

Figure 4.2: Water Meter Components (Source: Free Patents Online, 2003)

The categorisation of water meters can be done in many ways, by electronic vs. mechanical insert, displacement vs. velocity, metrological class, and by other functional characteristics of water meters.

An electronic water meter is simply that, a meter that relies on electricity to carry out its function of measuring the velocity, and therefore the volume, of fluid going through the water meter. Mechanical insert meters typically have a moving mechanism within the meter casing, this can sometimes be removed from the casing without having to remove the entire meter from the water line, for replacement or repair.

Displacement (also known as positive displacement) water meters use a mechanical insert, which the water physically displaces the moving mechanisms within the meter. Each motion of this displacement will be directly related to the amount of water passing through the meter – a good analogy for this is imagining a bucket or container continuously being filled and emptied. The meter totaliser is driven by a magnet connected to the moving measuring elements (Arregui et al, 2006). A velocity type meter measures the velocity of flow through the meter of known internal capacity. The speed of flow (which can be measured by the rotational speed of a fan or other device) is then converted into volume of flow for usage (Arregui et al, 2006).

The current or tested accuracy (or rather error) of a water meter is generally referred to as its metrological class – from D (most accurate) through to A (least accurate), under the old *ISO 4064:1993*. However the revised *ISO 4064:2005* version of this only has 'Class 1' and 'Class 2' rather than D, C, B, and A.

First of all the meaning of 'error' must be highlighted. The error is the calculation of either the under-performance or the over-performance of the registered volume in relation to the actual volume going through the water meter. The start-up flow-rate (Q_a) is the absolute minimum flow-rate, and differs, sometimes significantly, between water meters. The permanent flow-rate is given as Q_p, while the overload flow-rate is given as Q_s.

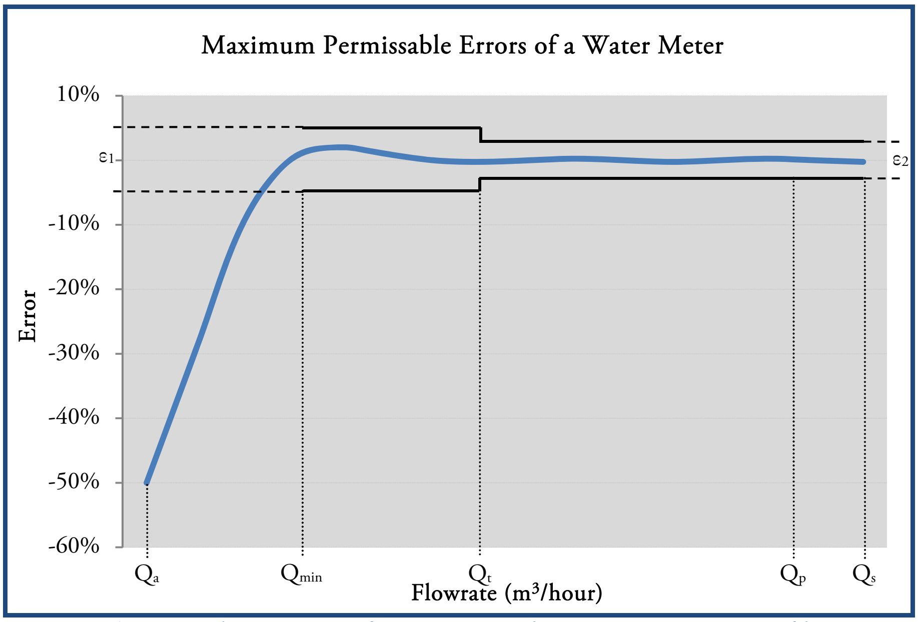

Figure 4.3: Typical Error Curve of a Water Meter showing Maximum Permissible Errors (Source: Arregui et al, 2006)

All metrological classes have the same maximum (Q_s) and nominal (Q_p) flow-rates, the difference between the four classes is the minimum (Q_{min}) and transitional (Q_t) flow-rates, please refer to Appendix B7 for details and characteristics of flow-rates per metrological class. This is further outlined in Figure 4.3, using the maximum permissible errors as a guide.

A – Least accurate;
B – Commonly used for bulk applications, typically >40mm, flanged;
C – Commonly used for domestic applications, typically 15mm – 40mm; and
D – Most accurate.

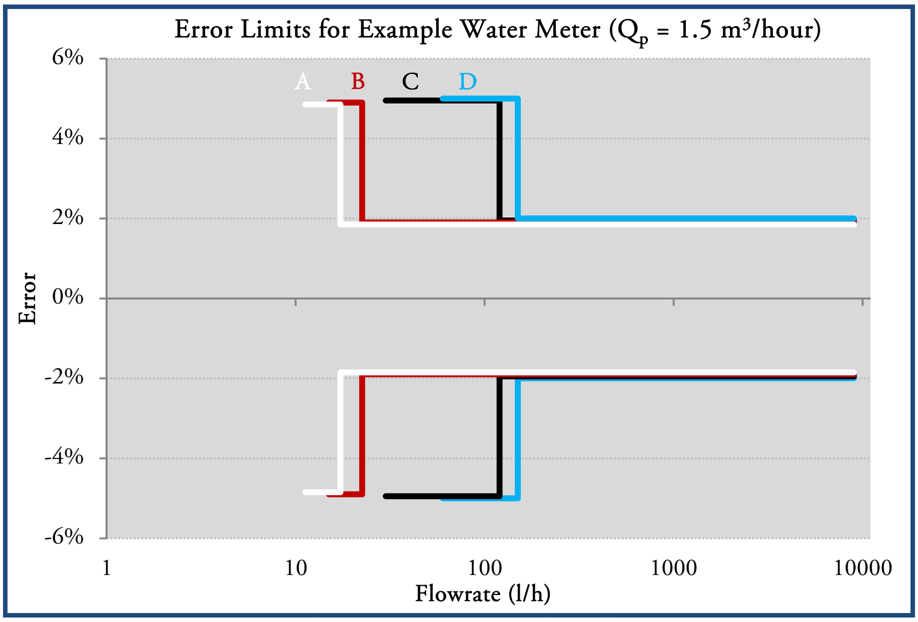

Figure 4.4: Error Limit of Example Water Meter for Differing Metrological Classes (using Q_p = 1.5m³/hour) (Source: Arregui et al, 2006)

In New Zealand, for residential or commercial buildings the council installed water meter must reach at least a Metrological Class C; for bulk water meters, a Metrological Class B must be achieved (Head, 2010).

So why not only use class 'D' water meters – the most accurate? The response is very much a financial one. Most water meters perform better than they are classed, however it is generally not accepted as the cost to certify at more accurate classes is much higher. A class 'D' water meter is noted as very much uncommon in New Zealand, except for in testing facilities and calibration, etc (Head, 2010).

The positioning of the water meter is determined by the type of meter itself, and the manufacturer's specifications. They are generally best fitted after a water filter, otherwise grit and dirt within the water network will cause wear on the mechanical inserts of the meter; also before any outlets – to measure the total consumption. It should also be noted that the length of straight pipe before the meter should be at least ten times the pipe diameter, and the length of pipe after the meter should be five times the pipe diameter (Environment Waikato, 2010), again depending on the water meter, manufacturers requirements, and the owners specified needs/use.

4.2.1. WATER METER TYPES

The eight more commonly used water meters in domestic and commercial applications are listed below. Each water meter is outlined and discussed, using the principles outlined in the previous sub-chapter, above.

WATER METER	TYPE	METROLOGICAL CLASS
Electromagnetic	Velocity	D
Ultrasonic	Velocity	D
Oscillating Piston	Displacement	D / C
Nutating Disc	Displacement	D / C
Single Jet	Velocity	C / B
Multi-Jet	Velocity	B
Woltmann (Helix)	Velocity	B
Combination	Velocity & Displacement	C / B

Table 4.5: Water Meters

Each meter produces a pulse per unit of flow. Some pulses are calculated based on the magnetic coupling of the mechanical inserts, other by a calculator of the rotational velocity of the blades on the wheel or impeller, or the velocity or volume of the water passing through the meter. This pulse can then be recognised and recorded with appropriate monitoring equipment (see Chapter 4.3).

4.2.1.1. ELECTROMAGNETIC

Electromagnetic meters are commonly referred to as 'mag' meters, and are one of the most accurate devices for measuring the flow of a liquid. A mag meter consists of a portion of non-ferromagnetic piping with a magnetic field (perpendicular to the flow of water) around it, and two electrodes to detect electrical voltage changes (Arregui et al, 2006).

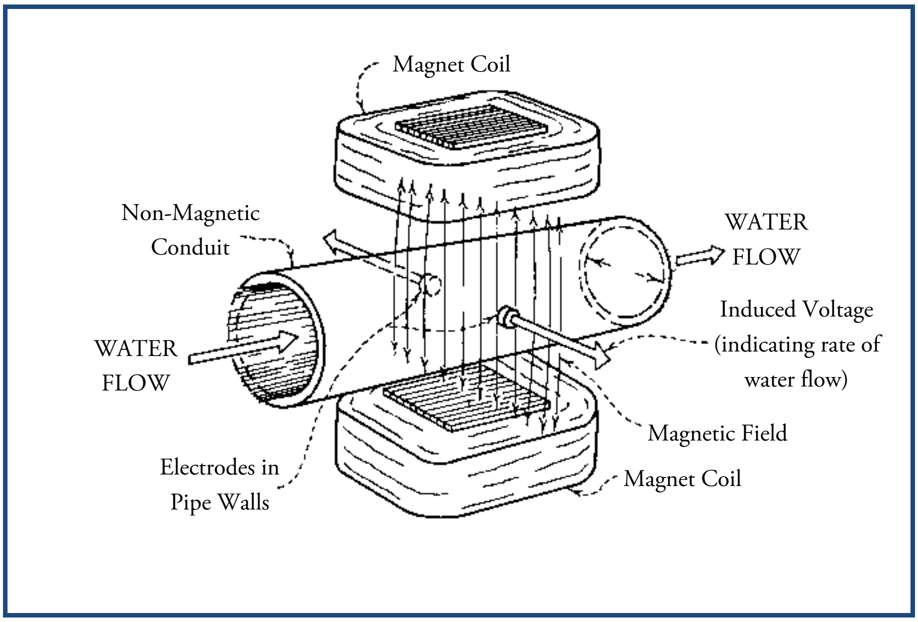

Figure 4.5: Electromagnetic Water Meter (Source: United States Department of the Interior Bureau of Reclamation, 2001)

Mag meters are based on Faraday's Induction Law. When a conductive fluid (like water) flows through the non-conductive pipe area, an electrode voltage is created in the fluid, which is proportional to the velocity of that fluid. The electrodes in the probe detect the voltages generated by the water. The voltage measurement can then be translated into velocity, and flow-rate (Arregui et al, 2006).

Ideally this type of meter can only be used in vertical installations, and in some cases horizontal if the pipe is guaranteed to always be full. It should be noted that this system is reliant on the supply of electricity. Due to the nature of the meter, the associated capital cost is generally high.

4.2.1.2. ULTRASONIC

These meters employ a number of ultrasonic transducers to measure water velocity passing through a portion of pipe. The measuring elements are either fixed on the outside of the pipe (temporary or permanent clamp-on) or as wetted permanent (in-line) transducers. At least two ceramic piezoelectric transducers that can work as both emitters and receivers of the sound waves need to be present (Arregui et al, 2006).

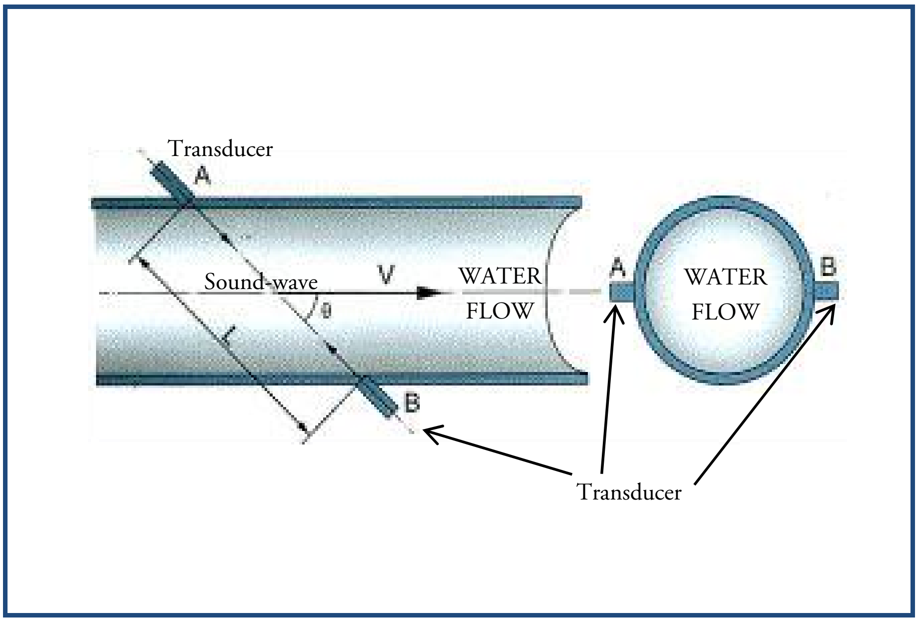

Figure 4.6: Ultrasonic Water Meter (Source: Shenitech, 2008)

The transducers act by sending ultrasonic sound waves through the pipe. The velocity is calculated by measuring the time taken for the pulse from the emitter to reach the receiver, and by incorporating pre-programmed characteristics of both the pipe-work and the water. This can then be converted into a measurement of volume (Arregui et al, 2006).

These are known to be one of the more accurate and robust water meters. They have no moving parts, and are therefore very durable. The position of installation is more about the distance and positioning of the transducers in relation to one another, rather that the axial configuration, and can be installed in pipe sizes of up to 8,000mm (Arregui et al, 2006). However, one disadvantage is the need for a continuous electrical supply, and the high associated capital cost.

4.2.1.3. OSCILLATING PISTON

'These meters are probably the most common water meters found in domestic applications around the world' (Arregui et al, 2006). The oscillating piston meters use the positive displacement method for measuring water, whereby, a chamber of known capacity is continuously filled and emptied in opposite tandem with another chamber of exact comparison. The mechanical insert for this type of meter, is a rotating piston with an eccentric motion around the metering chamber axis (Arregui et al, 2006).

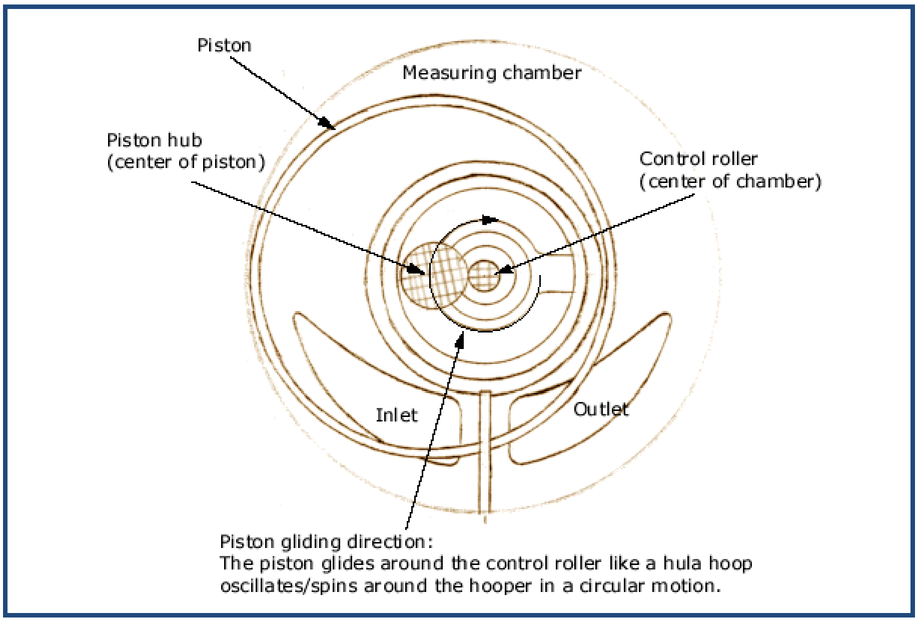

Figure 4.7: Oscillating Piston Water Meter (Source: eFunda, 2010)

Another method is the grooved oscillating piston, which uses grooved pistons to aid extended durability by preventing the adherence of particles to the surfaces of the piston and chamber. It should be noted here that the noise produced from these meters at higher flow rates, and when in contact with another surface, can be bothersome (Arregui et al, 2006). These meters are available in class 'D', and can mostly be installed in any position without affecting the registered accuracy – however the measurement can be significantly distorted by suspended solids.

4.2.1.4. NUTATING DISC

The nutating disc water meter uses a circular or oval disc, which oscillates around a central vertical shaft. This meter is a displacement meter, as a chamber of known capacity is filled before the rotation of the water meter can begin, and the chamber is again emptied as the disc is oscillated to the other side of the meter (Arregui et al, 2006).

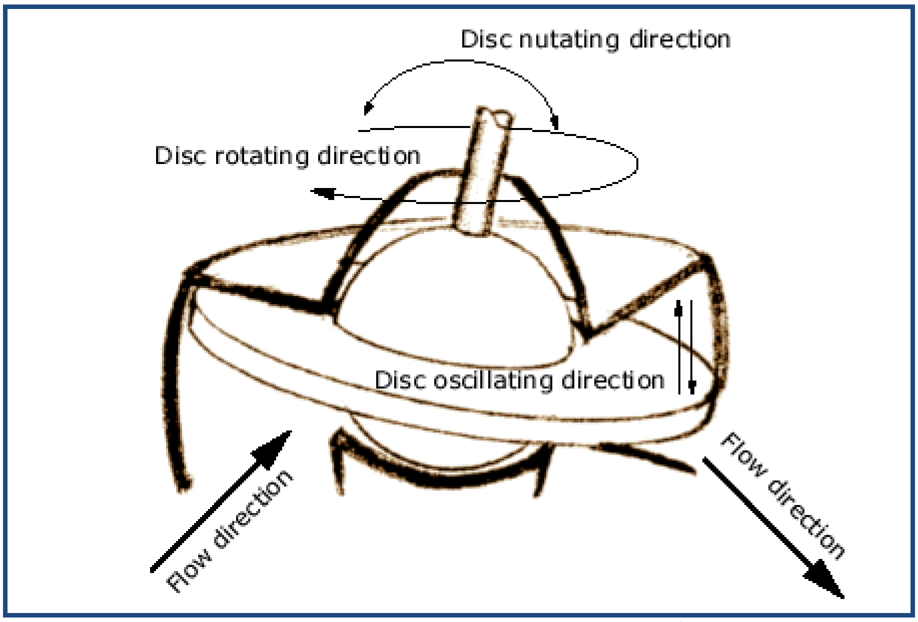

Figure 4.8: Nutating Disc Water Meter (Source: eFunda, 2010)

This water meter has moving parts, causing wear and reduced durability if not installed in the right axial configuration.

4.2.1.5. SINGLE-JET

A single-jet water meter (sometimes known as a paddle wheel water meter in larger applications) uses a mechanical insert, velocity system to measure the flow of water through the meter. It employs an impeller with radial vanes, where a single jet of water causes the impeller to rotate. The rotational velocity of the impeller is proportional to the impact velocity of water (Arregui et al, 2006).

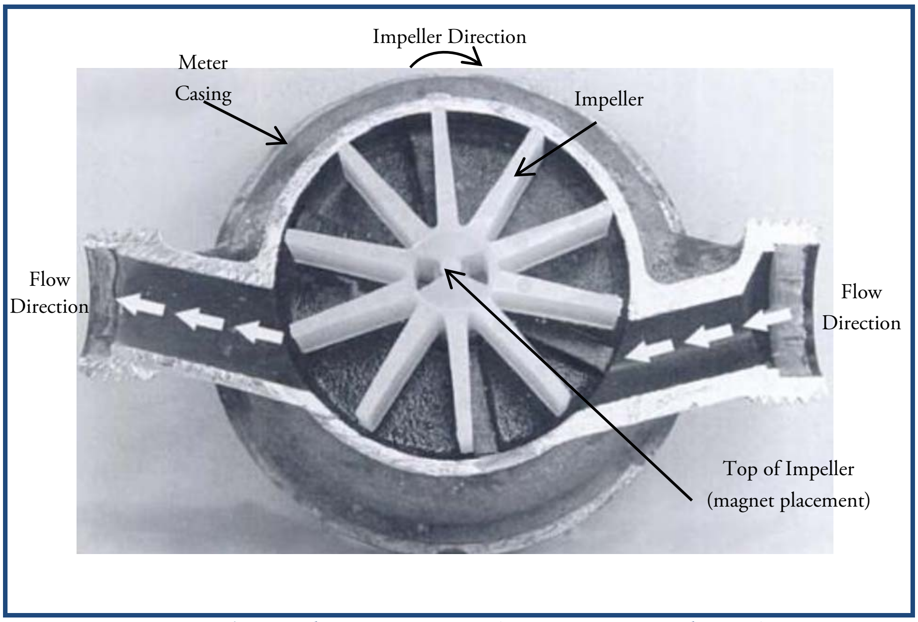

Figure 4.9: Single Jet Water Meter (Source: Arregui et al, 2006)

A magnet is fixed to the top of the impeller. This acts as a coupler with the follower magnet placed in the totaliser, allowing for a transmission of the motion without the need of physical contact between parts. These meters are usually designed to operate in a horizontal configuration, depending on the construction characteristics of the meter, this can significantly affect the accuracy of that meter. The single-jet meter is generally rated as a class 'C' meter, with a low start-up flow-rate.

4.2.1.6. MULTIPLE JET

A multiple jet (multi-jet) water meter also uses an impeller (as for the single-jet meter), horizontally on a vertical shaft. The difference between the single-jet and the multi-jet meters is distinguished by either one or a number of water jets directed toward the impeller, hence the name. The benefit of using a multi-jet meter over a single-jet meter, is the balance of pressure placed upon the internal mechanisms, including the impeller – whereby the jets are placed at several evenly spaced ports around the circumference of the element, not just one point – minimises (balances) wear on the moving pieces, particularly the vertical shaft (Arregui et al, 2006).

Multi-jet meters commonly will have lower start-up flow-rates. These meters can sometimes be more expensive that others, due to the size of the housing needed (Arregui et al, 2006).

4.2.1.7. WOLTMANN (HELIX)

The Woltmann meter (introduced by German Engineer Reinhard Woltmann) uses helices and a wheel facing the flow in its axial direction. The "rotational speed of this wheel is a function of a flowrate, which determines the impact velocity of the water on the blades, and the design of the blades and their angle" (Arregui et al, 2006). There are three possible configurations of a Woltmann meter: vertical vane; horizontal vane (most common); and angled.

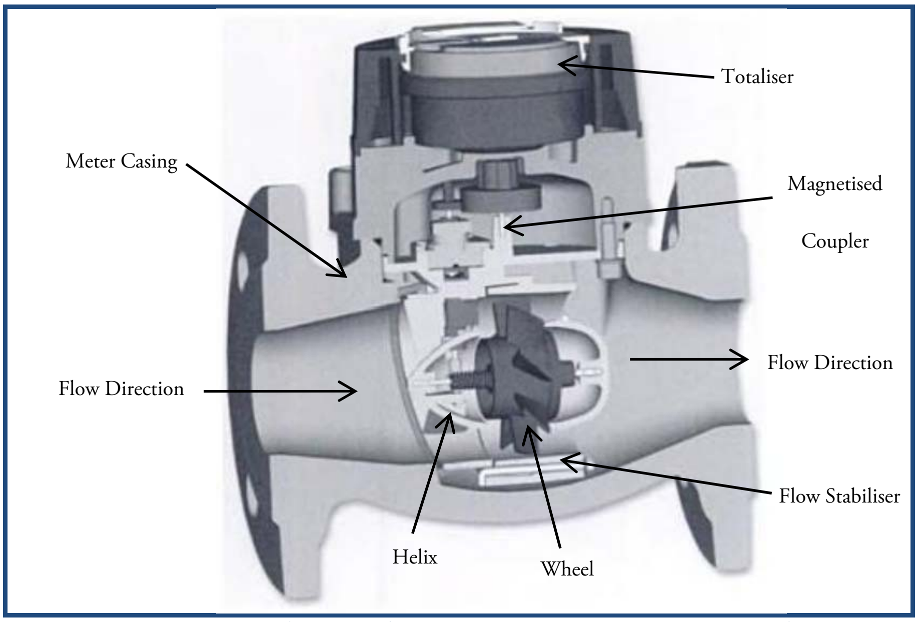

Figure 4.10: Horizontal Vane Woltmann Water Meter (Source: Arregui et al, 2006)

The accuracy of the water meter can be greatly distorted when a rotational motion is present within the water stream, disturbing the measuring wheel (Arregui et al, 2006). Therefore, the Woltmann meter incorporates the use of flow stabilisers, as seen in Figure 4.10.

4.2.1.8. COMBINATION METERS

Also called 'compound' meters. In order to accommodate the range from high (peak) to low flow-rates found in certain installations, a compound meter can be used. This typically incorporates the volumetric meter, as well as one (or more) higher flow-rate meters (commonly a Woltmann type meter). The installation can either be as two meters in separate casings, or within the same casing (thus minimising size/space).

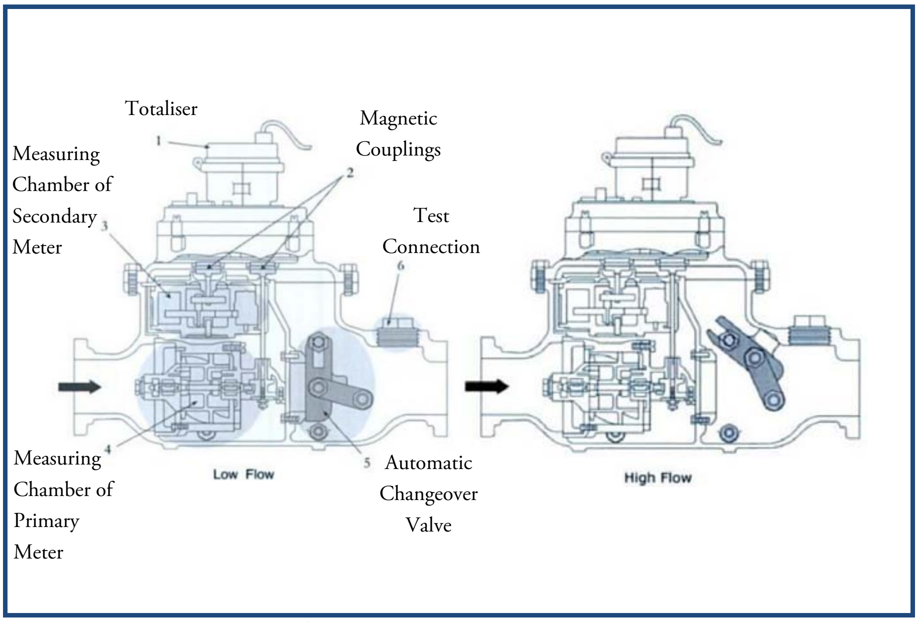

Figure 4.11: Combination Water Meter (Source: Arregui et al, 2006)

The meters are arranged in parallel. The changeover valve (determining which meter is active) is located downstream from the two meters, and is activated by the pressure (and hence the flow) of the water stream, and therefore either opening the valve to the main meter (closing the valve to secondary meter) or closing it (Arregui et al, 2006). This changeover valve however, can create increased wear and lowered durability, and therefore increased maintenance costs.

The axial installation configuration of these meters depends on both of the meters' manufacturers specifications.

4.3. MONITORING EQUIPMENT

In order for a fully detailed water audit to be undertaken, some monitoring and logging equipment needs to be installed to make the detailed part obtainable. The two primary pieces of equipment used are the pulse sensors and data loggers. However, if further fingerprint analysis is desired, then additional software and consideration is needed.

4.3.1. PULSE SENSORS

A pulse sensor is a portable device which can be connected to a water meter to enable the recording of the water flowing through the water meter at a given time. Sensors are the way in which time-of-use water data can be obtained, but not by themselves; they must also have a data logger installed. The pulse sensors must be compatible to the model, size, and type of water meter installed, as each meter has a different method of receiving the pulse outputs – that of optical, inductive, or reed switch.

Some meters provide the option for two, if not all, of the sensor types. This provides the option of using electricity or not. Below is a Table of the commonly available pulse sensors in New Zealand, and their compatible water meters. However, these may not be true in all cases, as age is also a factor.

Pulse Sensor		Water Meter		
Code	Type	Brand	Type	Code
BGP20 & PG100	Optical	Eslter-Kent	Woltmann Combination (Woltmann) Combination	H4000 C4000 (main) C4200 (main)
HRI 620	Inductive	Sensus	Piston	620 Series
HRI Mei	Optical	Sensus	Woltmann Woltmann	Meistream Plus Meistream
HRP, LRP, & MEN4071	Optical	Eslter-Kent	Woltmann Woltamann Combination	H2000 H3000 C3200 (main)
PR6	Inductive	Eslter-Kent	Piston Single Jet Piston Woltmann Combination (Woltman)	MSM-T S2000P V200 H400P C4000 (main)
PR7	Inductive	Eslter-Kent	Single Jet Piston Woltmann Combination (Woltmann) Combination	S2000 V200 H4000 C4000 (main) C4200 (main)
RD 01	Reed Switch	Eslter-Kent	Combination (Multi-Jet & Piston)	Meitwin
RD 02	Reed Switch	Eslter-Kent	Woltmann	WPD
RD MSM-T	Reed Switch	Eslter-Kent	Piston Combination (Piston)	MSM-T C4000 (bypass)
RD PSM-T	Reed Switch	Eslter-Kent	Piston Combination (Piston) Combination (Piston)	PSM-T C3200 (bypass) C4200 (bypass)
RSDS	Reed Switch	Sensus	Single Jet	Madalena

Table 4.6: Pulse Sensor and Water Meter Compatibility

The pulse sensor works by sensing the pulse from the water meter totaliser, for each given quantity of water passing through the meter. The data logger then counts those pulses at the set recording interval, and stores those counts. In order to calculate accurately the pulses per litre (PPL) rate, take a manual reading at installation and removal (or a specified time). Then calculate the use between readings, and divide by the sum of pulses within that period to determine the use per pulse.

4.3.2. DATA LOGGERS

Data loggers work with the pulse sensors, which are attached to the existing or newly installed water meters. The pulse sensor gives an instant output of the water meter, while the data logger receives and stores this at regular time intervals.

Figure 4.12: Data Puck Logger (Source: Sensus, 2010)

Figure 4.13: LogOr Data Logger (Source: A. D. Riley & Co. Ltd., 2010)

Figure 4.14: BRANZ USB Data Logger

The desired monitoring outputs (flow velocity, temperature, volume, etc) will determine which logger, or rather interface, is needed. There are many differing types of data loggers; Figure 4.12 and Figure 4.13 show the most commonly available ones in New Zealand. Figure 4.14 shows the one available from *BRANZ* for research purposes, which is not water-resistant, but is used in the field in a protective case.

4.4. AUDITING TECHNIQUES

There are various measurement techniques available such as self-monitoring and the installation of sub-metering. However, under the scope of this research it is the employment of an independent auditor, and the water auditing processes which are discussed here.

Audits are predominantly undertaken to understand the performance of buildings and facilities, so the areas with potential for both consumption- and cost-savings can be identified (Jayamaha, 2006). Generally water monitoring and auditing is not occurring throughout New Zealand. However, from previous studies carried out in the United States of America (*CIEUWS*), the United Kingdom (*CIRIA* C657 and *Watermark* project), and in Australia (*Exergy, NABERS* and *SWC*), a generalised method can be described.

Fortunately, there are very few methods for investigating the water consumption of a building; the processes can be compared to those used for energy auditing, and will be defined as a Survey Level Water Audit (SLWA), and a Full detailed Water Audit (FWA).

The desired output from the audit will determine the level of the water audit to be undertaken. This can of course be increased during the course of the audit, especially as unforeseeable differences come into perspective.

These have all been further discussed below outlining processes, advantages, and disadvantages. Both of the stated methods can be equally as accurate, depending on: the situation; the required output; and the auditor's experience on similar buildings.

4.4.1. SURVEY LEVEL WATER AUDIT (SLWA)

The SLWA is achievable by building management personnel, or by an independent water auditor. It uses a minimum of 24 months' worth of water consumption data, and depending on the type and function of the building will determine a performance indicator which can (ideally) be compared to water benchmarks for similar buildings in that region.

It also assesses that the right meter is being charged for the site under investigation. A site investigation is undertaken to determine and record all water consuming fittings and fixtures for their type, size, and physical condition. Consideration must be given to the types of heating and cooling services installed, and any other major water using processes.

The overall aim of a water audit at this level is to determine the water performance for the building in comparison to industry benchmarks for similar buildings. This involves participation from multiple areas, as the collection of historical consumption and billing data from utilities, and specific building characteristics from building management and observations are all needed.

4.4.2. FULL WATER AUDIT (FWA)

A FWA incorporates all requirements allocated under the SLWA, however it is far more in depth, and requires a larger allocation of time, specialisation, and financial investment to reach a conclusion. It should be noted that "installing any device into the plumbing system of large commercial buildings is proven difficult and expensive" (Dziegielewski et al, 2000). A FWA which involves the installation of sub-metering can be expensive.

As well as site inspections and investigations, suitable locations for sub-metering and monitoring equipment are determined and the equipment installed. For reliability, and to deal with any seasonal variation, meters need to be in the system for a full twelve months or more, and the use of specialised software is required. This however enables daily profiles, weekly cycles, and some weather features of water use, as well as seasonal and annual trends to be calculated and distinguished (Roberti, 2009).

As water use is typically only recorded in New Zealand at a minimum of monthly manual readings, without a FWA a water balance is extremely difficult to calculate, therefore can only be estimated – depending on the complexity of the building. A water balance compares the amount of water supplied to the building with how and when the water is being used within the building; by the appliances identified on-site inspections and investigations.

The resultant report will typically provide justification for any further investment for reducing the consumption of water within the building. Depending on the enthusiasm of the client, this step is very important in reducing water consumption, and is 'a key part of water management' (Quinn et al, 2006), and in determining accurate benchmarks for water consumption.

4.4.2.1. FINGERPRINT ANALYSIS

A fingerprint analysis enables the water end-uses to be disaggregated into a percentage of the total water use, and thus a load balance. In order to undertake the fingerprint analysis, access to the building is necessary during quiet times (when the building is not occupied) to allow a fingerprint of each appliance (one at a time) to be determined. Then using a software programme developed by *Aquacraft, Inc.* in the USA, called *TRACEWIZARD* (discussed in greater depth in Chapter 5.2.3.1), these can be used to disaggregate the water use within the building during normal operating hours. This involves using time-of-use logging equipment to enable this disaggregation of water use.

4.5. SUMMARY OF WATER ALLOCATION & MEASUREMENT

It is surprising that some of those regions facing shortages (as outlined in Chapter 2) may be encouraging higher consumption levels through poorly structured tariffs and allocation strategies, such as the 'decreasing block rate'. However, there does not appear to be any legislation challenging or informing these structures in New Zealand. Through appropriate metering, water can be measured and charged for accordingly; thus, educating the users of the water.

The next step in understanding how demand management can help, is through monitoring and auditing water use in the office buildings, to help formulate an indicator (or benchmark) which users and managers of these buildings can easily implement into their current operational strategies.

5. BENCHMARKING & TOOLS

This chapter is divided into two halves – firstly benchmarking processes and examples, and secondly tools for analysing water use and performance. Benchmarking refers to the process of normalising a building's water use, and developing regional indices/targets, while tools refers to the different analysis software and interfaces available for the analysis of water consumption and end-use, and/or water performance data.

5.1. BENCHMARKING

The term 'benchmark' can be defined as "a standard or point of reference" (Oxford Dictionaries, 2012). This is a point of reference whereby the water consumption for one building is able to be compared in an un-biased manner to water consumption benchmarks for similar buildings.

This chapter provides the background to the purpose of performance benchmarks, the benchmarking processes, and examples of in-use benchmarks around the world. This chapter will explain the benefits of developing a strategy such as this, in order to improve awareness and understanding of the performance of water in commercial office buildings in New Zealand.

5.1.1. PURPOSE OF A BENCHMARK

The purpose of a benchmark is to normalise consumption for water use, which in-turn allows buildings to compare their water consumption intensity relative to buildings of a similar use. Without a benchmark it can be extremely difficult to accurately assess a building in terms of its performance or efficiency level. With the help of these benchmarks, targets can be set, and consumers can begin to understand how their buildings are using their purchased water.

There are two main types of benchmarks commonly used; those used as "a point of reference" also known as consumption benchmarks; and those that "designate efficient levels of use" (Dziegielewski et al, 2000) also known as performance benchmarks. Both are significant, in that one indicates the standard level of consumption with regard to a particular region, and the other indicates the level of efficiency within each building.

5.1.1.1. CONSUMPTION BENCHMARKS

A consumption benchmark is a typical standard of performance. In order for a benchmark to be meaningful and accurate, it must take into account the whole population, or sample size (*n*). A typical benchmark is considered to be the median value, or the fiftieth percentile, of the sample, whereby half the population are above, and half are below the benchmark value (Kitchen et al, 2003).

Consumption benchmarks can be used for comparison with other regions, and provide the grounds for regional standards and design targets to be established. A consumption benchmark will state a typical value for that population, and occasionally a best and a worst practice value will also be given as the twenty-fifth and seventy-fifth percentiles respectively.

5.1.1.2. PERFORMANCE BENCHMARKS

Performance benchmarks are indicators of performance and are often given as a rating out of five (*NABERS*, *Exergy*, *SWC*). The middle tier of performance will normally equate to the typical consumption benchmark outlined above, but not always. Performance benchmarks are often used as a method of incentive to achieve better efficiency within the buildings. Performance benchmarks follow the same principles as consumption benchmarks, where the tiers are worked out on percentiles of the sample population, instead of only the fiftieth percentile. It is the performance benchmarks that are included into some BSRTs – such as the *NABERS* tool in Australia (Quinn et al, 2006). *WELS* is also an example of a performance benchmark, refer to Table 3.2.

5.1.2. CONSUMPTION MODELS

This chapter uses overseas studies to illustrate the development of a consumption model. Specific consumption units must first be established, and these differ according to the use of the building, and the type of establishment. As water is usually in a fluid state, the consumption of water is typically measured as a volume; as kilo litres (kL) or cubic metres (m^3). The consumption model is a measure of water consumption against a driver.

The drivers are assumed to be an indicator of water use on a common level, whereas the driver increases it can be assumed that the water consumption will increase (or decrease) also. Some of these drivers have been outlined in Chapter 3.3. From previous studies the common drivers are NLA, FTE Occupants, and Cooling Degree Days (CDD). These are compared against each other to find the most statistically appropriate driver for the sample of building activity and establishment type.

A correlation coefficient (*r*) is a statistical method of determining the strength of a relationship between two factors, whereby a coefficient of 1 is a very strong relationship, and 0 is a very weak relationship. In the instance below in Table 5.1, it is the relationship between water, and the drivers specified. The examples given are those which have been published only.

International Examples:	Sample Size	Correlation Coefficient (*r*) with Water				
		NLA	FTE Occupant Density	FTE Occupants	Hours of Occupancy	CDD
Watermark project	555			Not Published		
CIRIA C657	2,592	0.99		0.97		
Exergy	132	0.83	0.03		0.03	0.51
CIEUWS	5	Not Published				

Table 5.1: Determination of Appropriate Consumption Model for Commercial Office Buildings Water Use

As can be seen from Table 5.1 above, the NLA and FTE Occupancy seem to be the most common drivers of water use. Cubic metres of water per square metre of NLA per year (m^3/m^2/year) and cubic metres of water per FTE Occupant per year (m^3/person/year) can be assumed as the most appropriate models of consumption for analysis. These studies are further discussed within each country below.

After determining the most appropriate consumption model from the dataset, relevant to activity and type of building, a further analysis normally requires the data to be explored in detail before benchmarking can begin. This includes identifying possible outliers and removing them if found in error, as well as some basic descriptive statistics.

Firstly, as outlined earlier, there are two types of benchmarks; consumption and performance. A general rule observed throughout other similar studies is that the percentage of the sample population dictates the benchmark, for example a typical benchmark must cover half of the total population, therefore the fiftieth percentile is used. This is further outlined below in Table 5.2 for the two types of benchmarks.

CONSUMPTION BENCHMARK	PERCENT OF SAMPLE AT THIS LEVEL OR BETTER	PERFORMANCE BENCHMARK[1]
	10%	5
	20%	4
Best Practice	25%	
	30%	
	40%	
Typical	50%	3
	60%	
	70%	2
Worst Case	75%	
	80%	1
	90%	

Table 5.2: Typical Percentages of Sample Populations at Rated Levels

Performance benchmarks are usually rated out of five, with five being the 'best practice'. As noted earlier, the 'typical' consumption value need not always align with the middle tier of the efficiency value.

However, it is here that the debates begin on whether average performance should depict a middle tier of performance or the lowest – or in fact no level of efficiency. It has become apparent that the intended purpose of benchmarking often turns it into a market-based tool, rather than a true efficiency rating tool. This is demonstrated in Table 5.3, where the performance benchmarks have been separated into market-based and efficiency-based examples.

MARKET BASED Percent of sample at this level or better	RATING BAND -/5	EFFICIENCY BASED Percent of sample at this level or better
10%	5	2%
35%	4	14%
50%	3	26%
65%	2	38%
80%	1	50%

Table 5.3: Examples of Market-based and Efficiency-based Performance Benchmark Rating Bands

An 'efficiency-based' system would give a 0 (or no) rating to buildings performing below the average (median) level, thus only giving a rating for buildings on the basis of efficient water use. A 'market-based' system could give a mid-point rating to half of the population, with higher and lower rating bands covering better or worse performance. This study will only explore a 'market based' index system to enable both comparability with existing studies, and usability uptake during the implementation phase.

Such international examples as those below typically use benchmarks which represent market based benchmarks rather than true representation of water efficiency.

5.1.3. INTERNATIONAL EXAMPLES

This chapter outlines those few influential studies found on the benchmarking of water in commercial buildings. However, as stated earlier, the local climate can influence the consumption of water used in each location as, for example, cooling equipment must work harder as the difference between set-point temperatures inside and ambient temperatures outside increases.

Therefore, a climate normalisation formula has been used in some instances (e.g. *Australian Building Greenhouse Rating* (*ABGR*), and now *NABERS*) to more accurately compare these studies' results. The climate normalisation equation outlined below is the equation used throughout the international studies to follow. This equation normalises "water consumption effectively to Sydney" (Bannister et al, 2005), and is sourced from the empirical research conducted under the *Exergy* study and report.

$$N = W + W_{corr}$$
$$W_{corr} = 0.56158 - 0.001038CDD_{15wb}$$

Equation 5.1: Climate Normalisation Equation (Source: Bannister et al, 2005)

Where W is the water consumption intensity, W_{corr} is the climate normalisation, CDD_{15wb} is the number of cooling degree days to 15 °C wet bulb temperature, and N is the normalised water consumption intensity (Bannister et al, 2005). This will allow a comparison to be made between different climatic regions; this is further discussed later in Chapter 11.5.1. Under the scope of this chapter each study will not be compared against each other, rather they are demonstrated by their scope, and method of development.

5.1.3.1. UNITED KINGDOM (UK)

Several benchmarking studies have been conducted in the UK, however, only two are on a national scale; the *Watermark* project (Kitchen et al, 2003), and the *CIRIA* C657 study (Waggett et al, 2006b).

5.1.3.1.1. Watermark project

The *Watermark* project was a UK wide project administered by *OGCbuying.solutions* (Kitchen et al, 2003; Parkinson et al, 2003), the main contractor of this project. After publication of the results in the *Final Project Report to HM Treasury* in June 2003, *Advanced Demand Side Management (ADSM)* continued the project, and proved very successful in their research (Parkinson et al, 2003). This project is known to be one of the most in-depth and accurate studies undertaken for the purposes of water consumption in commercial buildings (Quinn et al, 2006). An online forum was developed with an interactive tool and knowledge database for participants of this study, and for other interested parties. Approximately 1% of the total office building population of the UK was analysed under this study. This study considered 555 buildings at the SLWA level in the UK.

LEVEL	WATER CONSUMPTION FTE OCCUPANT (m^3/person/year)
Typical (50%)	9.3
Best Practice	6.4

Table 5.4: Watermark Project Consumption Benchmarks for Commercial Office Buildings (Source: Kitchen et al, 2003).

For the statistical analyses conducted under this research, correlation coefficients were not given, however, FTE occupants was deemed as the most statistically appropriate model for their study. This project followed statistical techniques such as utilising the 'Bell Curve' and 'Student's t-test', as well as 'Regression and Correlation Coefficients' to determine benchmarks (Kitchen et al, 2003).

Unfortunately since the completion of this project in 2003 it has disappeared from the World Wide Web. However, using the *Way Back Machine* enables historic web information to be viewed (Web Archive, 2009), though the tool is inactive.

5.1.3.1.2. CIRIA C657

The study *Water Key Performance Indicators and Benchmarks for Offices and Hotels (CIRIA C657)* conducted by the *Construction Industry Research and Information Association* (*CIRIA*) was statistically based. One of their main objectives was that the study be easily replicable by other studies (Waggett et al, 2006b). The sample size was 2,592 commercial office buildings throughout the UK, studied at about the SLWA level.

LEVEL	WATER CONSUMPTION	
	NLA ($m^3/m^2/year$)	EMPLOYEE ($m^3/person/year$)
Best Practice Use (25%)	0.4	2.0
Typical Use (50%)	0.6	4.0
Excessive Use (75%)	0.8	7.0

Table 5.5: CIRIA C657 Consumption Benchmarks for Commercial Office Buildings (Source: Waggett et al, 2006a).

Under this study both the NLA and total employee consumption models were used as normalisation measures, as this provided comparison with other studies internationally, and without having to standardise NLA or occupancy via the density of employees within each building. However, this study uses 'total number of employees' rather than FTE occupants within the building.

For statistical purposes, a correlation coefficient of $r = 0.99$ dictated NLA to be the most appropriate model under their study.

5.1.3.2. UNITED STATES OF AMERICA (USA)

The only benchmarking study found for water in commercial buildings is that of the *Commercial and Institutional End-Use Water Study (CIEUWS)* sponsored and published by the *American Water Works Association (AWWA)* (Dziegielewski et al, 2000).

5.1.3.2.1. CIEUWS

The *CIEUWS* project looks only at commercial and institutional buildings in the USA. This covered commercial office buildings, hotels/motels, restaurants, and other building types under this category title, which were then broken down further as consumption differences became apparent (Dziegielewski, 2000). Building uses were also broken down by *Standard Industrial Category (SIC)* codes, similar to those of the *ANZSIC* codes in New Zealand and Australia (Trewin et al, 2006). It should be noted that these results were drawn from only five office buildings, but at an extensive SLWA level (some at FWA level), so may not be statistically representative of the USA.

LEVEL	WATER CONSUMPTION NLA ($m^3/m^2/year$)
Typical Use	1.53
Best Practice (25%)	1.06

Table 5.6: CIEUWS Consumption Benchmarks for Commercial Office Buildings (Source: Dziegielewski et al, 2000)

Under this study, both consumption (Table 5.6) and performance benchmarks (Table 5.7) were developed. This is an example of the 'typical' consumption value differing from the efficiency equivalent.

LEVEL	WATER CONSUMPTION NLA ($m^3/m^2/year$)
1 (10%)	0.79
2 (20%)	1.03
3 (50%)	1.59
4 (70%)	2.24
5 (90%)	2.97

Table 5.7: CIEUWS Predicted Performance Benchmarks for Commercial Office Buildings (Source: Dziegielewski et al, 2000)

In this study, levels of performance are rated with 1 being the 'best practice', and 5 the worst or 'excessive use'.

5.1.3.3. AUSTRALIA

Much investigation has been conducted over the past decade into ways of conserving water in buildings, and benchmarking has been provided as part of a BSRT – the *NABERS*. *Exergy*, *NABERS*, *DEH* and *SWC* have all undertaken research over the past decade, and have all developed benchmarks for consumption and efficiency in commercial buildings. There are also residential ratings available from *NABERS* and other projects such as the *BASIX* tool (BASIX, 2011).

5.1.3.3.1. NABERS

The *NABERS* tool is a publicly available, online tool. The tool covers water, energy, waste, indoor environment, and transport ratings for Australian buildings. The online tool allows assessment of the subject building prior to undertaking a formal assessment by an accredited assessor. Within this tool each assessed section is given a rating out of five – with five being the 'best building performance'.

LEVEL	WATER CONSUMPTION NLA ($m^3/m^2/year$)
1 (poor water management or systems – 80%)	1.73
2 (below average building performance)	1.39
2.5 (typical – 50%)	1.21
3 (above average performance)	1.04
4 (strong performance)	0.87
4.5	0.52
5 (best building performance)	0.35

Table 5.8: NABERS Performance Ratings for Commercial Office Buildings (Source: SWC, 2007)

As seen above, an efficiency rating of '2.5' is given as the 'typical' benchmark, rather than a rating of '3'. This gives higher incentives above the 'typical' value. It should be noted that these ratings are for Australia as a whole, however when determining a rating for the subject building, rated benchmarks differ between states, dictated by differences in climate as determined by the difference in CDD, causing a difference in evaporative losses. These indices are also design based.

5.1.3.3.2. Exergy

Exergy is an energy efficiency company with a focus on sustainability. This research was undertaken by *Exergy* on behalf of the *Australian Government Department of the Environment and Heritage (DEH)* (Bannister et al, 2005), now the *Australian Government, Department of Environment and Climate Change (DECC)*. The dataset of this study included 132 office buildings located over six states across Australia (Bannister et al, 2005).

LEVEL[1]	WATER CONSUMPTION NLA (m^3/m^2/year)
1 (80%)	1.50
2 (63%)	1.25
2.5 (50% - Typical)	1.125
3 (56%)	1.00
4 (17%)	0.75
5 (5%)	0.50

Table 5.9: Exergy study Performance Benchmarks for Commercial Office Buildings (Source: Bannister et al, 2005)

This study also shares the same system of rating levels of efficiency as *NABERS*, however with differing values for each level, this study also displays the levels going from 5 being the best practice, and 1 the worst. In fact this study contributed to the development of the *NABERS* benchmarks, and it is assumed that the difference in values is due to the climate normalisation process for Australia.

5.1.3.3.3. Sydney Water Corporation (SWC)

SWC is a government company based out of New South Wales, Australia. They have performed a number of studies looking at the water consumption and benchmarking of buildings, and of cooling equipment in those buildings.

In *Best Practice Guidelines for Water Conservation in Commercial Office Buildings and Shopping Centres*, comparison was made between buildings using cooling towers, and building not using cooling towers as a method of heat rejection. This study aimed to be a "practical resource to help building managers improve water efficiency" (SWC, 2007), and gives a more accurate benchmark for a building's actual water consumption by including building characteristics into the benchmark. It should be noted that this study is based solely in Sydney, therefore benchmarks will differ from those studies based on a national scale in Australia (*Exergy*, above). Due to this being an ongoing study under the *Every Drop Counts* programme, the number of buildings used to make the benchmarking study was not published (SWC, 2007).

LEVEL	WATER CONSUMPTION NLA (m^3/m^2/year)	
	With Cooling Towers	Without Cooling Towers
Average (50%)	1.01	0.64
Economic Best Practice	0.84	0.47
Well Managed	0.77	0.40

Table 5.10: SWC study Consumption Benchmarks for Commercial Office Buildings (Source: SWC, 2007)

SWC is also the only study to have published literature ('*Best Practice Guidelines*') regarding water consumption benchmarking for cooling towers, and for differing occupancy and establishment types. They have also undertaken a study looking at buildings with small retail areas on the ground floor.

[1] The *Exergy* study gives a rating out of 5.

LEVEL	WATER CONSUMPTION NLA ($m^3/m^2/year$)
Average (50%)	1.08
Economic Best Practice	0.90
Well Managed	0.82

Table 5.11: SWC Consumption Benchmarks for Office Buildings with Small Retail Areas (Source: SWC, 2007)

5.2. ANALYSIS TOOLS

Analysis tools include the use of interfaces to analyse water performances, or even water end-uses. However, the way in which these 'tools' are used in practice does not always represent the initial purpose as conceived by the tools' designers.

All of the schemes discussed here are based on a rating system of collecting credits that apply to a wide range of building types, including both new buildings and existing buildings. All cover a range of environmental issues such as materials, energy, water, pollution, indoor environmental quality, and building site.

5.2.1. BUILT ENVIRONMENTAL (SUSTAINABILITY) RATING TOOLS (BSRTs)

Tools, such as BSRTs, rate buildings on a number of factors, including energy, water, materials used, transportation, Indoor Environmental Quality (IEQ), waste, and more. Within each category there is usually a set of credits with a specific number of points attached to each credit. The credit points are generally then weighted and contribute to the overall rating. Ratings are not given per individual category – only the overall/combined rating. Typically these schemes will have technical or instruction manuals, but is necessary for an accredited assessor to rate the individual property to be registered/certified.

The more illustrative of these building environmental assessment schemes are perhaps the *BREEAM*, *Green Star*, and *LEED* schemes.

5.2.1.1. NEW ZEALAND

In New Zealand, there has been very little work focussing on water consumption and efficiency in the commercial building sector, other than that of the *BEES* project through *BRANZ*. The only effort directed towards water conservation is that of the *GSNZ rating tool*, which was adapted from the *Australian Green Star rating tool* in 2007 (NZGBC, 2009).

The most up-to-date version of the *GSNZ rating tool* has been used to assess its performance in terms of rating water consumption; this version is the *Office Design & Built 2009*. Under this tool energy is rated to use a maximum consumption of 105kWh/m^2/year (NZGBC, 2007), however there is no maximum apparent under the water rating section of the tool. This is primarily due to levels of normalised performance being unavailable and/or unknown in New Zealand.

It has become apparent that no benchmarking system has been attempted in New Zealand for commercial buildings.

5.2.1.2. BREEAM (UK)

The *Building Research Establishment (BRE) Environmental Assessment Method (BREEAM)* is the most widely used voluntary building environmental rating scheme in the UK (Roderick et al, 2009).

The *BREEAM* has a number of schemes available for differing types of buildings. In this instance, only the *BREEAM* Offices scheme will be discussed, unless otherwise stated.

There are four credits under the water category heading:

Credit	Points	Credit Criteria
WAT 1- Water Consumption	1 2 3	Where consumption is 4.5-5.5m^3/person/year for sanitary appliances (restroom taps, urinals, toilets and showers). Where consumption is 1.5-4.4m^3/person/year. Where consumption is <1.5m^3/person/year.
WAT 2 – Water Meter	1	Water meter with pulsed output will be installed on the mains supply.
WAT 3 – Major Leak Detection	1	Evidence of a leak detection system specified or installed.
WAT 4 – Sanitary supply shut-off	1	Evidence that proximity detection shut-off is provided to the water supply to all toilet areas.

Table 5.12: BREEAM Water Credit information (Source: Building Research Establishment, 2009)

This recognises water efficient equipment and appliances, and the necessity of having both water meters installed, a leak detection, and shut-off system in place.

5.2.1.3. GREEN STAR (NZ, AUSTRALIA, SOUTH AFRICA)

The *Green Building Council* is a world-wide organisation, split into country segments, with the *Green Star* administration in Australia, New Zealand, and South Africa. It was initially developed in Australia, and now it is the most followed voluntary building environmental assessment scheme within the respective countries.

This tool looks at a number of environmental characteristics, including management (MAN), IEQ, energy (ENE), transport (TRA), water (WAT), materials (MAT), land use & ecology (ECO), emissions (EMI), and innovation (INN) (NZGBC, 2009). The water credits are listed below in Table 5.13.

Credit	Points	Credit Criteria
WAT-1 Occupant Amenity Potable Water Efficiency	5 7	Reduce predicted water consumption for sanitary use within the building (using WELS). As above, <u>and</u> no water based heat rejection is used or water based heat rejection systems use 90% non-potable water.
WAT-2 Water Meters	1 2	Water meters installed for all major uses within the building. As above, <u>and</u> having those meters linked to a BMS or equivalent automated monitoring system that provides alarmed leak detection.
WAT-3 Landscape Irrigation Water Efficiency	1	90% of irrigation water is rainwater collected on-site, or recycled site water; OR water efficient irrigation system (with specific requirements) is installed servicing ≥50% or irrigated area; OR use of drought-tolerant plants.
WAT-4 Heat Rejection Water	2	Cooling tower water treatment can achieve ≥6 cycles of concentration for water based cooling systems; OR natural ventilation mode of a mixed mode system reduces HVAC cooling water consumption by at least 50%; OR no water based heat rejection systems are provided.

Table 5.13: GSNZ Water Credit Information (Source: GSNZ, 2011)

The *GSNZ* scheme identifies the high consumptive properties of water based cooling equipment, and awards points for use of natural cooling, air-cooled chillers or non-potable water supplied cooling equipment and the use of lower water demand e.g. drought tolerant plants (NZGBC, 2009).

It also awards points for onsite storage capacity, use of the *WELS* rated appliances within the building, and surface area for capturing rainwater, where the absorption coefficient is also taken into account when calculating annual harvest from storm water run-off. This is assessed against a pre-programmed climate database of annual rainfall for that region.

5.2.1.4. LEED (USA)

The *Leadership in Energy and Environmental Design (LEED)* scheme was developed, and is administered by the *United States Green Building Council (USGBC)*. It has registered projects in over 24 countries (Roderick et al, 2009).

LEED also offers a range of tools for differing buildings however, the one commented on herein is the 'New Construction and Major Renovations' tool, due to it being most closely related to commercial office buildings.

Credit	Points	Credit Criteria
WE Prerequisite 1: Water Use Reduction	PRE-REQUISITE	Employ strategies that in aggregate use 20% less water that the water use baseline calculated for the building (toilets, urinals, lavatory faucets, showers, kitchen sink faucets, and pre-rinse spray valves).
WE Credit 1: Water Efficiency Landscaping	2 4	Reduce potable water consumption for irrigation by 50% from a calculated mid-summer baseline. As above, and either use only captured rainwater, recycled waste-water, recycled grey-water, or water treated and conveyed by a public agency specifically for non-potable uses for irrigation.
WE Credit 2: Innovative Waste-water Technologies	2	Reduce waste-water generation by 50% through use of water conserving fixtures or on-site waste-water treatment to tertiary standards.
WE Credit 3: Water Use Reduction	2 3 4	Employ strategies that in aggregate use 30% less water than the water use baseline calculated for the building. Employ strategies that in aggregate use 35% less water. Employ strategies that in aggregate used 40% less water.

Table 5.14: LEED Water Credit information (Source: USGBC, 2009)

This tool appears to be the most performance based with hands-on/efficiency based approaches of the tools so far discussed. It has a prerequisite to achieve lower water use through efficient appliance and irrigation applications. This can then be aggregated towards the third credit – for the overall building.

5.2.2. WATER EFFICIENCY RATING TOOLS

In the context of this research, water efficiency rating tools refers to those that assess individual building water use, and rate it based on performance. Generally they are used as a performance (analysis) tool, rather than a design tool. Again there are few tools available, all with varying structures and purposes, from the USA and the UK.

5.2.2.1. AWWA (USA)

AWWA has a publicly available *MS Excel* based residential tool, designed "to help quantify and track water losses associated with water distribution systems and identify areas for improved efficiency and cost recovery" (AWWA, 2010). This *AWWA* tool can be downloaded from www.awwa.org in *MS Excel* format.

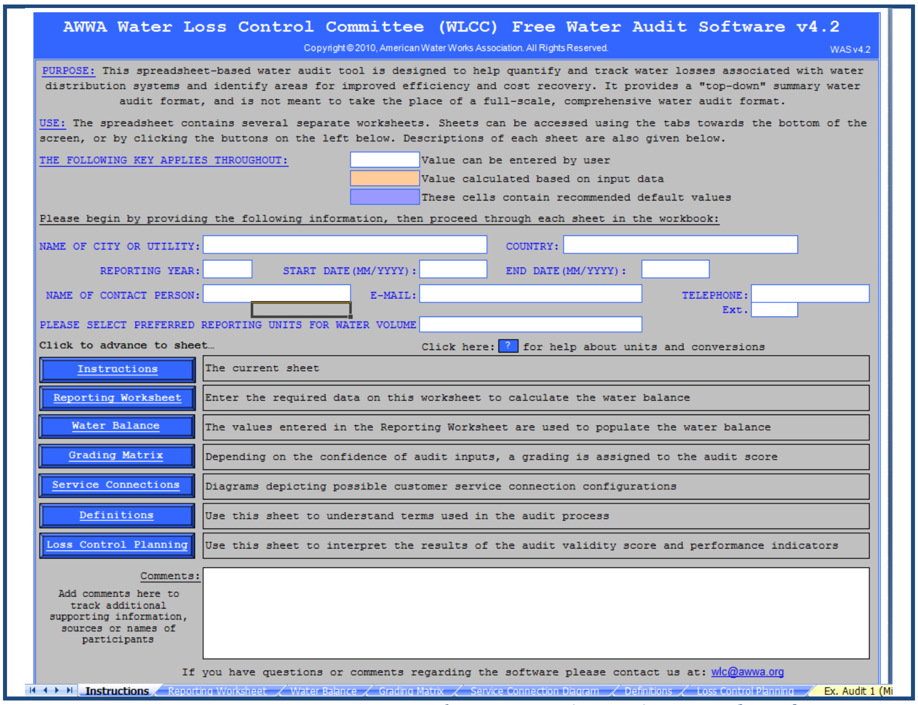

Figure 5.1: AWWA Water Loss Control Committee (WLCC) Free Audit Software (Source: AWWA, 2010)

Within the spreadsheet, the requirements are quite complex – as the user is technically replacing the water auditor by using this system. Firstly, an instruction sheet is displayed, whereby location and timing details are entered. A reporting worksheet is next, where the required data is entered to calculate a water balance, which is then displayed.

The tool also provides a grading matrix, diagrammatic service connections, and definitions, as well as a loss control planning score and generic advice. For a residential tool, this is found to be a very detailed version.

5.2.2.2. NABERS (AUSTRALIA)

The *NABERS* tool is perhaps the most well-known calculator available for measuring water performance. It is only a preliminary calculator, as in order to gain certification an accredited assessor must assess and rate the property.

The *NABERS* tool also assesses energy, waste, IEQ, and transport, as well as water. It provides individual star ratings for each category (as well as an overall rating). However, the water section will be the only *NABERS* category discussed here. As potable water is generally only measured once as it enters the building under *NABERS*, only the whole building can be rated, unless areas are sectioned off by sub-meters.

The required inputs for this category are simply a minimum of twelve months water consumption data, the NLA, and the hours of occupancy. The location provides the climate zone.

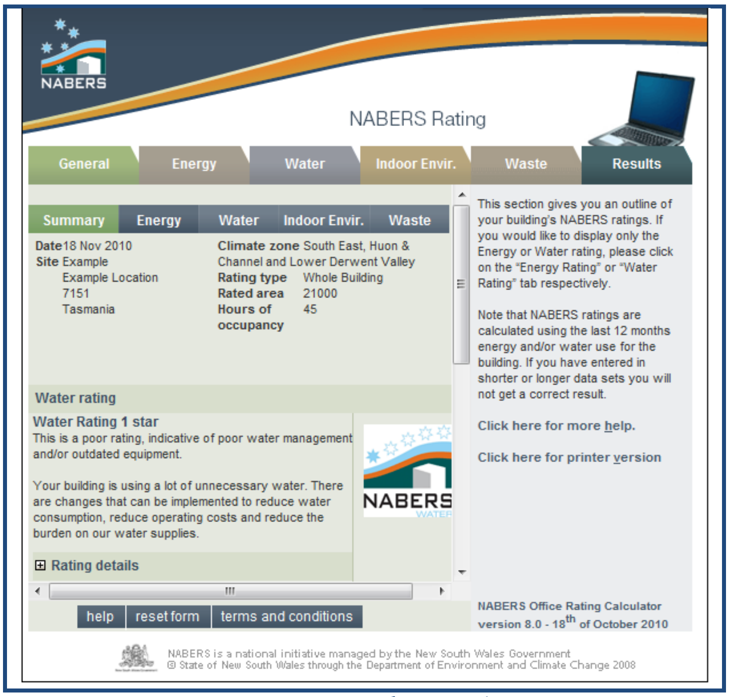

Figure 5.2: NABERS Rating Tool Output (Source: NABERS, 2009)

The output of the *NABERS* tool provides a star rating for each category, including water. The star rating is assigned depending on the calculated water use index. It also offers a brief descriptive outline of how the water performance could be improved, and explains what the given rating means in terms of water use.

5.2.2.3. THE WATER CALCULATOR (WATERWISE – UK)

The Water Calculator is a tool for quickly analysing daily consumption. The user first selects their desired target (in L/person/day), and then goes on to specify the number and types of installed sanitary and kitchenware. When selecting water appliances, the specific type is selected (by manufacturer, etc), and then quantity. The tool has built-in flow rates, etc so the user does not need to find this information.

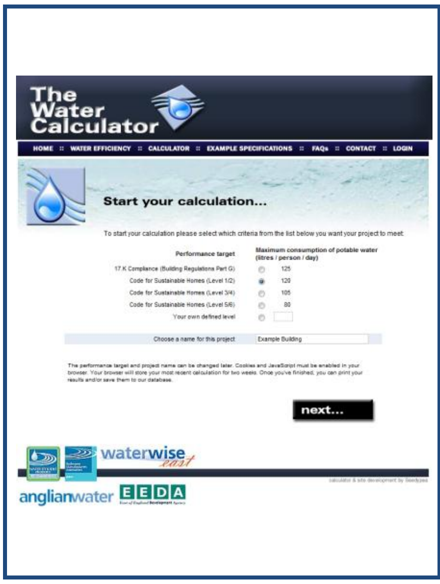

Figure 5.3: The Water Calculator Target Selection (Source: Waterwise, 2010)

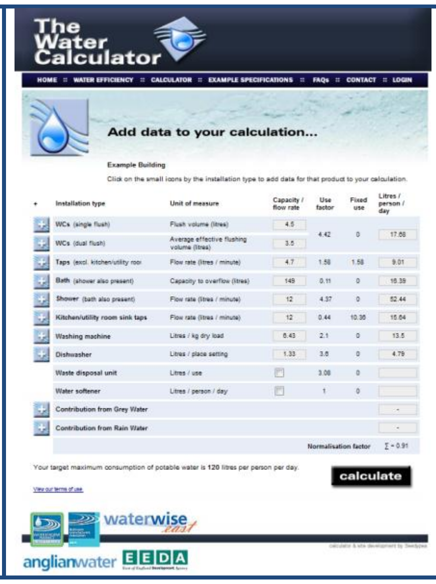

Figure 5.4: The Water Calculator Appliance Input (Source: Waterwise, 2010)

Figure 5.5: The Water Calculator Results (Source: Waterwise, 2010)

However, this *Water Calculator* tool is only designed to be used for residential scale buildings (Waterwise, 2010). The final results from this tool outline estimated daily performance in relation to the target specified at the beginning, and briefly outline what that means.

5.2.2.4. WATER CONSUMPTION HEALTH CHECK (ADSM UK)

ADSM is a UK based firm specialising in energy and water efficiency. Their online interface offers a very quick calculation of how a building is performing in terms of water or energy use. Below the three phases of this tool are displayed.

Figure 5.6: Water Consumption Health Check Input (Source: ADSM, 2009)

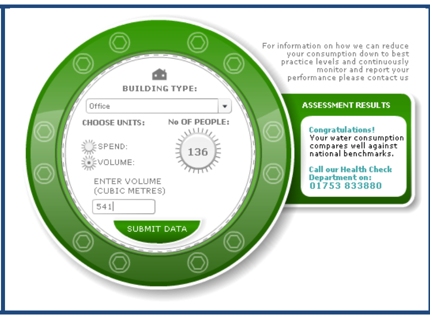

Figure 5.7: Water Consumption Health Check Green Zone (Source: ADSM, 2009)

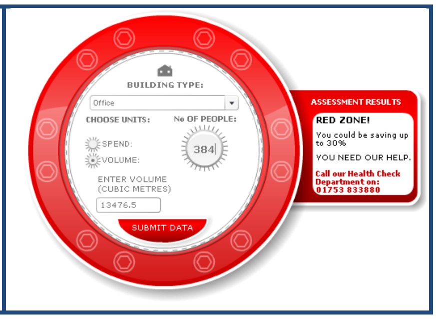

Figure 5.8: Water Consumption Health Check Red Zone (Source: ADSM, 2009)

The basic inputs required are the annual water consumption (in either cubic metres or the monetary value), the number of persons within the establishment, and the selection of the type of establishment being assessed. This tool therefore only calculates the water performance based on the number of persons, not the floor area.

It should be noted that this company were the principal consulting contractors for the *Watermark* project, whose results of their benchmarking statistical analysis conveyed that the total annual water use was more strongly correlated to the number of persons as opposed to the floor area of the building (Kitchen et al, 2003). See Chapter 5.1.3.1.1 for more details.

Once the data has been inputted, the 'submit data' button is pressed to see how the building performs. If the result is above a pre-determined *ADSM* benchmark, then the assessment results show the 'Red Zone', and the percentage above the benchmark for the building, and offers contact details.

If the water use is below the benchmark, the assessment results show the 'Green Zone', and offer contact details to further reduce the water consumption down to best practice levels. It should be noted, that not at any time was the benchmark, or its units displayed.

5.2.3. OTHER TOOLS

There are a few other tools available around the globe, some similar to those outlined in the above two sub-sections, and other providing other forms of results. For instance, *TRACEWIZARD* is a tool which can be used to calculate the percentage of domestic water going to different areas of a building.

5.2.3.1. TRACEWIZARD (AQUACRAFT)

TRACEWIZARD is a software program created and administered by *Aquacraft, Inc.* in the USA. This program allows the user to input default water use patterns to determine and disaggregate the percentage of water going to each type of appliance, over a selected period of time. But is limited to residential dwellings only, and has a limiting factor of a maximum of ten appliances running simultaneously.

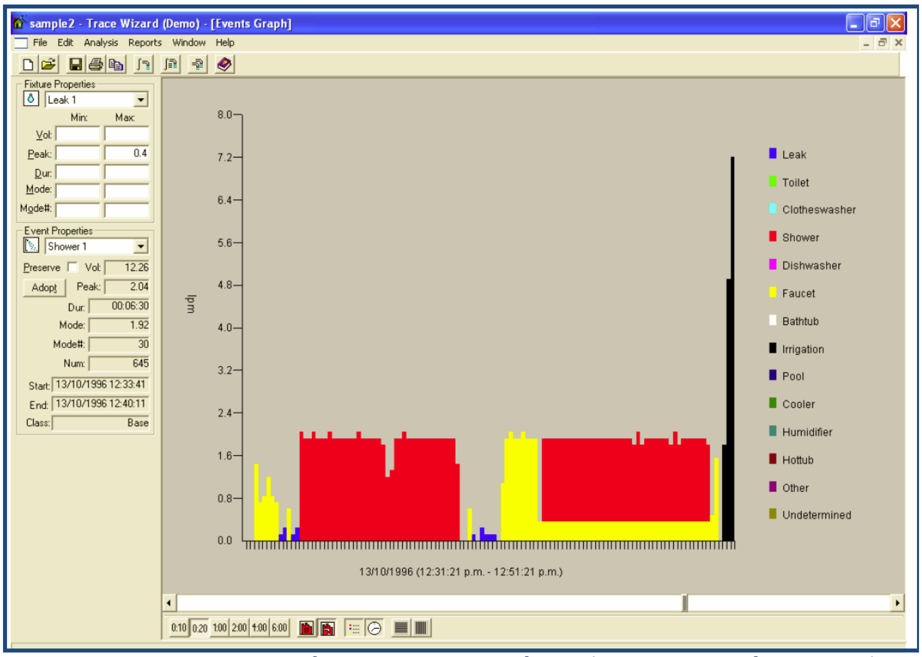

Figure 5.9: Screen-Dump of TRACEWIZARD Software (Source: Aquacraft, Inc, 2010)

It requires a *MS Access* '97 (*mdb) file to be opened within the programme, from here appliances and events can be self-identified (or using a default function) to calculate the percentage of water use going to each appliance, as well as allowing daily profiles of water use (determined by colour coding – as in Figure 5.9) to be identified. It differs from the other tools in that it collects its own data.

5.3. SUMMARY OF BENCHMARKING & TOOLS

Performance benchmarks allow their respective categories and regions to be assessed for water consumption and water efficiency. At the present time, no formal benchmarking system exists in New Zealand for commercial buildings. This makes impossible any comparison between cities, and even countries, other than that of total annual consumption per category or per capita. This also makes it impossible to award points for efficient levels of water consumption in any sustainability tool.

It is this lack of any assessment system which the research is to explore and report on, the studies outlined above will be used to help design a New Zealand based study on water consumption leading to efficiency benchmarking being possible in New Zealand commercial office buildings. This will build on the monitoring and auditing techniques found in Chapter 4, and help respond to the many issues posed in Chapters 2 and 3.

SECTION THREE: METHODOLOGIES

This section provides the methodology outline. It aimed to provide the principal methods for both collecting the water performance data, and turning that data into useful benchmarking indices through analysis.

Chapter 6. Building Selection & Sampling Approach outlines the method and criteria for selecting the sample and its size. Chapter 7. Water Auditing Methods describes the survey phase strategies, while Chapter 8. Data Analysis Methods summarises the analysis and benchmarking techniques for the water benchmarking index system. This chapter does not outline any results; its sole purpose is to define the methodology to be tested under this study.

6. BUILDING SELECTION & SAMPLING APPROACH

An investigation has been conducted on a number of commercial office buildings within both the Auckland and Wellington CBDs for this research. This has been undertaken in order to assess water consumption in the New Zealand context. A non-random sampling technique based on a focus sample has been used.

6.1. CBD BOUNDARIES

A method of ensuring accuracy within the results can be done by selecting a specific focus group within the overall population. Thus, commercial office buildings within Auckland and Wellington CBD locations have become the focus group under this investigation. Confining the investigation to an attainable sample size pushed the research towards the selection of a specific precinct in two of New Zealand's main centres; forming a non-random (non-probability) sample with regard to location. Below are the approximate study boundaries for the two cities.

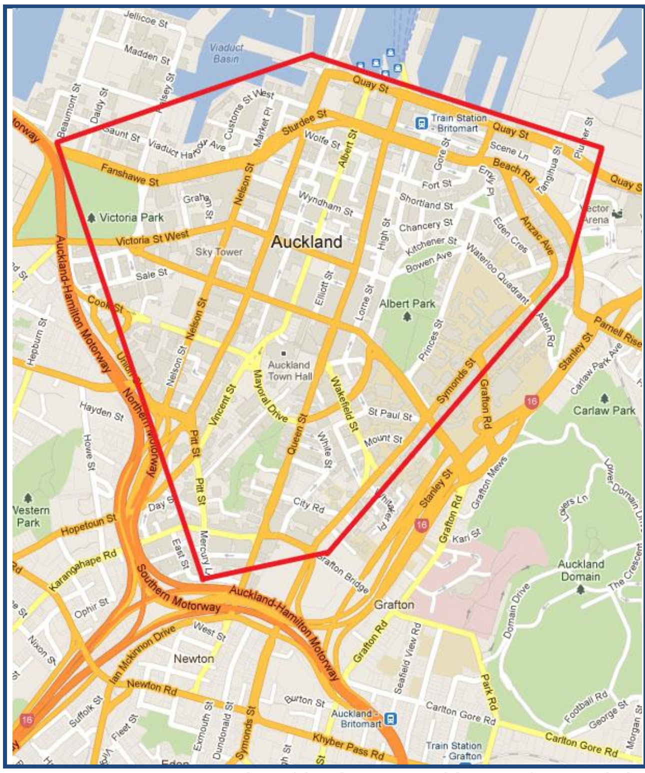

Figure 6.1: Location of Auckland CBD Buildings to be sampled (Source: Google Maps, 2012)

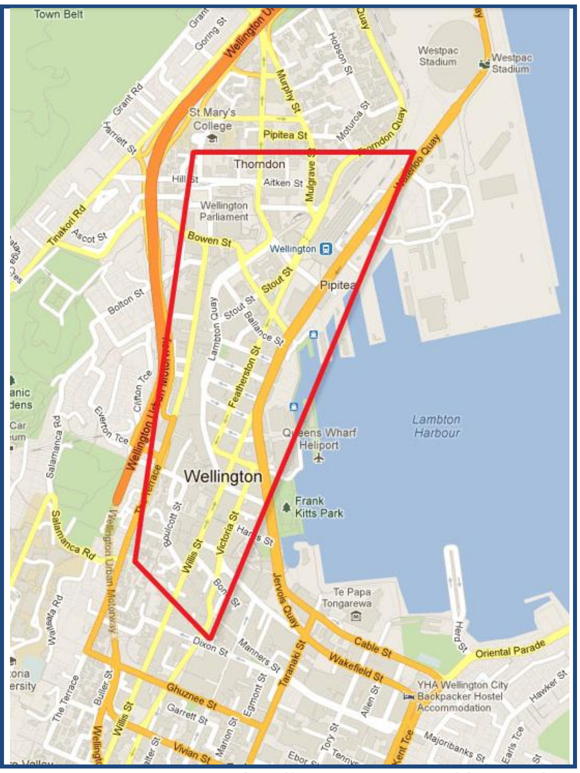

Figure 6.2: Location of Wellington CBD Buildings to be sampled (Source: Google Maps, 2012)

The Auckland and Wellington CBD precincts are predominantly commercial offices, retail, and temporary accommodation buildings; with few other building types scattered throughout the area. The number of buildings to be used in this study was selected to be at a minimum of 90, in order to gain enough variability within the two samples to ensure comparability. However, as there are differing levels of investigation, outlined below, the sample numbers also differed for each water auditing level.

The study sample size is as follows (please refer to Chapter 7 for details of water auditing):

Survey Level Water Audit (SLWA):

- 37 in Auckland,
- 56 in Wellington.

Full Water Audit (FWA):

- 0 in Auckland,
- 4 in Wellington (3 successful).

A total of 93 buildings were surveyed (37 in Auckland and 56 in Wellington).

6.2. OFFICE BUILDING CRITERIA

The buildings that were chosen for participation in this study had to meet a number of criteria. The reason for this was to ensure that the boundaries of the overall study were not broken, and to ensure that like-for-like comparisons were made. The following rules were applied in the 'selection' of buildings to be approached:

- ≥80% of NLA[1] determined as 'office' use:
  - as stated on the Building Warrant of Fitness,
  - determined by administrative activities, and sometimes including institutional activities.
- Multi-Storey;
- Metered Water Connection(s); and
- Within the CBD boundary, see Figure 6.1 and Figure 6.2 above.

6.3. BUILDING CHARACTERISTIC VARIETY

In reference to Chapter 3.3, it was desired that within the two samples, enough variability over each of the drivers could be achieved. These included building drivers (such as building age, footprint, size, height, materiality, and HVAC types), occupant drivers (such as number and type of tenants, hours of occupancy and operation, and occupant density), and appliance drivers (such as number and types of end-use appliances within the building). Table 6.1 shows the minimum, mean, and maximum values from the dataset.

Driver	Auckland			Wellington			Overall Study		
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
BUILDING DRIVERS									
Year Built	1957	1988	2009	1917	1980	2009	1917	1982	2009
Footprint (m^2)	611	998	2,100	145	588	3,213	145	762	3,213
Size (NLA – m^2)	2,002	9,953	39,490	1,636	8,559	24,387	1,636	8,951	39,490
Height (Storeys)	4	15	42	3	14	41	3	14	42
Heat Rejection Medium	Natural	Water	Water	Natural	Water	Water	Natural	Water	Water
OCCUPANT DRIVERS									
FTE Occupants	13	630	2,820	35	327	1,528	13	464	2,820
Hours of Occupancy	40	50	168	40	50	81	40	50	168
Hours of HVAC Operation	50	50	60	42	55	65	42	55	65
Occupant Density (m^2/occupant)	12	18	642	11	20	61	11	20	642
APPLIANCE DRIVERS									
End-Uses (i.e. Domestic Amenities)	63	206	699	51	175	623	51	193	699

Table 6.1: Building Characteristic Variability

For analysis purposes the *BEES* building categories were then used to split the buildings by size quintile. The size quintiles were as shown in Table 6.2:

[1] As specified by the *Guide for the Measurement of Rentable Areas* (BOMA et al, 1996).

Size Quintile	Number of Buildings per size quintile (as a percentage of total)		
	Auckland	Wellington	New Zealand
1 (≤649 m^2)	0 (0%)	0 (0%)	0 (0%)
2 (650 – 1,499 m^2)	0 (0%)	0 (0%)	0 (0%)
3 (1,500 – 3,499 m^2)	2 (0.38%)	8 (4.26%)	10 (0.74%)
4 (3,500 – 8,999 m^2)	15 (5.07%)	20 (11.90%)	35 (4.83%)
5 (≥9,000 m^2)	19 (21.35%)	24 (23.76%)	43 (16.73%)
Total	36 (0.87%)	52 (3.74%)	88 (0.64%)

Table 6.2: BEES Size Quintiles (Source: Isaacs et al, 2010)

6.4. BUILDING WARRANT OF FITNESS (BWOF)

In order to gain identity and contact information for each of the buildings within the selected boundary, each of the buildings was visited to visually inspect the information displayed on the Building Warrant of Fitness (BWOF) certificates, which are by law on display within public areas of each building (DBH, 2009a; WCC, 2009).

A BWOF is a statutory declaration, which, under the *Building Act 2004*, Part 2: Building, Sub-Part 3: Building Work, Section 108-111, must be supplied by the building owner (DBH, 2009a; WCC, 2009). It confirms that the systems specified in the compliance schedule for their building are conforming with the compliance schedule. The BWOF certificate is renewed on a twelve month interval basis. Minimum requirements, as per the *Building Act 2004*, to be displayed on a BWOF certificate are as follows:

- Building Name;
- Location (street address);
- Legal description;
- Original Date the Building was constructed;
- Building Ownership (name, mailing and email address, phone and facsimile numbers);
- Building Management/Agent (as above);
- Area (total floor area);
- Number of levels, including ground level and any levels below;
- Number of occupants per level and per use;
- Current lawfully established use;
- Fire risk; and
- Certificates of inspections, maintenance, and reporting (DBH, 2009a).

Refer to Appendix C2 for an example of a legitimate BWOF certificate.

However, it should be noted that although the above stated fields must be accurately completed, a large majority of the observed buildings display an incomplete, and/or empty BWOF certificate. A copy of the BWOF register can be accessed by contacting the local territorial authorities, in the case of this research, the *WCC* or *AC*.

6.5. SAMPLING APPROACH

A non-random (non-probability) sampling method has been used for this study; this means that the procedure of selection does not include the element of random selection. The sample is selected from a specified part of the population that was easily accessible (i.e. Auckland and Wellington CBDs). However, it is necessary to collect and examine a portion of the data before a solid sampling plan can be designed (Dziegielewski et al, 2002), which will provide the basis for a larger scale investigation. Therefore if further investigation is continued after the pilot phase, the parameters from this sample must be compared to parameters from a probability (random) sample taken from the same population (Dziegielewski et al, 2002).

In order to determine the size of the sample to be analysed, it is necessary to determine the confidence probability required for the margin of error considered acceptable, both as a measure of percentage (Dziegielewski et al, 2002). This can be approximated by using the below stated formula.

$$n_o = \frac{t^2 S^2}{r^2 \bar{Y}^2}$$

Equation 6.1: Sampling Confidence Probability

Where n_o is the first approximation of the sample size, t is the confidence probability, S is the population standard deviation, r is the relative error, and Y is the population mean value (Dziegielewski et al, 2002). However, in the case of n_o/N being somewhat significant (i.e. not insignificant), the finite population correction must be used, as outlined below.

$$n = \frac{n_o}{1 + n_o/N}$$

Equation 6.2: Sampling Equation

Where n is the sample size. The result indicates that if the average water use is unknown, a sample of n buildings would be required for the confidence probability and margin of error specified above (Dziegielewski et al, 2002).

6.6. SUMMARY OF BUILDING SELECTION & SAMPLING APPROACH

Based on the criteria established in Chapter 6.2, the office buildings to be part of this study will be selected non-randomly, using the CBD boundaries in Figure 6.1 and Figure 6.2. The buildings must also be multi-storey, have greater than 80% of their NLA specified as commercial office use, and they must be connected through a water meter to the city mains.

This has been done by entering each building identified within the boundary, and studying their BWOF. This provided both relevant contact details for the building owner or manager, and whether or not the building met the requirements outlaid above.

The results from this non-random study can then be used to design a complete statistically representative sample size for New Zealand office buildings.

7. WATER AUDITING METHODS

An investigation has been conducted on a number of commercial office buildings within both Auckland and Wellington for the purpose of this research. This has been undertaken to assess water consumption in the New Zealand context. Using the internationally published examples of water consumption studies and benchmarking tools (outlined in Section Two), a method of investigation has been established.

As this is a pilot study, its purpose is to test the methodologies as a way of predicting and benchmarking water consumption and efficiency in commercial office buildings. The selection of buildings to be surveyed, survey design and procedure, and analysis strategies are discussed below.

This chapter will not outline any of the resultant outcomes; rather it will discuss how the results and analyses were derived through identifying the methodologies. There were two levels of water auditing made available to the approached building owners and managers; SLWA, and FWA.

7.1. PERMISSION & CONSENT

Firstly a relationship between the researcher and the building manager or owner of each of the sample buildings needed to be formed. For this, a courtesy phone call was used, followed with a standard introductory letter and consent form, which were emailed out. These included the following areas:

- Courtesy Phone Call:
  - Brief Introduction of Research and Researcher,
  - Confirmation of Building Management and Contact Details.
- Cover Letter:
  - More in-depth introduction to Research and Researcher,
  - Name and Contact Details of Researcher,
  - Name and Contact Details of Research Supervisors,
  - Process to be undertaken under this survey,
  - Outlined aims and outcomes of overall research study.
- Consent Form:
  - Consent to participate,
  - Consent for identification of building within published work,
  - Opportunity to request individual analysis report upon completion.
- Water Account Permission:
  - Consent to access water billing history through nominated account and provider.
- Information Sheet (to be covered in Chapter 7.2.1).

These forms can be found in full in Appendix C4. This approach allowed the building manager the option to either consent to participate or not. The 'Information Sheet' was sent out at the same time as the 'Cover Letter', 'Consent Form', and 'Water Account Permission', in order to allow the building management to see what their participation under this project would entail, making the process as transparent as possible.

7.2. SURVEY LEVEL WATER AUDIT (SLWA)

Prior to conducting this survey some basic research was undertaken, so that the researcher could ask only a short list of questions, the answers to which could be easily obtained by building management. In order to assure that this method was as accurate as possible for the purpose of this investigation and the development of the required output, one building was initially surveyed as a 'pilot' for this method of investigation. This proved very successful in terms of minimising issues further down the track, and is discussed in greater detail within each of the following sub-chapters below.

Firstly, an initial walk around the CBD was undertaken to establish the boundaries, then BWOFs were used to identify the relevant contact information of the selected buildings within that boundary. Once a list of buildings had been established, all of the major property management companies were approached, and appointments made with Asset Managers, Property Managers, and/or Facilities Managers within each company.

7.2.1. INFORMATION SHEET DESIGN

As outlined above, the 'Information Sheet' was emailed out to the building managers of the selected buildings at the same time as the 'Cover Letter', 'Consent Form', and 'Water Account Permission'. One building was tested as a pilot for this study to ensure the amount of information requested was not overbearing or, on the other hand, not inadequate from the researchers' point of view.

Based on the Australian *Exergy* study (Bannister et al, 2006), the 'Information Sheet' was adapted for use on a more accessible scale, where only basic questions were included in the 'Information Sheet' design. Observations from other studies, such as the *Watermark* project in the UK, noted that from feedback these forms should be not more than one page in length, this improves the response rates, and the time consumed from the building managers in sourcing the respective data to complete the forms (Kitchen et al, data).

In Appendix C5, a demonstration of the 'Information Sheet' presented to the building managers under this survey is shown. The following discussion outlines each section of the 'Information Sheet' in further detail:

Building Identification: Firstly the building had to be correctly identified against the information gained by BWOF data, and also so that it could be correctly matched to water consumption data and billing data from the *WCC*, *Watercare Services Ltd,* and *Metrowater*. It should be noted that some of the information (e.g. year building constructed) displayed on BWOF certificates on public display are often estimates, therefore accurate data from building management/ownership is desired.

Building Management: The building management information was requested so the person in charge of management for their respective building was identified as the main point of contact. Also where an individual analysis report was requested, it could then be distributed at completion to the appropriate persons.

History of Building: The basic history of the building was required in order to assess if the building age has an effect on the water efficiency levels, also to check the accuracy of the data against the BWOF certification. Also, this section confirms when the most recent upgrade was undertaken, the NLA, building materials, number of storeys, and the installed HVAC type.

Description of Spaces: Here a description of each space was requested. This required tenant use, number of FTE occupants, NLA, and hours of occupancy for each space. These are the drivers to be tested under statistical analyses (refer to Chapter 11).

Building managers were also asked to define whether each of these spaces is separately sub-metered and air-conditioned. Under the pilot version of this study it was found that the building manager did not always know accurate FTE occupancy numbers and hours of occupancy per week for each individually tenanted space, thus requiring further investigation under the site survey phase of this study.

Water Service Providers: This question was asked to see if the building management are aware of their water consumption over the past five years. Confirmation of the corresponding water meter number(s) was also requested for validation with the water consumption data gained from the *WCC, Watercare Services Ltd,* and *Metrowater*, and later, during the site survey phase, against the water(s) meter installed on-site. However, in most cases, this proved difficult for the building management to obtain, thus an alternative was to provide their most recent water 'tax invoice' for account number and water meter number to be confirmed with water service provider documentation.

A copy of a typical floor plan was requested to help with further examination of the building, and to enable efficient use of time on-site. In most cases this was available, in the cases where the floor plan was not available, it was sourced from the relevant Archival Organisation. As some of the forms were printed and completed manually, a return postal address was required along with the return email address, in order to collect the completed forms without further difficulties. On completion of these forms, the pilot building management stated the form used seemed to be of a manageable size, and was not difficult in obtaining the requested data (other than that outlined above).

Once the completed forms were received and assessed, an appointment with building management, and a site survey time was requested and scheduled at the building managers' convenience.

7.2.2. ACCESS HISTORICAL DATA

Prior to undertaking the site visits, contact was made with the relevant water service provider to gain the historic water accounts for each building. In the case of *WCC*, *Watercare Services Ltd,* and *Metrowater*, they were also able to provide a description of both the installed water meter, and its location.

7.2.2.1. WELLINGTON

The water supplier for the Wellington CBD area [and of the Wellington region] is a company called *Capacity Ltd,* also known as *Wellington Water Management Ltd,* which is governed by the *WCC. Capacity Ltd* was contacted as part of this research project with the intent of obtaining the water consumption and billing record data. An excellent relationship was established for the duration of this research. Below in Table 7.1 are the 2010 and 2011 water service charges for a Wellington commercial building.

	A: Service Charge	B: Ingoing Water	C: Wastewater
2011	NZD$100 per meter	NZD$1.715 per cubic metre ($m^3$)	0.00130171% of Capital Value
2010	NZD$84 per meter	NZD$1.584 per cubic metre ($m^3$)	0.0044001% of Capital Value

Table 7.1: Wellington Water Tariff Structure

The water consumption and billing data were gained through the collaboration with both the *WCC* and *Capacity Ltd*. Both institutions proved to be very helpful and interested in providing assistance. From the water consumption and billing data received, the following data points were collected:

- Meter Numbers;
- Meter Brands;
- Meter Readings;
- Approximate Meter Reading Dates;
- Meter Locations;
- *WCC* Account Number;
- Street Address; and
- Any additional notes regarding the water meter on-site.

The water consumption and billing data provided by the *WCC* included bi-monthly (i.e. 6 times a year) meter readings for the period of July 2004 until date of enquiry, thus giving a base number of approximately 31 data points per building (ranging from 14 to 44), with an overall dataset of 1,767 data points for the Wellington sample.

Meter numbers were verified against both *WCC* 'tax invoices' (see Appendix C3 for example 'tax invoice') provided by management, and the water meter on-site. An issue identified, and with which the *WCC* is often faced, is the high variability in correct street addresses corresponding to the right meter numbers and records. This varies between legal title, BWOF data, and building management documentation, and has caused some conflict in the past in obtaining the correct data for particular buildings (Fleet, 2009).

The data received was then used to determine if any annual, seasonal, or bi-monthly patterns occurred within the water consumption for each building, and any significant trends. It was identified through personal communication with *Capacity Ltd* and *WCC* that no data analysis goes beyond that of the verification that the meter readings are in approximate order with recent historical meter readings (Fleet, 2009; Gribble, 2009). This data was assessed for any outliers and inconsistencies prior to conducting the survey phase of this research. However, the analysis relies upon the data collection from the survey phase to provide the development of a benchmark.

7.2.2.2. AUCKLAND

The Auckland research was made more complex by the formation of the Auckland 'super-city' during 2010. The water service provider for Auckland CBD, prior to November 2010, was *Metrowater*. After November 2010, *Watercare Services Ltd* became the sole (merged) operating utility. Below in Table 7.2 are the water service charges for applying to Auckland CBD in 2010 and 2011.

	A: Service Charge	B: Ingoing Water	C: Wastewater
2011	NZD$43 per meter	NZD$1.300 per cubic metre ($m^3$)	NZD$4.056 per m^3 based on 75% of B
2010	NZD$81 per meter	NZD$1.580 per cubic metre ($m^3$)	NZD$3.797 per cubic metre ($m^3$)

Table 7.2: Auckland CBD Water Tariff Structure

Both organisations were contacted prior to the 'Supercity' formation and access was arranged. This involved getting written consent from each account holder or account holder representative, authorising access for the duration of the study. Both organisations were extremely helpful in providing the water billing history, and following up on any unanswered questions. From the water consumption and billing data received, the following data points were collected:

- Meter Numbers;
- Meter Brands, Models, and Pipe Sizes;
- Meter Readings;
- Approximate Meter Reading Dates;
- Meter Locations;
- Relevant Account Number(s);
- Street Address; and
- Any additional notes.

Under both the *Metrowater* and *Watercare Services Ltd* system, readings are undertaken manually on a monthly basis (i.e. 12 times a year). In Auckland, readings back as far as account creation were able to be accessed. The number of data points per building varied somewhat dramatically (averaging at 67 data points per building, but ranging from 13 to 195) creating an overall dataset of 2,570 data points for the Auckland sample.

7.2.3. SITE VISITS

The site surveys were performed upon the return and assessment of the 'Consent Forms' and 'Information Sheets'. This allowed completion of the remainder of the information required to observe the more technical information within the building required by the study. This work was more appropriately carried out by the researcher rather than requesting the building manager to do so.

Firstly, a meeting was held with the building management in order to answer any outstanding questions not included on the 'Information Sheet', such as ambiguities found in water billing data or supplied information (i.e. meter faults or estimates); also to determine if photography of water using equipment and amenities was acceptable on-site.

Once on-site, the water meter(s) was/were located, and meter numbers and meter readings were recorded to be verified against the information provided by the water provider. Verification was undertaken to confirm that the correct water meters were being billed to the site. All water outlets are then located, identified, described and logged on the 'Site Survey Sheet'.

This process also involved consulting a member of staff within each of the tenanted spaces of the building, to complete the 'Information Sheet' as above, requiring FTE occupancy, and hours of occupancy figures, and also to determine types of tenanted offices within the building. However, due to the sensitivity of some tenants, this was not always an option, and therefore approximate numbers had to sometimes be estimated by the building manager.

The site visits typically took 60-120 minutes to complete. During the site visits the following areas were observed for type and for condition:

- Water Meter (Main Water Meter, any Sub-Metering);
- Plant Room (Heating, Cooling and Heat rejection, AHU, Other);
- Restrooms (Males, Females, Unisex/Disabled, and Showers);
- Kitchens (Common and In-Tenancy);
- Irrigation (System and Land Area);
- Water Features (Internal and External); and
- Miscellaneous (Tenancies, End-Uses, Sprinkler Valve Room).

The standard 'Site Survey Sheet' used on each of the site surveys to acquire the required data for the analysis to take place can be found in Appendix C6. The following discussion outlines each section of the 'Site Survey Sheet' in further detail.

Water Use Features On Site: This was an attempt to analyse where the purchased water may be going. Number, type, size, approximate age, and visual physical condition of each of the water using features on-site were observed and recorded. Space has also been allowed for items not listed.

Additional Water Information: This principally helped in identifying the awareness and the importance placed on water consumption within each of the buildings, to see how prevalent sub-metering is, and if any attention at all is given to the conservation of water in any of the buildings within the sample.

List of Plant Equipment: This allowed a more accurate detail of whether or not water is used for the cooling operation within each building, and the sizes of water consuming equipment providing the conditioning to each of the spaces. The main focus of this was to determine if water cooling towers were used, for as noted previously, if present these can be one of the largest consumers of water within the building (SWC, 2002).

Water Meter Information: The location of the meter is determined and recorded. The meter number(s) was/were also recorded, along with current readings for each meter located. 'Other' refers to other observations, this, for example, could be the type of meter used on-site, the physical condition of the water meter, and/or any difficulties in locating and accessing water meters for each building.

Additional Comments: An additional sheet of ruled paper was also attached to the 'Site Survey Sheet' to allow any extra notes and observations to be recorded while on-site.

Photographs were taken of all individual appliances observed within the building in order to prevent a second visit being requested for further analysis – unless absolutely necessary. These photos were then stored as digital files.

7.3. FULL WATER AUDIT (FWA)

The next phase in the process to understanding water consumption in office buildings is to undertake a FWA on a selected sub-sample of the SLWA buildings.

The type of installed water meter (which would be compatible with available sensors), identified during the SLWA, determined whether or not that building could be subjected to a FWA.

7.3.1. SELECTION CRITERIA

Buildings for the FWA phase were selected on the basis of the available equipment (pulse sensors and data loggers) available through the *BEES* programme. If the manager had specified that they were happy for a FWA to take place, they were informed of the cost of the equipment should the *BEES* programme not have it available, and allowed to decide whether or not to continue.

Once the SLWA portion of the study had been completed, photographs of the installed water meters, along with the written description received from the *WCC, Watercare Services Ltd,* and *Metrowater*, were taken to a water specialist, Andrew Curry from *Arthur. D. Riley Field Smart Technology*, for help in correctly identifying each meter model, and its compatible pulse sensor for *Kent*, *Elster*, and other meter types. Steve Drysdale from *Deeco*, provided the relevant data on *Sensus* type water meters.

Through the *BEES*, a range of pulse sensors were available for use in this study; along with the *BRANZ USB Data Loggers*, which were trialled in the *AWUS* and *WEEP* studies (Heinrich, 2008; Heinrich, 2007). Below is a table of the compatible pulse sensors with the relevant water meters.

Brand	Water Meter	Pulse Sensor	*BEES* Availability
Elster-Kent	H4000 C4000 (main) C4200 (main)	BGP20	
Elster-Kent	H2000 H3000 C3200 (main)	HRP, LRP or MEN4071	
Elster-Kent	H4000 C4000 (main) C4200 (main)	PG100	
Elster-Kent	MSMT S2000P V200 H4000P C4000 (main)	PR6	Yes x 1
Elster-Kent	S2000 V200 H4000 C4000 (main) C4200 (main)	PR7	Yes x 1
Elster-Kent	Meitwin	RD 01	Yes x 2
Elster-Kent	WPD	RD 02	
Elster-Kent	MSMT C4000 (bypass)	RD MSMT	
Elster-Kent	PSMT C3200 (bypass) C4200 (bypass)	RD PSMT	Yes x 5
Sensus	Madalena	RSDS	Yes x 1
Sensus	Sensus 620 series	HRI 620	Yes x 1
Sensus	Meistream Plus Meistream	HRI Mei	Yes x 1

Table 7.3: Compatible Pulse Sensors and Water Meters

The *BRANZ USB Data Logger* requires battery power, and software via the use of a *Hyper Terminal* function on a computer. It is also not water-proof; therefore extra provision was made by use of a *Tupperware* container, as shown in Figure 7.1.

Under this study, only the *BRANZ USB Data Logger* was used, as this was the most accessible, and simple to use. However, it should be acknowledged that there is a range of data loggers available, each of which offers a difference in the available outputs and the number of inputs, such as those outlined in Chapter 4.3.

Once a list of buildings was put together, a proposed plan was derived and discussed with the relevant building manager/owners. Once approval was sought from the plan, the installations could then begin. This took the form of three stages:

1. Pilot Study Five (5) Weeks;
2. End-Use Disaggregation (Fingerprint Analysis); and
3. Time-of-Use Monitoring for approximately Thirteen (13) Months (where possible).

7.3.2. PILOT STUDY

The pilot study looked at building W39 during 21 May 2010 to 18 June 2010 (~5 weeks) Building W39 is a 16-storey building with moderate water use (~6,300m^3/year). Please refer to Table 10.1 for more details.

Once the consent process was completed, the pulse sensor was connected to the water meter, and the data logger was then attached using re-usable zippy strips – as per image below. The water meter, in this instance, was a *Sensus 620* piston meter, with a 40mm pipe size. The compatible pulse sensor for this meter is the *Sensus HRI 620* sensor, which gives an output of one pulse per litre (PPL). This pulse rate was verified against the meter readings recorded at each data-logger changeover.

The first stage of the FWA phase entailed installing the monitoring equipment onto the existing main water meter within each of the selected buildings. This meant liaising with the service provider assets team to ensure installations would not interfere with any of their processes.

Figure 7.1: BRANZ USB Data Logger

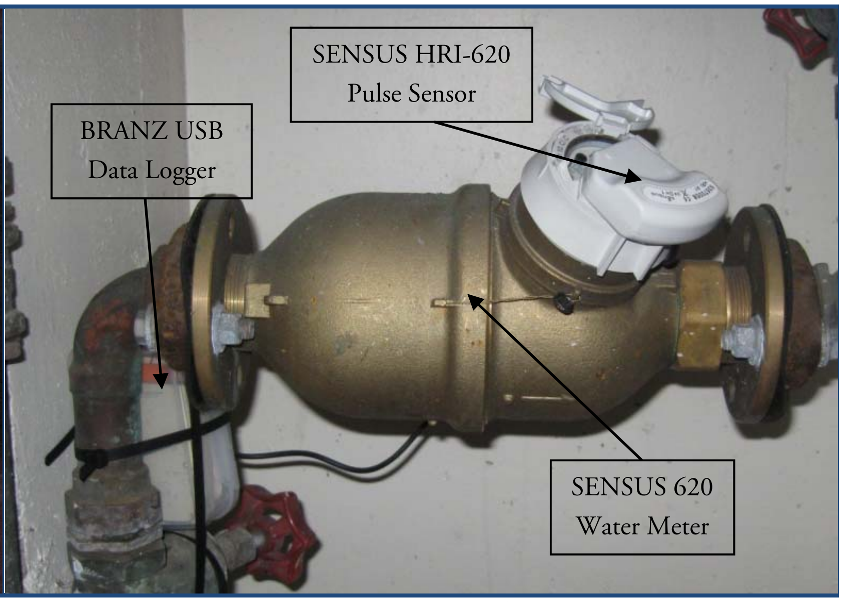

Figure 7.2: Water Meter, Pulse Sensor, and Data Logger Installation

For the first five weeks of the installation, the data logger was pre-programmed prior to installation to record pulses at ten (10) second intervals. This enabled maximum analysis if desired at a later date, and also for the fingerprint analysis methods. Every ten seconds a single number was recorded, which represents how many litres of water (or pulses) have flowed through that meter over the last ten seconds.

Once the installation was in place for a few days, the data logger was replaced, and the data was able to be analysed. The data were then formatted and examined using computer software, *MS Excel*. The output gave preliminary daily profiles for the building, and gave an indication of water usage patterns.

7.3.3. END-USE DISAGGREGATION

During the initial timeframe of five weeks, a fingerprint profile for each appliance within the building was created. This involved accessing the building when no water was being used. For this reason the fingerprint profiles were created between 10.30pm on Friday 4 June 2010 and 1.30am Saturday 5 June 2010, when the building was expected to be totally unoccupied.

Once the fingerprinting equipment was in place, access was obtained to the building when each of the water end-uses was switched off, i.e. after normal working hours/weekends; and the auditor then goes around the building using each appliance for one full cycle, at a recorded time.

This is called fingerprinting, as the profile (at the recorded time) will be given to that appliance once the data has been recorded. From here the data was to be analysed using the American software *TRACEWIZARD*.

Along with using each appliance, a set of rules were assumed in order to allow the fingerprints to be identified within the overall building water data output.

1- Location and description of each appliance recorded;
2- Time of each use was recorded;
3- Duration of each use was recorded;
4- Measuring container and stop-watch used throughout (except for toilets, urinals, dishwashers and the like);
5- Volume of each duration recorded;
6- Leaks recorded and photographed; and
7- Adequate [blank] time between each use to allow for any staging to be completed.

Below is a Table of the range in appliance water flow rates through the 16-storeys of the building, noting that the higher in the building, the higher pressure appeared to be.

Appliance	Minimum Flow Rate or Duration	Mean Flow Rate or Duration	Maximum Flow Rate or Duration
Toilet	3.40 seconds/flush	12.74 seconds/flush	27.80 seconds/flush
Urinal	2.40 seconds/flush	7.94 seconds/flush	19.40 seconds/flush
Wash Hand Basin – HOT	5.55 L/minute	16.13 L/minute	34.41 L/minute
Wash Hand Basin – COLD	6.19 L/minute	18.62 L/minute	56.96 L/minute
Wash Hand Basin - MIXER	4.19 L/minute	5.33 L/minute	6.68 L/minute
Shower	14.08 L/minute	20.30 L/minute	24.49 L/minute

Table 7.4: Fingerprint Measured Flow-Rates

Once the fingerprint was completed, the data logger was again replaced, the data formatted, and analysed. However, this time, the software *TRACEWIZARD* was trialled to see if the appliances could be identified according to the recorded timings on the fingerprint profile sheet.

TRACEWIZARD required the data logger files (*.txt) to be formatted using *MS Excel* (*.xlsx), and then transferred to *MS Access* (*.mdb). *TRACEWIZARD* then again converted the file format to suit to its file format (*.tdb). Thus, four stages were employed to get the data from the logger to the visual output. It should be noted that the *MS Access* (*.mdb) file is an old version of *MS Access* (2000-2007).

Once *TRACEWIZARD* had accepted the *MS Access* (*.mdb) files, events and fixtures could then be observed. *TRACEWIZARD* estimates the fixtures and events based on pre-calculated profiles for each (in this case, from the fingerprint analysis), this included the following information:

- Name;
- Time;
- Minimum Duration;
- Maximum Duration;
- Peak Flow;
- Minimum Flow; and

- Other.

The programme then finds each specified profile within the overall dataset and highlights them accordingly. The software was initially designed for residential to small commercial uses, where up to ten simultaneous uses could occur (Aquacraft, Inc., 2010). However, due to the 'noise[1]' within the dataset, *TRACEWIZARD* identified a series of events/fixtures as a one continuous event over the day, as shown in Figure 7.3. The programme did not allow for these identified events/fixtures to be separated into a number of smaller ones.

Thus, due to the scale of the commercial building in contrast to a residential building (for which *TRACEWIZARD* was designed) events and fixtures failed to be separable from the overall data file.

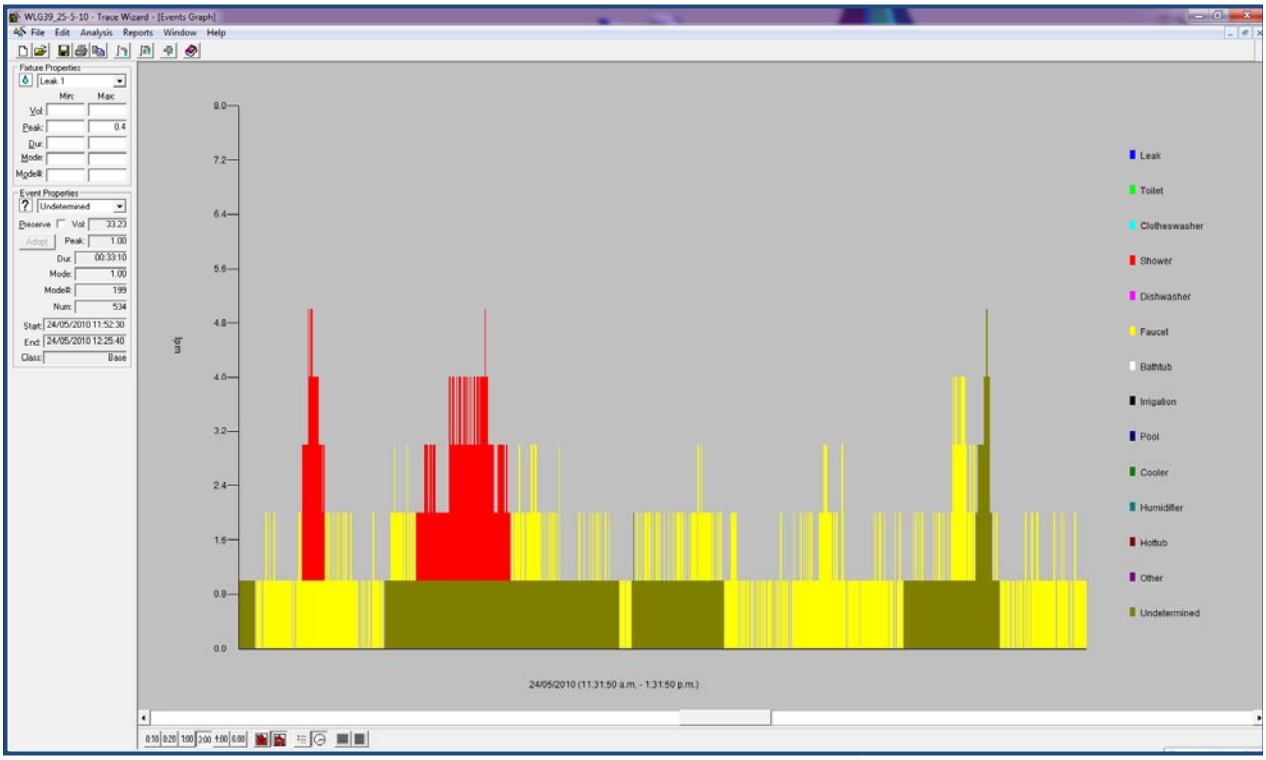

Figure 7.3: TRACEWIZARD Inaccuracy (Source: Aquacraft, Inc, 2010)

Therefore it was concluded that this software would not be suitable for this study, due to the sheer scale of the buildings being monitored compared to normal residential buildings.

Also, as the pulse sensor/water meter combination gave an output of 1PPL, this deemed the data to be inaccurate in a broad sense. Over periods of low-flow, the water meter will only allow a pulse output when the litre is full (i.e. does not allow parts of a litre to be identified). Therefore, depending on the time taken to reach one litre (1000 millilitres) the flow was estimated on that duration. *TRACEWIZARD* estimates the flow for the appliance based on that duration.

However, this in itself is not the reason for the inability of the software to determine any end-use patterns. Another factor identified within the trial, is the effects of the water storage, header, flushing, and staging tanks within the building. The reticulation system was essentially buffering the prospective recordings by re-filling the tank at a set flow-rate to reach the pre-determined levels within the tank. Ideally there should be a

[1] The number of appliances all working at once.

monitored sub-meter on the out-flow side of these tanks in order to get an accurate flow-rate for each appliance.

After the first fingerprint session, the building was re-visited to further inspect the water reticulation system installed, as well as obtaining the as-built water reticulation plans from the *Wellington City Archives*. Further inspection was also conducted to investigate possible locations for sub-metering, and to see if there were in fact any sub-meters already installed, but gone un-noticed.

After discussions with hydraulic engineers at *Aurecon*, a local engineering organisation, they described there as being two common methods of reticulating water through a multi-storey building of this type (as shown in Chapter 3.2). Without the full water reticulation drawings, the actual method is not always visually identifiable. Sometimes by looking in the restrooms the type of toilets installed had to actually be flushed to assess how the mechanism works, as sometimes it was impossible to categorise them (Holter, 2010).

It was suggested to install sub-meters to the out-flow lines for each tank feeding a different area (i.e. one for the toilet lines, one for the urinal lines, and another for domestic water (kitchen and wash hand basin) lines); or to monitor the rate of use in the restrooms and kitchens at more depth. The monitoring of tenants however, becomes an issue with the building owners and managers, and with ethical considerations. When enquiring with the subject building owner, their preference was for the tenancies not to be approached for this purpose.

When discussing these issues with further building and water industry personnel, it was noted that a number of Auckland commercial office buildings have sub-metering installed to the desired extent, and connected to their Building Management System (BMS). This has not been identified within the Wellington sample as of yet. Due to the cost and availability of monitoring equipment this opportunity was not pursued.

The proposed monitoring method (i.e. pulse sensor and data logger) is sufficient if only periodic profiles, leak detection, and the like are desired. As the fingerprint analysis was unsuccessful, the sensitivity of the data was assessed to see if the monitoring intervals could be increased without compromising the quality of the data for further analysis.

7.3.4. TIME-OF-USE MONITORING

For one full year of monitoring at 10-second intervals, 3,153,600 data points are recorded for one building. Thus, if the monitoring interval could be increased, the data could become more manageable by reducing the number of data points. Below is a visual plot of an average day recorded under the pilot study, to aid in the decision of optimum monitoring intervals.

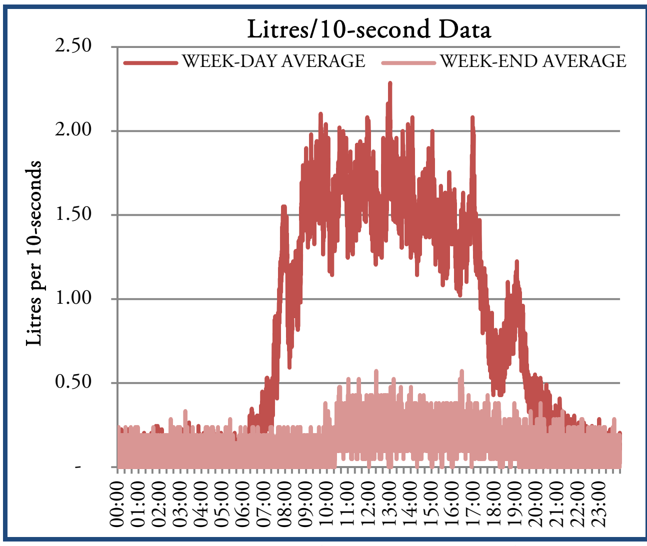

Figure 7.4: Daily Sensitivity of Litres per 10-second Monitoring Intervals

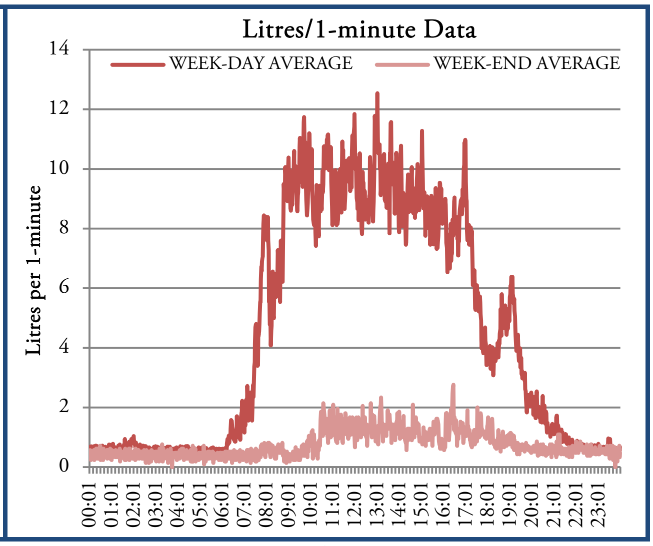

Figure 7.5: Daily Sensitivity of Litres per 1-minute Monitoring Intervals

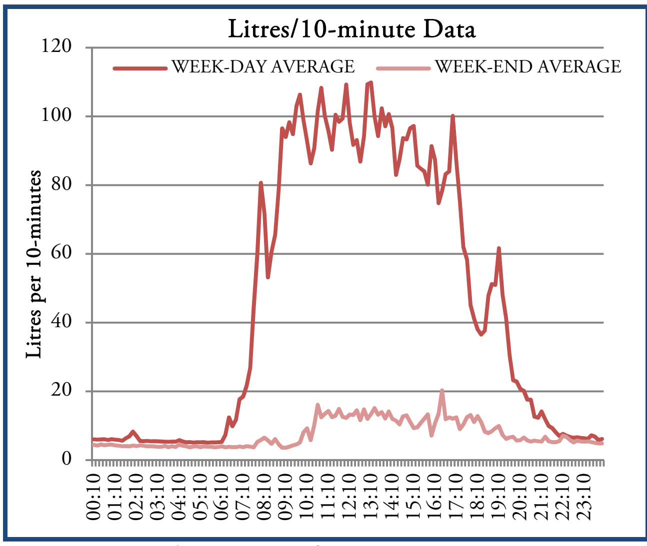

Figure 7.6: Daily Sensitivity of Litres per 10-minute Monitoring Intervals

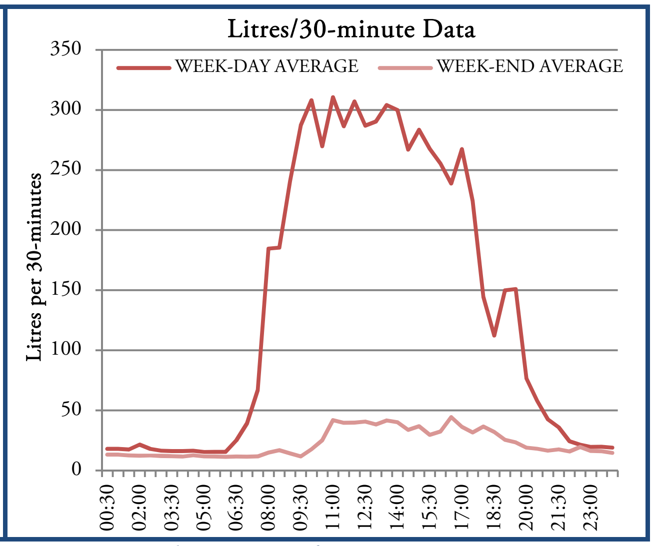

Figure 7.7: Daily Sensitivity of Litres per 30-minute Monitoring Intervals

Figure 7.4 to Figure 7.7 shows that recording once every 10 minutes still gave enough results for a daily water use analysis. It demonstrates the same pattern, but with more clarity in the charted format. Therefore, it was decided that the first five weeks of installation should be at 10-second intervals (giving 5,040 data points), and the remaining time, 10-minute intervals will suffice, giving an additional 52,560 data points. From here, discussion with the pilot building owner took place to determine:

(a) whether or not tenants can be monitored and/or surveyed;
(b) whether or not sub-meters are desired;
(c) other un-identified options for gaining this information; and/or
(d) if they are happy with the results, and if so, prepare to install equipment on the remaining buildings within the Wellington sub-sample.

For the remaining duration of the monitoring period, each building was analysed individually as each data-logger change-over occurred (every five weeks).

7.4. SUMMARY OF WATER AUDITING METHODS

The empirical investigation undertaken comprised of three main steps. The first step involved gaining permission and consent from the selected buildings' owners or managers. The SLWA formed the second step, whereby an Information Sheet completed by each building manager, and a Site Survey Sheet completed collaboratively while on-site were used. The information from this step then fed into the benchmarking analysis.

Finally, the FWA formed the third step, which included detailed monitoring on a sub-set of the SLWA sample. This detailed monitoring method was tested on a single building to begin with; which concluded that the optimum level of monitoring water through the water meter was at 10-minute intervals, both for the reasons of data management and clarity in the results when plotted visually.

The fingerprint analysis proved unsuccessful when using *TRACEWIZARD* due to the inclusion of staged tanks in the building design, and the tool being designed for residential applications only. It was also concluded that if monitoring were to exist in a commercial building, the best location would be on the outflow side of each staged tank.

8. DATA ANALYSIS METHODS

Once a consistent array of data, including water consumption/billing data supplied from *WCC, Metrowater,* and *Watercare Services Limited*, and the 'Information Sheets' and 'Site Survey Sheets' were completed by building managers and during the survey, had been collected and formulated, the analysis could then take place.

Each building was analysed individually for periodic patterns. A statistical analysis was undertaken in order to develop a benchmarking index model. This process is outlined further in depth below.

At the completion of the benchmarking index model, each of the surveyed buildings was analysed individually. An individual report was then created for distribution to the building managers who requested feedback. This included comparison with all of the buildings surveyed, including placement of their performance in graph format. The report also outlined recommended measures (if any) to be actioned in order to control visible wastage. An example is provided in Appendix C7.

8.1. STATISTICAL TECHNIQUES

In this chapter the statistical techniques are outlined and discussed. These techniques then feed into developing a benchmarking index model, using the variables and information identified throughout the field research. This study adapted the precedents and observations from the *Watermark* project (Kitchen et al, 2003), the *CIRIA* study (Waggett et al, 2006a), the *CIEUWS* project (Dzieglewksi et al, 2005), and the *Exergy* project (Bannister et al, 2006).

First the water consumption intensity – or Water Use Index (WUI) model needed to be determined. This is a measure of total water consumption (outcome variable) against an appropriate driver related to the building type (predictor variable). For the purpose of this assessment of commercial office buildings, several building parameters were tested for their statistical relationship, based on those outlined in Chapter 3.3.

The data was entered into spreadsheets, using *MS Excel* (add-ins such as '*StatPlus*' (Berk et al, 2010) and '*Data Analysis Toolpak*' were also used, both statistical packages) and *SPSS* (a statistical package), data were then investigated using both graphical and numerical examination. Information was collected on the possible demand drivers (predictor variables) for water use, identified from the 'Information Sheet' and 'Site Survey Sheet', which could then correlated against water use. *Victoria University of Wellington* Statistical Consultant, Dr. Dalice Sim, and *Massey University* Bachelor of Business Studies student, Bradford Smith, aided in the process of this analysis by providing advice on the statistical techniques and processes available.

The statistical analysis took the form of several tests. The first was to determine the most statistically appropriate predictor for water use in office buildings; this took the form of regressional observations and analysis (correlation coefficient, coefficient of determination, and linear and multiple regression).

In order to derive the most statistically appropriate benchmark predictor, a simple regression analysis was used. This technique uses the parameters outlined earlier, and measures the strength of the relationship between water and each parameter.

When both sets of number variables (X – outcome, and Y – predictor) are measurements (as in the case of this study) the Pearson's correlation coefficient (r) is used. A correlation coefficient is a decimal number between 0 and 1, where an r of ±1 depicts a perfect linear relationship, i.e. the data lie along a straight line when plotted visually. A coefficient of 0 depicts no relationship whatsoever (Clark et al, 2004). The computational formula for the value of r is:

$$r = \left(\frac{\sum XY - \frac{1}{n} \sum X \sum Y}{\sqrt{(\sum X^2 - \frac{1}{n} (\sum X)^2)(\sum Y^2 - \frac{1}{n} (\sum Y)^2)}} \right)$$

Equation 8.1: Pearson's Correlation Coefficient Formula

where X is the total annual water consumption (outcome), Y is the driver (predictor), and n is the number of variable pairs (Clark et al, 2004).

The coefficient of determination (r^2) shows what proportion of the variation in water consumption is associated with the variation in the driver (Dziegielewski, 2002). This is simply the correlation coefficient squared. A coefficient of determination of $r^2 = 1$ is a very strong relationship. This means that 100% of the variation in water use can be explained by the driver and is a perfect linear relationship, while 0.0 (0%) depicts no linear relationship whatsoever. In scientific studies, an r^2 of ≥0.6 (60%) is generally accepted as 'strong', 0.4 to 0.6 (40% to 60%) as moderate, and ≤0.4 (40%) as weak (Clark et al, 2004). However, a coefficient of determination greater than 50% is desired for statistical strength in this type of analysis (Sim, 2011).

Once the predictor variable has been established, the data can be summarised and investigated for any patterns, anomalies, and/or outliers. This was undertaken by examining some basic descriptive statistics.

When the data points are plotted for visual inspection it is very easy to assess which data points could be referred to as possible outliers, and/or which ones are in need of checking for accuracy. The following equations were used to identify the accuracy of the data points tentatively defined as outliers:

$$\begin{aligned} moderate\ outlier &= < LQ - 1.5 \text{ x } IQR \\ &= > UQ + 1.5 \text{ x } IQR \end{aligned}$$

Equation 8.2: Moderate Outlier Calculation Formula

$$\begin{aligned} extreme\ outlier &= < LQ - 3.0 \text{ x } IQR \\ &= > UQ + 3.0 \text{ x } IQR \end{aligned}$$

Equation 8.3: Extreme Outlier Calculation Formula

In Equation 8.2 and Equation 8.3, UQ is the Upper Quartile, or the 75th percentile of the data set (i.e. 75% of the observations are less than it); LQ is the Lower Quartile, or the 25th percentile of the data set, and IQR is the Inter-Quartile Range, which is the difference between the UQ and LQ (Clark et al, 2004). From further investigation once outliers were identified, they were removed from inclusion in the benchmark index development. Outliers were also checked against original documentation for any mistake in the manual transfer of data to the spreadsheet used; and against meter malfunction in the historical data received from the billing utility.

In order to undertake the subsequent analysis steps, it is assumed that the data have a standard normal distribution. This was firstly tested using graphical methods, such as the histogram and normal probability plot. If the dataset appears to lack normality, then the Central Limit Theorem (CLT) may be applied. This requires the sample size to be large enough (>30), and states that as the sample size is increased the distribution of sample means will be approximately normally distributed, which then aids in testing hypotheses of sample means (Clark et al, 2004).

It should be noted that as this survey was conducted over two regions, climate variability (among other things) should be tested for statistical stability under this study. This was achieved by using the ANOVA (ANalysis Of

VAriance – also referred to as a two sample t-test) technique, which incorporates a number of t-tests to determine whether any statistically significant differences occur in the building parameters measured.

A t-test measures the difference between the two sample means (μ) and gives the significance of that difference. This is used to test if the overall sample should be separated into multiple samples that are statistically different, for example by naturally and mechanically ventilated buildings, by size strata, location, or some other characteristic. This is done by testing a null and alternate hypothesis. In this case the null hypothesis (H_0) would be that two (newly separated) sample means are the same ($\mu_1 = \mu_2$), while the alternate hypothesis (H_A) would be that the two sample means come from a different population ($\mu_1 \neq \mu_2$).

The significance is given as a probability value (*p*-value), the acceptable range in these *p*-values is outlined in Table 8.1; where the *p*-value represents the probability that the difference could have arisen by chance (Kitchen et al, 2003), and guides as to whether or not the null hypothesis should be rejected (i.e. alternate hypothesis accepted).

If the test shows a high *p*-value (i.e. a low probability that the difference in normalised water use could have arisen by chance) then it is concluded that the tested samples come from a different population (Kitchen et al, 2003).

p-value	Significance meaning
> 0.10	No evidence to reject the null hypothesis
0.05 – 0.10	Some evidence to reject the null hypothesis
0.01 – 0.05	Strong evidence to reject the null hypothesis
< 0.01	Very strong evidence to reject the null hypothesis

Table 8.1: Probability Value Range (Berk et al, 2010)

Once the benchmark separation is confirmed (or disregarded), the variation in the dataset(s) is then examined. This involves considering the standard deviation, and percentage range of the expected benchmark accuracy. Once the above statistical techniques are applied, the results can then be used for supporting the analysis under the benchmarking index model.

8.2. BENCHMARKING INDEX MODEL

The aim of water benchmarking is to produce a consumption figure for individual buildings that allows comparisons with other similar buildings (Kitchen et al, 2003). As every building is likely to be different, the identification of which parameters such as the NLA, number of FTE occupants and hours of operation identified from water audits, must be taken into account. As it is important for this methodology to be simple enough for replication by building management, it should not be too difficult to obtain accurate individual benchmark figures for each building.

Typically, for office buildings, the WUI is consumption per NLA (m^3/m^2/year) or consumption per FTE occupant (m^3/person/year), but this research will test to determine the most appropriate WUI model.

The median of the dataset is generally used when determining a 'typical' benchmark value, as this covers approximately fifty percent of the population sampled; whereby half of the population will have achieved this benchmark without any change. Likewise when determining the 'best practice' benchmark value the LQ figure is used, this will cover twenty-five percent of the population without change (Dziegielewski et al, 2002). 'Excessive use' will be classed at the UQ figure, covering seventy-five percent of the population without change.

However, when determining bands for efficiency benchmarks, this approach can differ, as outlined in Chapter 5. The aim and purpose of the benchmarks to be published will be reflected in the bands of efficiency benchmarks; an example is given in Table 8.2 below.

MARKET-BASED Percent of sample at this level or better	RATING BAND		EFFICIENCY-BASED Percent of sample at this level or better
75%	Excessive Use	1	50%
		2	38%
50%	Typical	3	26%
25%	Best Case	4	14%
		5	2%

Table 8.2: Difference Between Market-based and Efficiency-based bands

Using this approach, in the 'efficiency-based' column of Table 8.2, buildings performing below the average (median) level will not be rated, thus only giving ratings for buildings on the basis of efficient resource use. Most current models of water benchmarking are 'market-based', where, as per the consumption model, they will adequately cover half of the population without change. However, this sparks a whole new debate, which is discussed further under Chapter 5 and Chapter 11. For the purposes of comparison against other studies this study will outline only a market-based index system.

To enable comparability with other international studies, the benchmarks to be used will be given as 'Excessive Use', 'Typical', and 'Best Case' ratings. Bannister et al (2005) notes there are a number of rules that must still be applied when designing benchmarks for a population. These are:

1- 80% of the sample population should be encompassed;
2- The median value should represent the typical value (not the mean);
3- The best score should 'represent a level of efficiency essentially beyond normal technological solutions, but attainable through innovation'; and
4- The rated bands of efficiency should be of equal steps, or linear.

Where any discrepancies occur between the rules, Rule 2 and Rule 4 take precedence over Rule 1 and Rule 3 (Bannister et al, 2005).

A comparative analysis is then set to take place; the climate normalisation equation outlined in Equation 5.1 is the last step in the benchmarking process. This method has been used to enable a comparative analysis between New Zealand and the other international studies, as well as between differing locations within New Zealand, producing performance benchmarks for water consumption.

The results from these statistical and benchmarking analyses will be used in the formation of the Water Efficiency Rating Tool (WERT). The WERT draws on both statistical data and physical observations, together with previously published literature conclusions to build a calculator able to identify a building's WUI, estimate its end-use disaggregation, and provide estimates of the financial viability of potential water savings and implementation methods.

8.3. SUMMARY OF DATA ANALYSIS METHODS

The data analysis methods used were adopted from both international studies and from examining the current dataset to ensure the most suitable models were applied. In simple terms, the data were analysed numerically and graphically to form the most appropriate WUI and benchmarking models. This analysis utilised both simple and multiple regression techniques, which was then followed by a series of ANOVA tests.

The benchmarking index model builds on Bannister et al's (2005) set of benchmarking rules, and follows the market-based approach to allow implementation later in the research.

SECTION FOUR: FIELD STUDY ANALYSIS

The results, analytical discussions, and benchmarking development form the basis of the fourth section; where its aim was to provide a practical response to three of the four research questions posed in Chapter 1.2.2:

- How is water used in New Zealand office buildings?
- What determines water use efficiency?
- How do New Zealand office buildings compare internationally?

The results are given in Chapter 9. Field Observations. This discusses the observations made through the data collection phase; from building management knowledge, and through site surveys for each of the buildings. Identification of demand drivers for water use are then determined. This chapter forms the basis for the benchmark analyses.

Chapter 10. Detailed Water Analysis discusses the results from the Full Water Audit (FWA), displaying the time-of-use water analysis from the monitored buildings. Then, under Chapter 11. Benchmark Analysis, statistical techniques outline the most statistically and pragmatically appropriate normalisation measures to be used under this dataset. From here, the statistical methods and processes adapted from previous international studies have been used to determine two distinct performance benchmarks. These performance benchmarks are then tested by analysing the normalised levels of water use between published international literature, and discussing the similarities of current New Zealand energy performance benchmarks.

9. FIELD OBSERVATIONS

This chapter outlines the field and analytical observations made during the field study phase. The participation rate from the buildings approached was approximately 90%, with 93 commercial office buildings in Auckland (37) and Wellington (56) having a SLWA successfully completed. Four Wellington buildings were subject to a FWA, where the results are discussed in Chapter 10.

In Wellington, the water consumption and billing data provided by the *WCC* gave bi-monthly meter readings for the previous five years (from April 2004 to the date of enquiry). This gave a base of approximately 31 data points per buildings, with an overall dataset of 1767 points.

In Auckland, the data was provided by *Watercare Services Ltd*, giving monthly meter readings from account creation to the date of enquiry. This gave a base of on average 67 data points per building, or 2570 points for the overall Auckland dataset. In order to protect the identity of the studied buildings, each was given a random numerical code, ranging from 1 to 93 – even where more than one building shared the same water meter(s) for any reason. The codes were given a non-numeric prefix, either an 'A' for Auckland, or a 'W' for Wellington.

9.1. WATER RELATED OBSERVATIONS

As displayed in Figure 9.1 below, the total water use in office buildings varied widely. Initially this was assumed to be due to the difference in the location and size of buildings within the studied sample, and in turn the number of occupants and types of cooling systems installed.

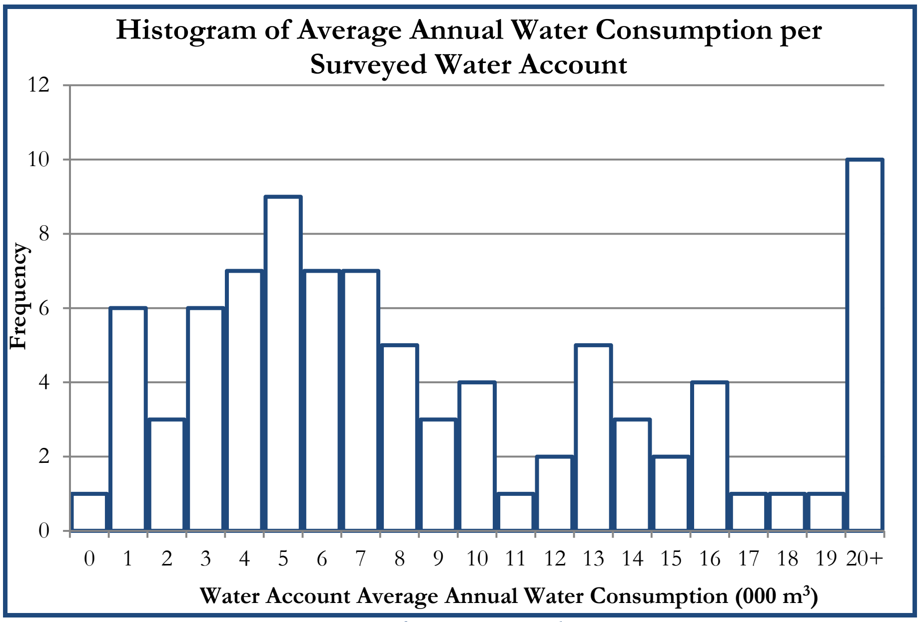

Figure 9.1: Histogram of Average Annual Water Consumption

Only 88 counts are included in Figure 9.1 above. The reason for this is nine of the buildings share metered accounts with one or more buildings. Therefore, the histogram is showing water accounts as opposed to buildings. In two instances two buildings shared a single water meter (two accounts for four buildings), in one instance two buildings had separate meters and one shared meter for their [shared] HVAC make-up supply (one account for two buildings), and in another instance three buildings shared three water meters (one account for three buildings).

Buildings which shared meters were generally owned by the same company, and if one of the buildings was sold off, then a separate meter was usually installed. However, one building also shared its water meter with numerous other buildings which were not studied, so the manual meter readings provided by the building manager were used.

The SLWA method of auditing the buildings was found to be sufficient for gathering the data needed for analysis. However, one additional item which was not identified on the 'Information Sheets' – the hours in which the HVAC (if any) was operating each week – had to be asked during the site visits when accompanied by the building manager.

Below is an example of the range in some of the characteristics identified through the 'Information Sheets', and the 'Site Survey Sheets'. A more detailed list of these by building can be found in Appendix D2.

Data	Minimum	Median	Maximum
Building Age	1917	1982	2009
NLA (m^2)	1,636	8,951	39,490
FTE Occupancy	13	464	2,820
FTE Occupant Density (m^2/FTEO)	11	20	642
Annual Water Consumption (m^3)	541	7,896	22,114
Number of Storeys	3	14	42
Number of Domestic Appliances	51	193	699
Cooling Method (HVAC)	Natural	Air-Cooled	Water-Cooled
Office Types	Private	Private	Government
Ground Floor Tenancies	Office	Retail	Hospitality
Footprint (m^2)	145	762	3,213

Table 9.1: Range in Building Characteristics of the Surveyed Buildings

A range of building features (e.g. presence of water based cooling equipment, number, type, and sizes of amenities and facilities on-site) were observed, some of which could be expected to impact on the water consumption patterns observed from water billing data.

It was found to be very important to undertake visual inspection of all water consuming equipment within the building (including restrooms, kitchens and showers, water fountains, irrigation, and HVAC plant equipment), and the water meter. This allowed accurate identification of the number and types of equipment found, and their physical condition. One benefit to the building management was the identification and reporting of a number of leaks, which may have gone unnoticed for some time.

Photographing each area and installation allowed them to be re-analysed without having to return to the building at a later date. Along with water consuming equipment, photographs were also taken of each building exterior, directory board, and BWOF within the surveyed buildings. By accurately identifying each business operating out of the building through the use of directory boards, different types of building users/tenants could be identified, such as an exercise facility (gym) or dentist/medical centre, and to see if any "office" differences could be observed in the recorded billing data.

Table 9.2 gives the number of different office uses based on *ANZSIC* codes as a percentage of the count of total premises (tenancies) recorded in the surveyed buildings.

ANZSIC[1] Code	Count (%)	
	Auckland	Wellington
G: Retail Trade	3	12
H: Accommodation & Food Services	3	6
I: Transport, Postal and Warehousing	1	1
K: Financial & Insurance Services	26	11
L: Rental, Hiring & Real Estate	4	2
M: Professional, Scientific & Technical Services	42	48
N: Administrative & Support Services	7	1
O: Public Administration & Safety	5	9
P: Education & Training	4	2
Q: Health Care & Social Assistance	3	7
R: Arts & Recreation Services	-	-
S: Other Services	2	-
Residential	-	1

Table 9.2: Building Uses by ANZSIC Codes

Table 9.2 shows that Type M: 'Professional, Scientific, & Technical' offices are the most predominant by count in both Auckland (42%) and Wellington (48%).

It should be noted that a large number of consultancy businesses are often found leasing a single office room on a floor, therefore, there could be some skewing of the data. However, if looking at office type by floor area, 'O: Public Administration & Safety' in Wellington would be the most predominant due to government agencies leasing larger proportions, in some cases all of, the building floor area; and 'M: Professional, Scientific, & Technical' more predominant in Auckland. As the areas occupied by each tenancy were not known in most of the buildings, this is only speculation.

After discussions with building managers, it was identified that within their portfolio, government ('O: Public Administration & Safety') offices will have a higher occupant density (usually ~15m^2/occupant) than private offices (usually up to ~40m^2/occupant).

The vast majority of retail and/or hospitality premises were located in the street level floors of the buildings.

9.2. BWOFS

Very few BWOFs on display within the selected office buildings were accurately and/or fully completed, with most displaying only fire hazard categories, and building management contact details, while some displayed only a blank, or signed form.

Upon discussion with the *Department of Building and Housing (DBH)* it was highlighted that it is a mandatory requirement by the *NZBC*, under Clause 108 (Hislop, 2009); to have all sections outlined in Chapter 6.4 adequately attempted.

When the BWOF team within the Wellington local authority were approached, they appeared to be very busy, and would only offer access to a BWOF register when matters concerning to them arose; therefore public access is very limited. No further investigation took place with the local authority to assess these issues.

However, use of the BWOF was still found to be an excellent method for determining appropriate management contact details.

[1] ANZSIC is the Australia New Zealand Standard Industrial Classification.

9.3. WATER METERS

Every commercial building within Wellington, Auckland, and most of New Zealand, is connected to at least one council registered water meter. These are read periodically by contractors (e.g. *Arthur D. Riley & Co. Ltd.* in Wellington), or employed water meter readers.

The water meters are not read on a strict periodic schedule. For example, in Wellington some periods will have been 58 days long, whereas some can reach up to 70 days between readings. Similarly in Auckland, periods ranged from 12 days up to 122 days between readings. However, the exception is for annual cumulative readings which were exactly 365 days apart, at least in Wellington (Fleet, 2009).

It was found through discussion with the Wellington billing and water agencies (*WCC* and *Capacity Ltd*), that the meter readings are only checked for reasonable consistency with previous readings corresponding to that billed period (Fleet, 2009). Therefore, minimal deteriorations in meter accuracy may go unnoticed for some time; which has been found to be the case in at least one of the surveyed buildings. Because there is no standard to say how much water similar buildings are expected to use, these issues have been left, with neither the building owner nor the water agency knowing how to resolve the issue as accurately as possible.

No readings are estimated, unless extenuating circumstances arise, such as the water meter readers being unable to access the water meter for some reason, etc. This is a very rare occurrence however (Tegg, 2010).

9.3.1. LOCATIONS

It was identified on-site that water meters are expected to be located in the ground or basement levels of the building and not always easily accessible by the public. In a large number of cases they were found in key-locked or pin-coded cupboards and/or in swipe-card access areas of the basement/carparking levels. In older buildings (pre-1920) water meters were generally found under blue street covers in the footpaths surrounding the building. In Auckland however, large steel and concrete covers were often found when the meters were in footpath locations, making it very difficult to access the meter.

Of the 93 buildings surveyed, only 27 (30%) of the building managers were aware of the water meter location in their buildings. This was surprisingly lower in Auckland (8, or 22%) where a greater awareness of water end-uses was demonstrated. Where water meter locations had to be identified during site surveys, they generally were found by starting with the mains or sprinkler valve inlet within ground and basement levels of the building.

However, where the meter(s) was unable to be located, the local billing utility was approached to see if they could identify these locations from their meter reader records. This information was then provided to the building management through the individual analysis reports at the conclusion of this study. However, even with this description, in some cases it still took multiple attempts at searching the premises for the water meter.

In one instance, it was found that the water meter readers have to arrange access for each meter reading with the on-site building management, primarily for security reasons. A few cases showed more than one building connecting to a single meter, making it difficult to establish which building used that water.

9.3.2. METER REPLACEMENTS

The most common types of water meters are a ‘rotary piston’ or a ‘helix’ meter. A high proportion of water meters appeared to have been replaced within the past five years. 15% of the surveyed buildings had had at least one meter replacement within the last 5 years.

Of the meters that could either be located (44 of the 88 metered building groups), or identified from service provider descriptions Figure 9.2 lists the most commonly found types of water meters.

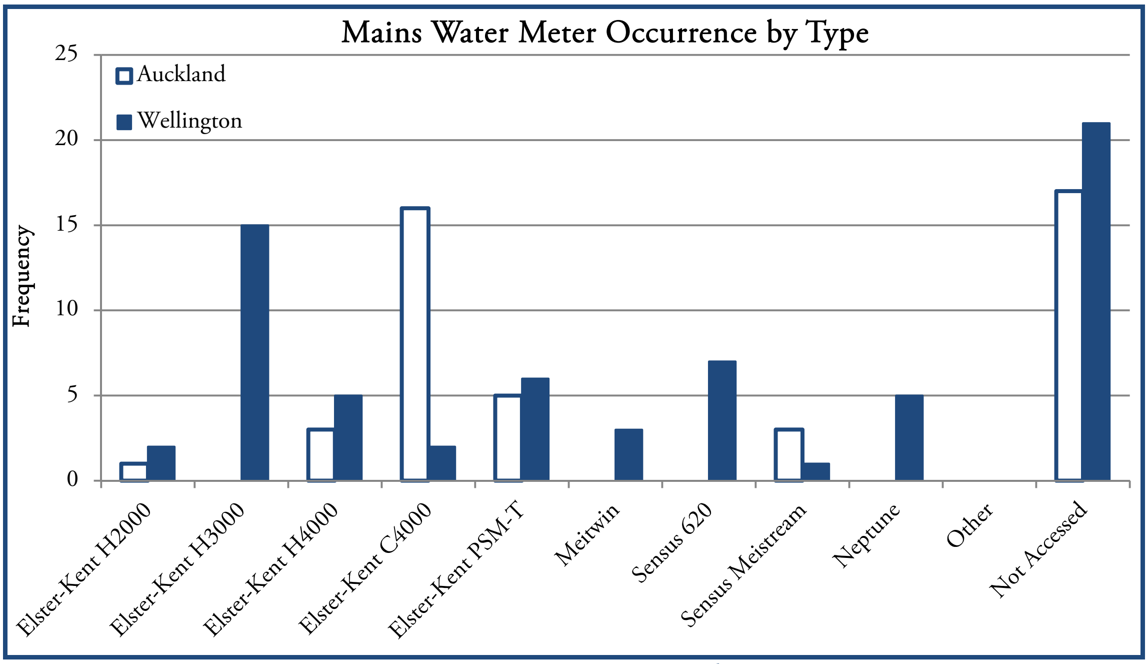

Figure 9.2: Water Meter Frequency by Type

A large number of meters in Wellington were *Elster-Kent H3000*, ranging in date of manufacture from 1972 to 2010 – determined by the first two digits of the meter identification number. In Wellington, if the pipe size is greater than 40mm, then a combination meter will be installed (either *Sensus Meitwin*, or *Elster-Kent C4000*), and if less than 40mm a single meter will be installed (either *Sensus 620* or *Elster-Kent PSM-T*) (Drysdale, 2011; Curry, 2011). A similar replacement guide is in place in Auckland.

After further discussions with *Capacity Ltd*, it was found that there is an ongoing maintenance regime, in which water meters greater than 10 years in age were replaced. This rate is assumed to mitigate the failure due to both wear from continuously moving internal meter mechanics, and/or the accumulation of dissolved solids within the water supply passing through the meter, as with age water meters are likely to become less accurate, as noted in Chapter 4.2.

In one of the surveyed buildings, the water meter was not able to be read due to the glass over the totaliser fogging up, thus an additional direct light source, such as a torch, would be useful to get an accurate reading. This meter was replaced prior to the next visit.

9.3.3. SUB-METERS

In the 24 (26%) buildings which had sub-meters (also known as 'check-meters') installed, seven (30%) of those buildings' managers were aware of the presence of these sub-meters, and/or their locations. Of the buildings which were aware of the sub-meters installed, only three (one non-*GSNZ*) of the buildings used the sub-meters to determine charge-recovery of the water bill, payable to the building manager. The sub-meters installed on certain equipment, i.e. cooling towers, were installed by service providers, and most of the building management were also unaware of these.

Sub-meters are identifiable by the distinct difference in size and type of meter, such as those below. Figure 9.3, left, shows a typical mains water meter (local authority registered – the one the billing utility reads to measure water consumption), while Figure 9.4, right, shows a typical sub-meter installation.

Main meters were typically near the mains water supply entrance for the buildings, whereas sub-meters were generally found near separation of water supply to specific tenancies or equipment, throughout any level of the building where water pipework was found.

Figure 9.3: Main Water Meter

Figure 9.4: Sub-Meters

There are many different types and brands of water meters, in a range of sizes; however, the most distinct difference is the size, and location of the water meter.

9.4. WATER CONSUMING EQUIPMENT

As the water consuming equipment within each building is assumed to be the primary contributors to water demand, they must therefore be assessed for their importance and their efficiency levels. This includes the cooling equipment, restroom and kitchen facilities, irrigation and leakages, and other building occupancy types.

9.4.1. COOLING SYSTEMS

As outlined earlier, mechanical cooling can contribute to approximately 31% of the annual water bill. The bigger the building (by NLA) the higher the likelihood that water-using ventilation equipment can be expected to be installed within the building. For example, the buildings within the selected sample with the largest (>10,000m^2) NLA were the buildings which typically utilised water-cooled systems. Air-cooled buildings were predominantly ranging between 5,000m^2 and 10,000m^2, while naturally ventilated buildings were mainly the smallest in size (<5,000m^2).

HVAC Type	NLA (m^2) Minimum	Median	Maximum
Naturally Ventilated	1,636	4,469	12,218
Air-Cooled HVAC	2,442	8,300	18,000
Water-Cooled HVAC	3,154	10,764	39,490

Table 9.3: NLA Range by Methods of Cooling in Surveyed Buildings

This is also supported by Quinn et al's (2006) Australian study, which identifies that larger commercial and public buildings in particular, utilise cooling towers as their method of cooling/dealing with heat rejection.

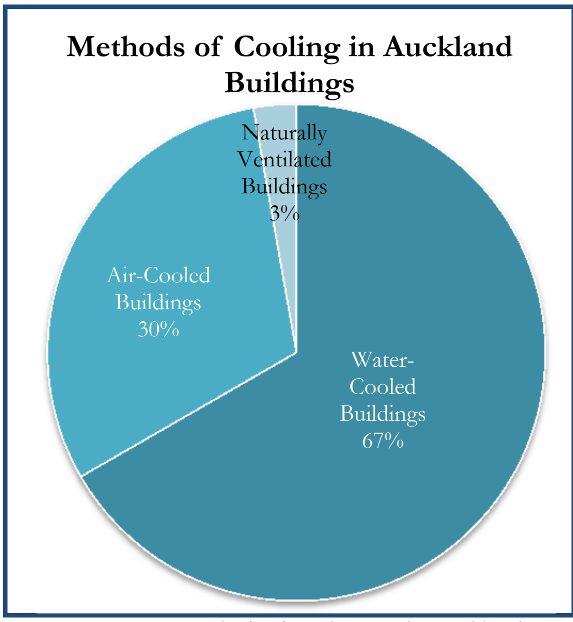

Figure 9.5: Methods of Cooling in the Auckland Buildings Studied

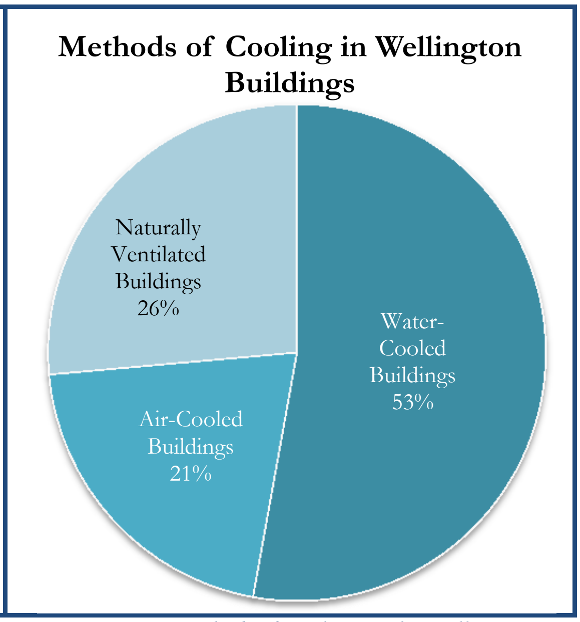

Figure 9.6: Methods of Cooling in the Wellington Buildings Studied

Approximately 56% of the surveyed buildings (overall) utilised cooling towers as their method of cooling. From these buildings, the water consumption was generally higher, which again is assumed to be due to the sizes of the buildings.

HVAC Type	Annual Average Water Consumption (m^3/year)		
	Minimum	Median	Maximum
Naturally Ventilated	520	5,227	13,477
Air-Cooled HVAC	1,762	5,373	31,949
Water-Cooled HVAC	1,935	10,299	32,671

Table 9.4: Range in Annual Water Use by Methods of Cooling in the Surveyed Buildings

However, from discussing the water related issues with *ProChem*, a building refrigeration specialist company, it was suggested that the water demand is driven by the size of the water circulating pump for the cooling tower that aids in determining the water needed for make-up supply, not the cooling tower alone. An example calculation used by a company specialising in cooling tower water treatments, is outlined below; of course the design calculations are more complex, however this simple calculation is simply for determining the hourly water required in the make-up feed (Symons, 2011).

$$\boldsymbol{M = E + D + B}$$

$$E = RR \times 3600 \times 0.01 \times \Delta T$$
$$W = E/(CR - 1)$$
$$D = RR \times 3600 \times 0.001$$
$$B = W - D$$

Equation 9.1: Cooling Tower Make-up Equation (Source: Symons, 2011)

Where the letters can be substituted for the following:

M - the make-up supply required in L/hour;
E - is the evaporative losses in L/hour;
RR - is the reticulation rate from the water circulating pumps;

ΔT - is the temperature differential (between make-up water and water exiting the tower) in degrees Celsius;
W - is wastage in L/hour (can also be calculated as D + B);
CR - is the concentration ratio of total dissolved solids (TDS) between make-up water and water exiting the tower;
D - is drift in L/hour; and
B - is bleed in L/hour.

One of the biggest issues found with water-cooled systems over air-cooled mechanical ventilation systems, is the need to treat for the prevention of air-borne bacteria, more specifically Legionella bacteria, which incurs additional cost, time, and maintenance. However these systems can be a much more effective method of heat rejection and cooling for larger commercial buildings, depending on local climate, passive solar design, layout, and orientation.

It should also be noted that there has been no analysis found on water consumption due to the heating portion of the HVAC system. However, in the buildings surveyed 85% had a gas fired boiler present, which fed the heating for their air-conditioning systems, and which were all closed-loop. The remaining 15% of buildings either used individual heat pumps or domestic type portable heaters to heat their internal environments.

9.4.2. RESTROOMS

In the sampled buildings, typical equipment found within the restrooms included varying types and efficiency levels of toilets, wash hand basins, showers, and cleaner tubs, with urinals in the men's restrooms only.

The majority of domestic appliances within the office buildings surveyed showed considerable opportunities for improvement. For example, it is assumed that the majority of appliances observed would achieve zero-to-low *WELS* ratings. The uptake of *WELS* rated appliances for commercial buildings does not appear to be large at this stage. However, discussions with building managers and equipment wholesalers suggest that common areas (i.e. core stairwells containing restrooms, showers, cleaner facilities, and the like) are upgraded only every 15 years or so, which is longer than the current [voluntary] standard has been in place (Standards New Zealand, 2005). Approximately 15% of the studied buildings employed some (or all) *WELS* rated appliances.

As previously outlined, restrooms within commercial buildings can consume as much as 40% of the total water bill. This possibly due to the domestic appliances within the restrooms (urinals, toilets, taps, and showers) all being identified as common sources of leakages and maintenance costs (Quinn et al, 2006), and it being a necessity for human hygiene, as opposed to a kitchen.

9.4.2.1. TOILETS

There are a number of different types of toilet flushing still found in commercial buildings, such as single flush, dual flush, flush valve (which can all be either in-line or cistern controlled), and composting toilets. The toilets within the buildings sampled in this study were assessed for their flush model, any visible signs of fault of leakage, and photographed and recorded on the 'Site Survey Sheet' for that building.

During the fingerprint analysis (refer Chapter 7.3), toilet flush durations varied substantially, from 3.4 seconds per flush, up to 27.8 seconds per flush. Some toilets needed to be flushed twice to stop the water flowing into the pan.

Figure 9.7: Flush Valve Toilet

Figure 9.8: Dual Flush In-Line Toilet

Figure 9.9: Single Flush Cistern Toilet

The majority (64%) of toilets within the surveyed buildings have single flush (cistern or in-line) systems installed. With flush valve systems also only offering a single flush option, in total least-efficient flushing systems comprise 89% of all toilets identified and recorded. These single flush systems have been recorded to consume anywhere from 5L to 11L per flush (Quinn et al, 2006).

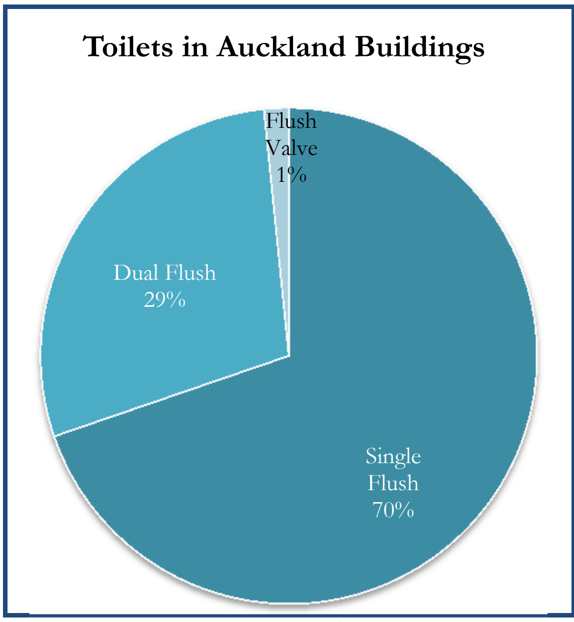

Figure 9.10: Auckland Toilet Types

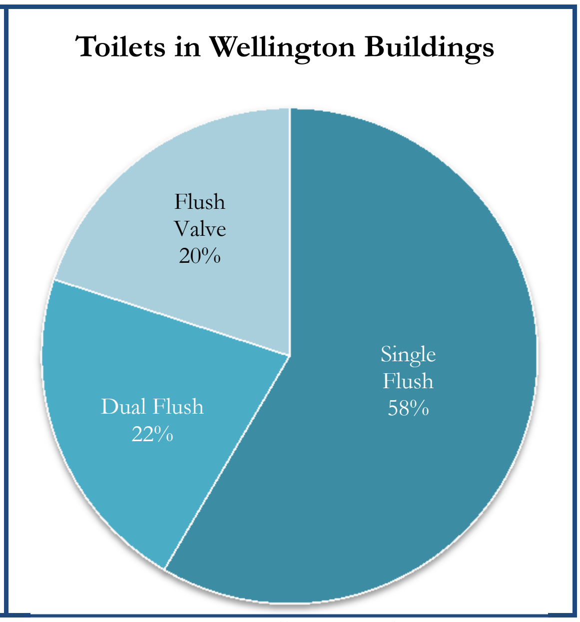

Figure 9.11: Wellington Toilet Types

As noted in Figure 9.10 and Figure 9.11 above, Auckland toilets appear to be less efficient. However, they also appeared to be newer and possibly with smaller cistern or flush capacities. Whereas in Wellington, the vast majority of buildings appeared to employ much older and larger (~12L) cisterns.

In newer or recently refurbished buildings, more modern dual flush systems were present; which are deemed [by *WELS*] to be more water efficient than the single flush models, above; offering as little as 3L for a half flush.

No composting toilets were identified in any of the 93 studied office buildings. However, at least one occupied commercial building is known to have these systems installed in Auckland (Landcare Research, 2012).

By replacing each of the older single flush toilets (~12L/flush) with a more modern 4.5/3L dual flush cistern, approximately 7.5L per flush can be saved. If applied to building W6, for example, this would equate to 17,250L (17.25m^3 or NZD$29.58) saved per day, based on 1,150 people using the toilets on average twice per day.

Alternatively, other (cheaper) options can be implemented, such as that of a cistern weight, which can be installed at any time with minimal costs of approximately NZD$5.00 per weight (Stewart, 2009). These are simply hung over the ball-cock lever/middle stem to reduce the amount of water entering the cistern, and in turn the amount of water used for each flush.

During discussions with international water professionals, it was identified that culture and/or ethnic background may also influence water consumption. It is apparently a customary tradition for some Asian cultures to flush twice with each toilet visit, once as a 'courtesy flush', and the other as per normal, to remove effluent/waste (Sakaue, 2011); whereas, if automated infrared sensor flushing were installed, this could possibly be controlled more effectively.

9.4.2.2. URINALS

From the site surveys conducted 45% of the buildings have a sensor or manual flush system installed controlling the flush activation for the urinals. This is deemed to be far more water efficient than a cyclic flushing system, which flushes at intervals of approximately 20 minutes, 24 hours a day, seven days a week, fifty-two weeks of the year.

The vast majority (98%) of the male restrooms had some form of urinals installed. These urinals were more commonly (81%) single-user wall-pod urinals.

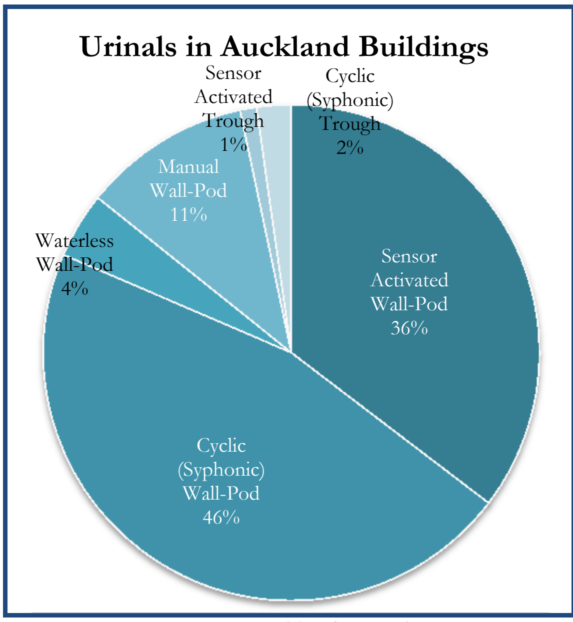

Figure 9.12: Auckland Urinal Types

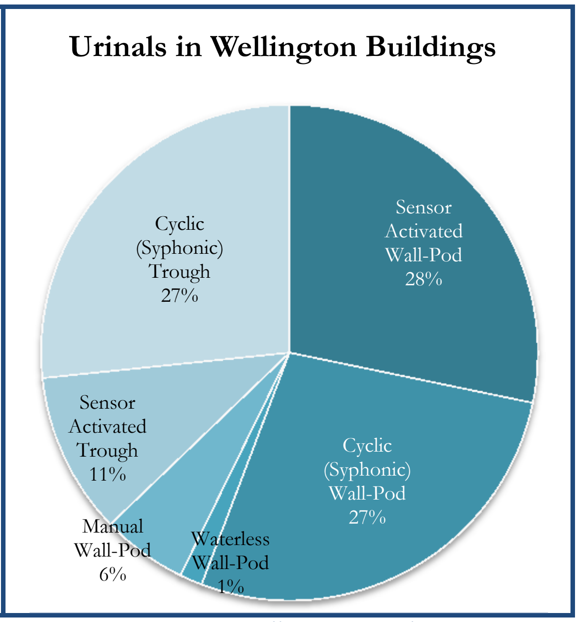

Figure 9.13: Wellington Urinal Types

The large proportion (52%) of buildings with cyclic (syphonic) flushing urinals should be highlighted here. However, the accuracy of this assumption of cyclic flushing is questionable, due to inability to access hidden (in roof and/or walls) microwave group sensors, where building management awareness was low, and the as-built reticulation drawings did not indicate their presence. This presence or absence of sensor activated flushing was simply tested with motion around the subject area, and monitoring of time intermittence, if any.

During the fingerprint analysis, it was identified that the duration of each flush varied, ranging from single 2.4 seconds per flush, up to dual 2.4 second then 16.5 second flushes. However, the cistern size and/or inline quantity would (hopefully) be a fixed volume.

Most urinals were on an automated cleaning cycle, which occurs every 12-24 hours, usually after (or before) normal working hours. The urinal undergoes a larger than normal flush, depending on the cistern (if any), to aid in both odour control and cleanliness. This is especially important in per use flushing systems (manual or sensor activated flushing), where the device may go unused for some time.

Figure 9.14: Manual Flush Wall-Pod Urinal

Figure 9.15: Urinal Flush Sensor

Figure 9.16: Cyclically Flushing Trough Urinal

Figure 9.17: Waterless Urinal

In building W6, adjusting the flushing automation from time intermittent (cyclic) to group microwave sensor activation, means approximately 43% savings could be achieved, with uses of 8,064 L/day and 4,600 L/day respectively. This calculation is based on 575 males, using one of the 28 urinals twice per day (with no overlap) – as opposed to cyclic flushing every twenty minutes (Stewart, 1995).

Waterless urinals, and their many different cartridge types, have been found to cause nuisance. One building owner stated they created more maintenance than other urinal types, and the cartridges could only be replaced by specialised suppliers (Anonymous Building Managers, 2010). This company are now replacing older urinals with low volume manual or sensor activated flushing, while refitting their remaining urinal cartridges with less specialised DIY alternatives. It should be noted that there may also be an increased impact on the pipe work if retrofitted with lower flow urinals, due to increased acidity concentration, and consequential damages.

9.4.2.3. WASH HAND BASIN FAUCETS

All restrooms observed had at least one wash hand basin present. Most buildings (97%) used a hot and cold mixer tap or individual hot and cold faucets (Figure 9.22 and Figure 9.23), while the remaining used either self-closing or infrared motion sensor faucets (Figure 9.20 and Figure 9.21).

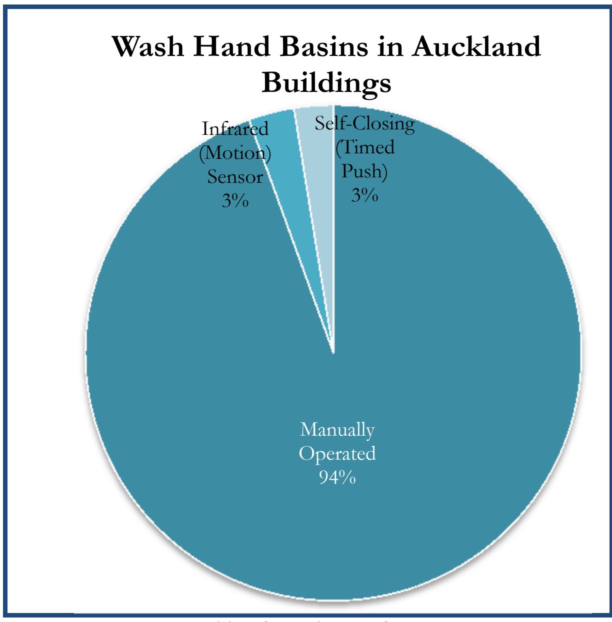

Figure 9.18: Auckland Wash Hand Basin Faucet Types

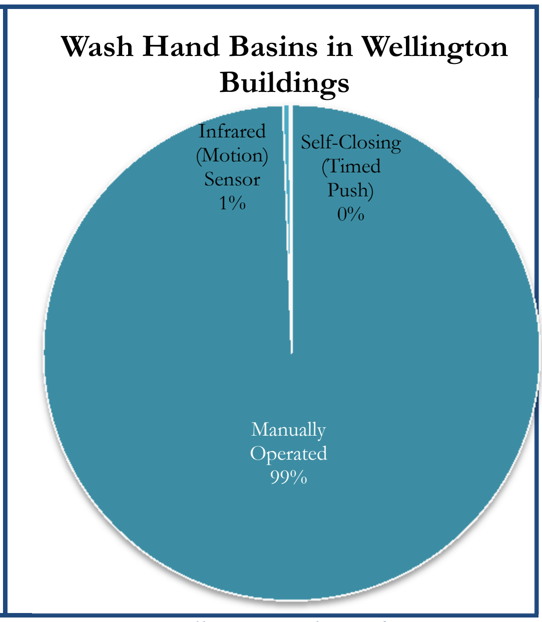

Figure 9.19: Wellington Wash Hand Basin Faucet Types

Auckland buildings had a higher occurrence of newer technology in wash hand basin faucets, such as self-closing and infrared sensor taps. This technology was however, only found in a small number of buildings in Auckland, and an even smaller number in Wellington.

Using a self-closing or infrared sensor faucet means the duration of each wash is restricted, and in some cases vandal-proofed. This of course, is best done in combination with inline flow restrictors (Joseph, 2011).

Figure 9.20: Infrared Sensor Faucet

Figure 9.21: Self-Closing Faucet

Figure 9.22: Manually Operated Individual Faucets

Figure 9.23: Manually Operated Mixer Spout

Again, there were issues as noted from some building management with the self-closing and/or infrared sensor faucets. In particular the lag time for hot water was not accounted for. After further discussing this with equipment wholesalers, they confirmed that where this is the case, it is recommended to have in-restroom hot water cylinders, or an inline electric water heater.

In previous studies, flow rates have been found to be between 15-20 L/min, which is excessive for the single purpose of hand washing (SWC, 2002), creating splash onto the user rather than being contained in the wash hand basin itself. In the pilot building in Wellington (refer Chapter 7.3), the average wash hand basin flowrate was 13.4 L/minute.

Simply installing an aerator or flow restrictor into each tap nozzle will reduce the amount of unnecessary water used for the process of hand washing by as much as 25% (for building W6, approximately 1,734 L/day could be saved).

9.4.2.4. SHOWERS

Showers have been found in numbers of between 1 and 22 within 80% of the surveyed buildings, with only 14 buildings employing water efficient (low-flow) shower roses. The remaining buildings could either simply install a water efficient rose, or install an inline flow restrictor. Reducing the amount of water wastage, in turn reduces the amount of energy required to heat the water used for showering.

The heating energy needed to heat one litre of water from cool (15°C) to warm (45°C), is approximately 0.035 kWh (or 125.6 kJ). This is shown as:

$$Q = mc(dT)$$

Equation 9.2: Heating Energy Calculation

Where, Q is the energy required, m is the mass of water in kg, c is the specific heat capacity in J (the specific heat capacity of water is around 4186 J kg^{-1} $°C^{-1}$), dT is the change in temperature in °C. The pilot building flow rates varied between 14.1 L/minute and 24.5 L/minute, at an average temperature using the mixer controls for adjustment.

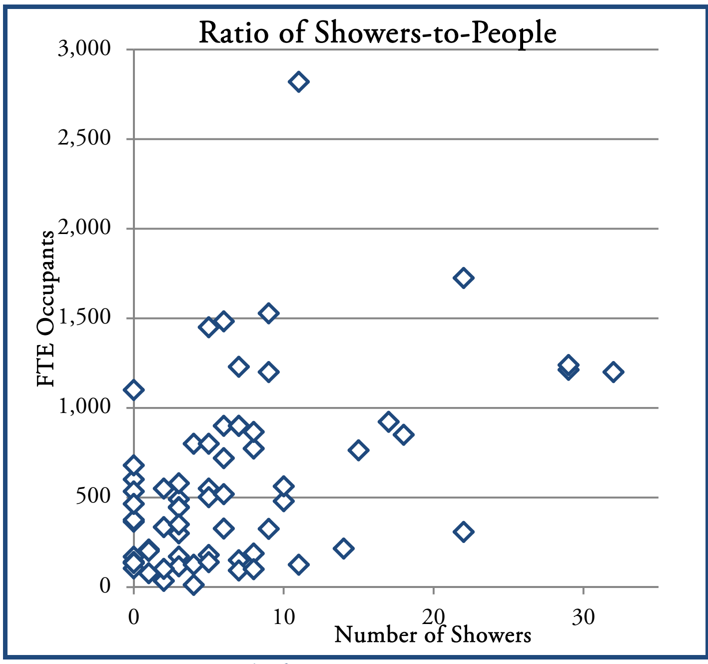

Figure 9.24: Showers-to-FTE Occupant Ratio

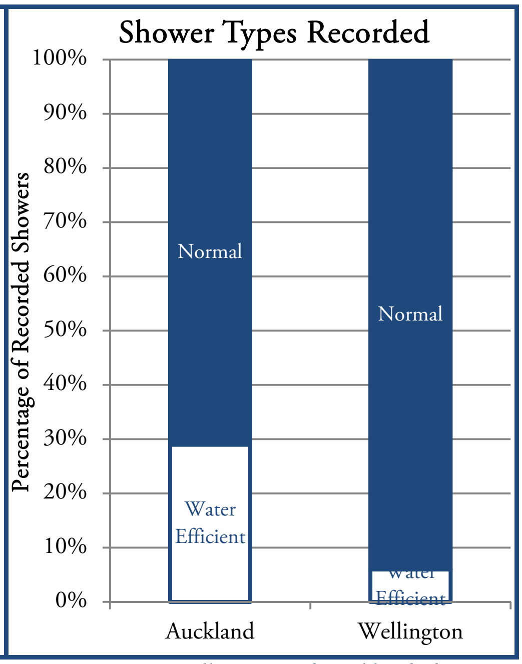

Figure 9.25: Wellington and Auckland Shower Types

It was found that there was no set *NZBC* requirement for showers to be installed, and therefore the number ratio to NLA or FTE occupants varied substantially, causing little-to-no statistical relationship (r^2 = 0.20), refer Figure 9.24. Some of the larger buildings had minimal showers between 1,000+ people, and some of the smaller buildings had 20+ showers between ~300 people.

The use of showers is assumed to be around 8.1 minutes per shower (Heinrich, 2008). It is estimated that between four and five people will use each shower per day in general. Thus a per shower usage rate as opposed to a per person usage rate has been applied.

For example, in building W39, approximately 164L of water is for just one shower per person, and therefore 6 kWh. Translated to the total building daily use, this is approximately 5,920L of water, and 207 kWh of electricity.

Other options now available on the market include infrared sensor with time-restriction and self-closing shower tap ware – both with pre-adjustable time-outs by management.

9.4.2.5. CLEANER FACILITIES

In most cases at least one cleaner cupboard, containing one cleaner tub, will be present on each floor of a commercial building. This was either within the male or female restrooms, or in its own space near the restrooms on each floor.

Figure 9.26: Cleaner Tub in Cupboard

Figure 9.27: Cleaner Tub in Restroom

Quantity as opposed to flow is desired to achieve the purpose and functional requirement of this appliance. Therefore, water efficiency measures can only be in the form of behavioural and/or cleaning product concentrations. As Joseph (2011) rightly points out "a flow restrictor in this case would only prolong the cleaning contractors' bucket being filled to the desired level." In most cases the taps are left open, with flows reaching ≥45 L/minute.

9.4.3. KITCHENS

As kitchens are typically located within tenancies (as opposed to common areas), they are upgraded more frequently, with each new tenancy retrofit.

For the majority of kitchens and kitchenette facilities the most common appliances found were: a typical kitchen sink (with either a mixer tap or individual hot/cold faucets, both manually operated); domestic dishwasher; a water heater (either a 'zip' or 'billi' tap over sink); and in some buildings plumbed coffee machines and/or water coolers were identified. Where restaurant, food, and/or catering facilities were present, commercial dishwashers and in some cases ice-machines were found.

Figure 9.28: Typical Kitchen

Figure 9.29: Drinking Fountain

Figure 9.30: Aged 'Zip'

Figure 9.31: 'Billi' Tap System

As kitchen taps generally have a much higher usage rate than bathroom taps, they are more likely to have more wear, and leaks may go un-reported for some time. Quinn et al (2006) point out that 'a single dripping tap can waste more than 24m^3 (24,000 L) per year'. Again water flow rates were not measured in kitchens; however, an aerator or flow restrictor, as above, is inexpensive and can also be installed into kitchen tapware to reduce wastage, if quantity (as opposed to pressure) is not the main functional requirement.

9.4.4. LEAKAGE, IRRIGATION & OTHER

Of the leakages identified, the four main areas were from toilets (solenoid not operating correctly) and urinals continuously flushing (i.e. solenoid in need of remedy or adjustment), dripping/running taps in need of washer replacement, mechanical equipment leakages, and unnoticed leaks in services ducts and tanks.

Figure 9.32: Garden Irrigation

Figure 9.33: Irrigation Control Unit

Figure 9.34: Leaking Pipe in Duct

Figure 9.35: Heavy 'Splash' from a Cooling Tower

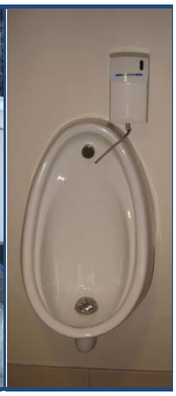

Figure 9.36: Leaking Urinal Solenoid

Within one of the surveyed buildings, a leak was located within the services duct between the second and third floors of the building, identified by the stagnant pooling of water within the water meter room at basement level. As this space is generally only visited by the water meter reader, it had obviously gone un-noticed and/or un-reported for a significant period of time.

Quinn et al (2006) state "leakage losses of between 10% and 30% are not uncommon," as found in their Australian study. As no monitoring as such was undertaken on the buildings within the sample, the amount of water leakage cannot be commented on under this investigation, other than what has been estimated by the billing and supply utility, and that calculated from similar Australian studies (Quinn et al, 2006; SWC, 2002).

Of the buildings surveyed, approximately 16% were identified as having garden area irrigation installed, and operating. This does not take into account the indoor plants/vegetation which are manually watered from indoor kitchen/restroom facilities. Quinn et al (2006) found in their sample of Australian buildings, irrigation water use varied between 1% and 20% of total water use. This depends on the location, and the amount of vegetation in contrast to the scale of the building.

Similarly internal and external water use features (i.e. fountains, aesthetic installations) were not common within the selected sample, with only 4% having these implemented.

Two large office buildings (W54 and A67) contained swimming pools, both were indoor, with one situated on the ground floor, and the other was situated on the eighth floor of the building. Both were monitored independently by the current tenants, both of which were operating as fitness centres; however this monitoring data was unable to be released for this study due to confidentiality reasoning. Research shows that for an outdoor pool, approximately 15.5mm per m^2 can be lost to evaporation each day (Lee et al, 2008).

9.4.5. GROUND FLOOR USE

Very few office buildings have been found to be entirely used for office purposes. In the sample, most (80%) had either retail of some form, and/or a hospitality facility occupying ground floor space. These non-office uses can contribute considerably to the total water use, as the manner in which water is used in such functions differs dramatically from that of an office space (SWC, 2002).

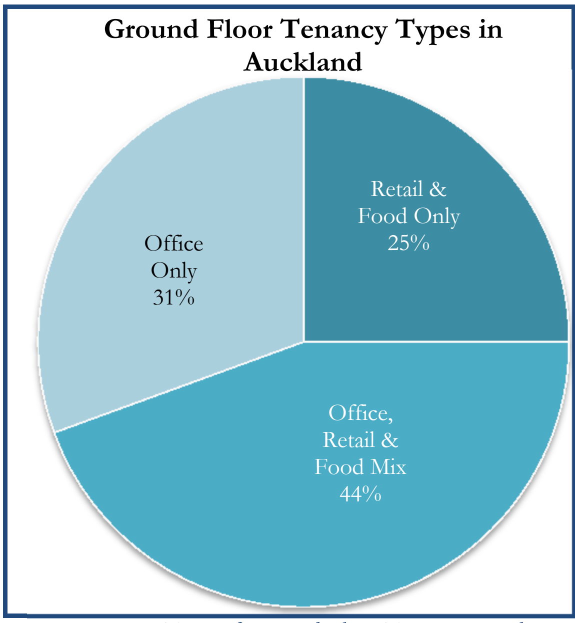

Figure 9.37: Types of Ground Floor Tenancies in the Auckland Buildings surveyed

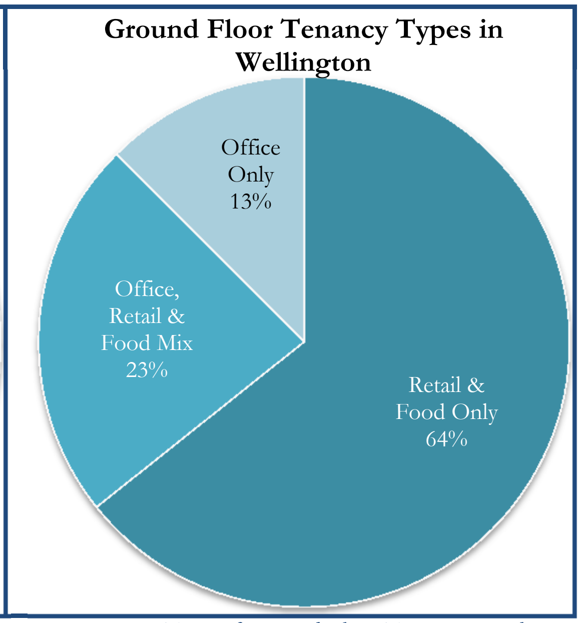

Figure 9.38: Types of Ground Floor Tenancies in the Wellington Buildings surveyed

However, as it was a consistent finding to have non-office spaces on street level floors, it can be assumed to be typical for the sampled office buildings. Unless sub-metering had been installed it was impossible to analyse the water use data any further. An Australian study stated the expected annual difference in water consumption to be $0.08m^3/m^2$/year higher for an office building with food facilities on ground floors (SWC, 2007).

Most building tenants were on a 'gross lease' i.e. the building manager or owner pays the bills directly (while the allocated budget is incorporated in the lease amount), which also means no monitoring of water used takes place, and hence there are few incentives to reduce water consumption as an end-user.

Only three of the 93 buildings in this sample employed 'net lease' agreements with their tenants (i.e. cost recovery by volume used), by the use of sub-metering.

9.5. 'GREEN' BUILDINGS

Of the 93 buildings, three had *GSNZ* Office Design ratings (W49, W52, A76), and another had a *GSNZ* Office Interiors rating (A89/A90). A number of buildings owned by a company with sustainable water management strategies in place had been recently retrofitted with water efficient appliances, which, in some cases were much better than any of the *GSNZ* certified building systems (see Table 9.5 below). The owner of these buildings noted a "significant difference in their water bills once the retrofits had occurred" (Anonymous Building Manager, 2010).

Proportion of Appliance Types by Building Management Practices				
Appliance Type		*GSNZ* Certified Buildings	Water Management Practices in Place	Other Buildings
Toilets	Single Flush	50%	7%	70%
	Dual Flush	50%	79%	19%
	Flush Valve	0%	14%	11%
	Composting	0%	0%	0%
Urinals	Cyclic Flush	67%	19%	55%
	Manual Flush	0%	19%	8%
	Sensor Flush	12%	40%	33%
	Waterless	21%	22%	4%
Wash Hand Basins				
	Mixer/Individual	75%	85%	99%
	Infrared Sensor	16%	7%	1%
	Self-Closing	9%	8%	0%
Showers				
	Water Efficient	86%	37%	8%
	Normal	14%	63%	92%
Water Features		20%	17%	1%

Table 9.5: Difference in Appliance Types by Building Management Practices

Three of these four *GSNZ* buildings included rainwater harvesting, with one having only a single functioning month from the thirteen (at time of enquiry). Due to an error in the design, climate, and reticulation considerations, it was being corrected.

Below is a graph of the monthly water use from another *GSNZ* building, showing their total water consumption over one year, using monthly manual water meter readings.

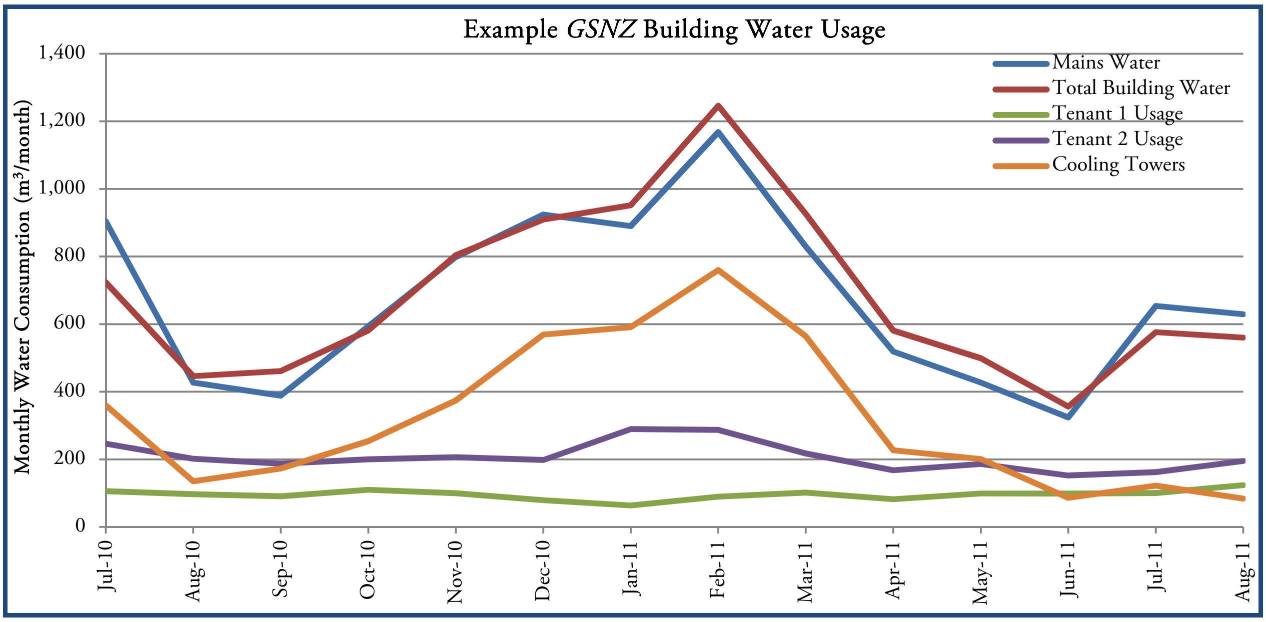

Figure 9.39: A studied GSNZ Buildings' Water Use

This shows a relatively constant tenant usage over the 13-months recorded, however the cooling tower usage is significantly higher during the peak summer periods, as expected. From this chart, it can also be noted that the difference between mains supplied water and total building usage (i.e. rainwater harvest) is not as significant as expected. The water use was assumed to be much higher due to evaporative losses from the cooling towers present in this particular building. The most opportunity appears to be in July.

The complexity in design of these rainwater systems was found to be rather high, especially as it aimed to serve toilet flushing, showering, and irrigation water for the whole building. This also meant the system connection to an internal BMS was vital to achieve the extensive monitoring required. The image below is an example reticulation schematic, from a BMS system in one of the buildings, demonstrating the level of metering (dark blue circles), pipe network detail (white for mains water, and pale blue for rainwater), and the general complexity that is required in its design. Each billed period (monthly), all sub-meters are tallied to ensure overall metering accuracy, help in identifying any leaks or irregularities, and/or for determining the cost recovery for certain areas within the building.

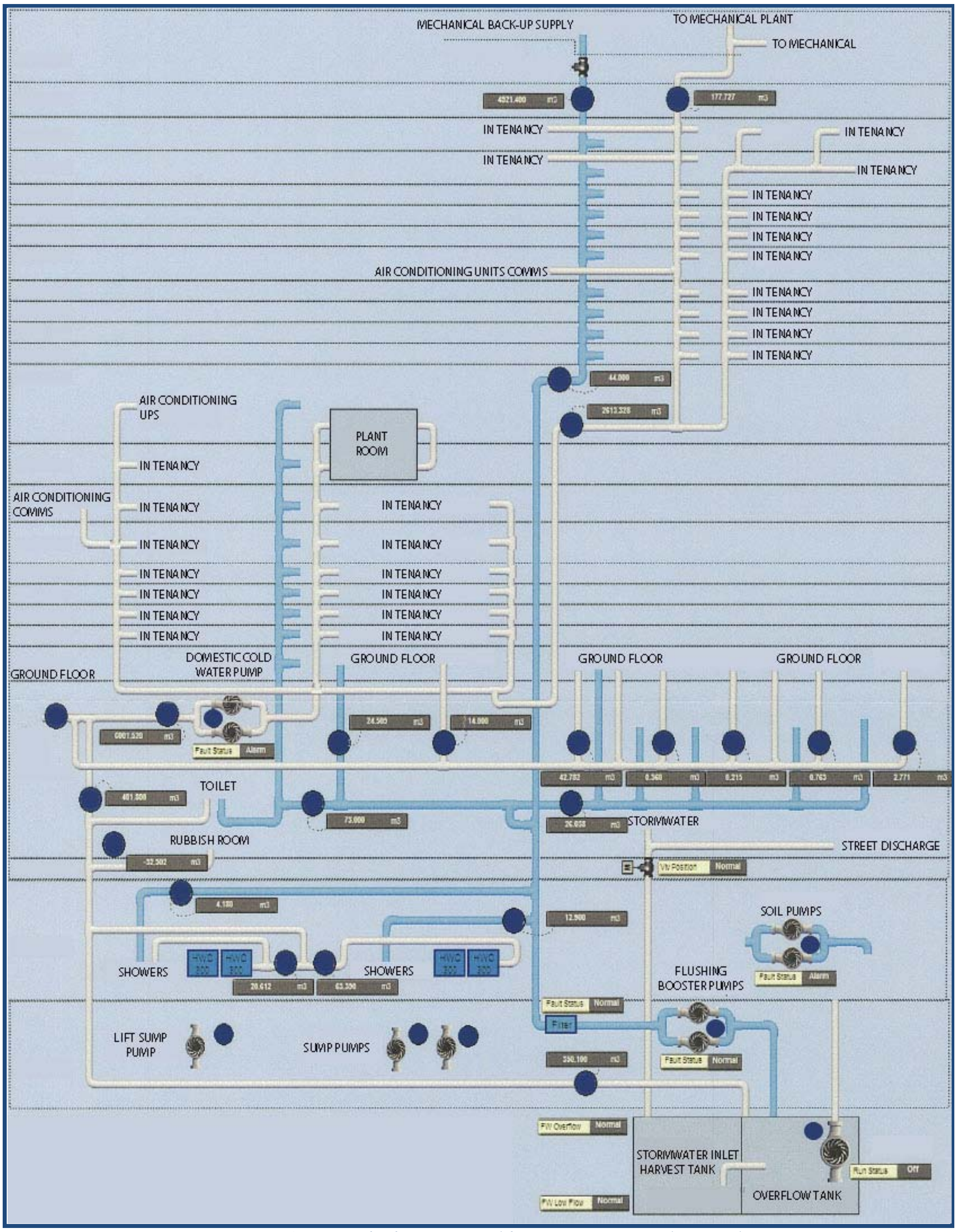

Figure 9.40: A studied GSNZ Buildings' Water Reticulation Plan

In one other building, the extensive monitoring that did take place was not kept for more than 7 days, i.e. the data was deleted due to storage capacity after seven days. Once, the importance of storing the data was explained to the building managers, they opted to upgrade their data management and storage systems for optimised management and analyses of the data, if necessary. However, as this was still low on their priority list, it was not immediately implemented.

Other buildings harvesting rainwater managed to reduce the amount of mains supplied water by ~25%, for example in building W49. These buildings also benefitted from additional wastewater tariff incentives in Auckland.

It needs to be highlighted here, that as only a very small number of *GSNZ* certified buildings have been analysed, this is not representative of all *GSNZ* certified buildings. A substantial random sample would be needed to draw any substantial conclusions.

9.6. TARIFF STRUCTURES

The tariff structures in Auckland and Wellington, the two subject locations, differ – as do all of New Zealand water tariffs, as shown in Appendix B2. Discussing this with building managers who held commercial portfolios in both cities, they felt "we pay four times as much in Auckland than we do in Wellington" (Anonymous Building Manager, 2010). After further investigation it was concluded that Auckland's tariff structure offers more visual incentives for the reduction of water use, where metered connections exist, than is the case in Wellington.

Below is an outline of the difference in both price and charging mechanism for Auckland and Wellington. However, as the majority of the gathered building water data relates to the year 2010, both 2010 and 2011 structures have been demonstrated below.

Auckland Tariff	Charge	Wellington Tariff
NZD$81/meter	Annual Service Fee	NZD$84/meter
NZD$1.580/m^3	Ingoing Potable Water	NZD$1.584/m^3
NZD$3.797/m^3	Outgoing Wastewater	0.00144003% Capital Value

Table 9.6: Tariff Structures as at 2010

A hypothetical building scenario (NZD$59,000,000 capital value, 28,000m^3/year water consumption) has been applied to determine if any difference exists. Once volume and capital values were applied, the difference becomes clear. Prior to 2011 in Auckland, commercial property owners had the opportunity to undertake wastewater audits, whereby if evaporative or manufacturing losses could be proved, that proportion would be deducted from the wastewater part of the charges (Metrowater, 2010).

From the Auckland sub-sample of buildings, analysis shows that 77% of ingoing potable water quantity is the average billed wastewater amount. For this 2010 scenario, this wastewater percentage reduction has not been applied, as the auditing was a voluntary process, not all buildings utilised/benefitted.

Auckland		Charge	Wellington	
Appears on Water Invoice	Total Charge		Total Charge	Appears on Water Invoice
NZD$81	NZD$81	Annual Service Fee	NZD$84	NZD$84
NZD$44,441	NZD$44,441	Ingoing Potable Water	NZD$44,329	NZD$44,329
NZD$106,529	NZD$106,529	Outgoing Wastewater	NZD$86,258	Not on Invoice
NZD$151,060	**NZD$151,060**	**TOTAL**	**NZD$130,670**	**NZD$44,412**

Table 9.7: Hypothetical Scenario of costs in 2010

On 1 November 2010 the Auckland super-city was formed, with the merging of eight district and regional councils around Auckland (*Auckland Regional Council*, *Auckland City Council*, *Franklin District Council*, *Manukau City Council*, *North Shore City Council*, *Papakura District Council*, *Rodney District Council*, and *Waitakere City Council*). This meant that all tariff structures were combined into one uniform rate under the *AC* system. The wastewater tariff now has a fixed wastewater proportion (75% of ingoing potable water quantity) applied. Therefore, the following analysis is based on 2011 tariffs or the tariffs since the super-city formation.

Auckland Tariff	Charge	Wellington Tariff
NZD$43/meter	Annual Service Fee	NZD$100/meter
NZD$1.300/m^3	Ingoing Potable Water	NZD$1.715/m^3
NZD$4.056/m^3 Based on 75% of Ingoing Water	Outgoing Wastewater	0.00130171% Capital Value

Table 9.8: Tariff Structures as at 2011

When the hypothetical building scenario has been applied, Wellington users are in fact paying ~3% more than Auckland. Auckland buildings still have the ability to reduce the amount they are paying (if applying the same efficiency measures in Wellington) due to the wastewater tariff structure being directly linked to the quantity of ingoing potable water.

Auckland		Charge	Wellington	
Appears on Water Invoice	Total Charge		Total Charge	Appears on Water Invoice
NZD$43	NZD$43	Annual Service Fee	NZD$100	NZD$100
NZD$36,400	NZD$36,400	Ingoing Potable Water	NZD$48,020	NZD$48,020
NZD$85,176	NZD$85,176	Outgoing Wastewater	NZD$76,801	Not on Invoice
NZD$121,260	**NZD$121,260**	**TOTAL**	**NZD$124,921**	**NZD$48,120**

Table 9.9: Hypothetical Scenario of costs in 2011

Even though the Auckland tariff structure is more visually incentivising for water reduction savings, buildings which employ rainwater harvesting have the ability to reduce both water and wastewater, as wastewater charges are based on 75% of ingoing potable water – NOT what is going down the drain. The amount of measured ingoing potable water is reduced, and therefore the amount of charged wastewater is reduced. This incentive is not present in Wellington.

9.7. SUMMARY OF FIELD OBSERVATIONS

From examining the 93 buildings in this sample, it was found that in a number of cases multiple buildings share one or more water meters; which meant their data were combined to understand the consumption appropriately.

The vast majority of businesses (by count) were in the *ANZSIC* categories "financial and insurance services" and "professional, scientific, and technical services", which meant the selection criteria was applied appropriately. The occupant density was skewed based on whether government agencies occupied the building (partially or wholly), where smaller floor areas per person for government agencies, and larger for private offices were identified.

It was found that a significant portion of the building owners or managers were largely unaware of the location of their water meter(s). While the installed meters showed the older *Elster-Kent H3000* (Helix) meters were prominent in Wellington, and the newer *Elster-Kent C4000* (combination) meters were dominant in Auckland. Sub-meters were largely absent from the studied buildings.

While the majority of buildings were mechanically ventilated, 67% in Auckland and 53% in Wellington were water cooled (by evaporative cooling towers). The type of cooling for each building showed some correlation to building size, and to annualised water use.

A significant proportion of the appliances observed were not of the most efficient standard. 70% of the toilets in Auckland were single flush, with 58% in the Wellington sample. 54% of the urinals (both trough and wall-pod) in Auckland were cyclic (syphonic), and 48% in Wellington. The ratio of showers to people was largely random, as there is no legislative specification for them to be installed in office complexes.

Office buildings were found to be retrofitted every ~15 years, while the *WELS* was published ~7 years ago. It has been assumed that the uptake of *WELS* rated appliances in these buildings is will increase in the coming years. However, this may also be linked to the tariff structures placing little incentives for buildings to have water efficient appliances installed.

Based on the Auckland and Wellington tariff structures, when applied to a hypothetical building scenario, it appears that Auckland's tariff is much more visually incentivising (having all water related charges appearing on the one invoice), yet Wellington pay ~3% more (as of 2011). This confirms that the tariff structures can make a difference in educating and promoting action for water demand reduction to its end users.

10. DETAILED WATER ANALYSIS

This chapter outlines the detailed analysis of the SLWA dataset, together with more in depth attempts at understanding water use. This process is then compared to the monitoring output from four office buildings within the Wellington sub-sample under the FWA.

The buildings undergoing detailed monitoring (FWA) were not only selected on the basis of the building owner/manager's willingness to participate, but also the compatibility of the currently installed water meter with the available pulse sensors for this study. For each building the local supply utility and the contracted water meter readers were notified of each installation.

10.1. SURVEY LEVEL WATER AUDITS (SLWA)

As well as those field observations outlined previously, a number of additional water related analyses were identified. Dziegielewski et al (2000) suggest that differences in climate may affect the amount of water used for irrigation and air-conditioning, as well as general cooling water requirements. *Watercare Services Limited* (2008) also identified that there was a strong relationship between air temperatures and the demand for water. Therefore, this chapter assesses the relationships between water demand, ambient temperatures, and water use in the surveyed buildings, on an annual, seasonal, and weekly basis.

10.1.1. SEASONAL DEMAND

The data were used to explore for annual, seasonal, and any other periodic patterns for each building, and any significant trends. In Figure 10.1, the blue line represents the average weekly demand for Auckland CBD, while the pale blue columns represent the average weekly water use for the studied buildings. In Figure 10.2 the red line shows the Wellington region average weekly water demand across the year, while the pale red columns give the average weekly water use for the sampled buildings.

The water demand for both Auckland and Wellington was provided on a weekly basis by the relevant water utility, while the sampled buildings only had monthly or bi-monthly revenue readings, so it is only possible to provide the weekly averages for these billed periods.

As can be seen in Figure 10.1 and Figure 10.2, the summer months display a trend of both higher overall water demand, and higher consumption in the surveyed buildings (apart from the dip over Christmas/New Year). It is hypothesised that this is due to the warmer summer climate, influencing possibly an increased cooling load, an increased need for irrigation (if any), and any other evaporative losses.

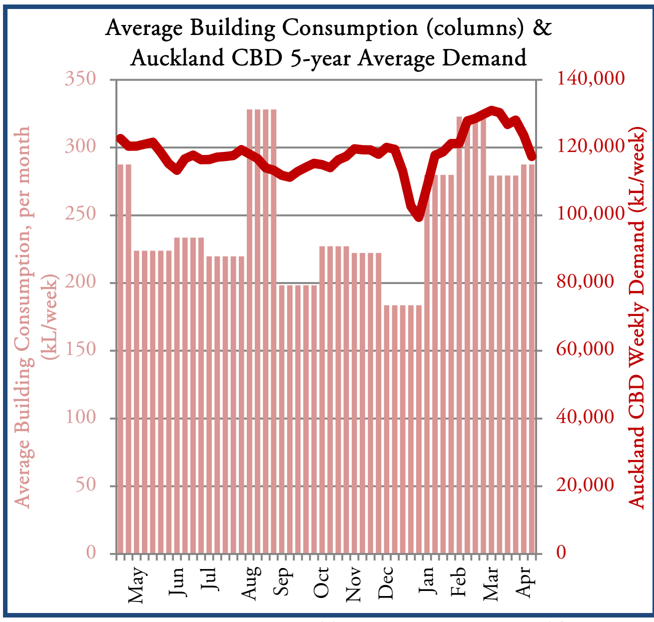

Figure 10.1: Average Weekly Consumption in Buildings Surveyed (column) & Auckland CBD 5-year average Weekly Demand (line) (Source: Reed, 2011)

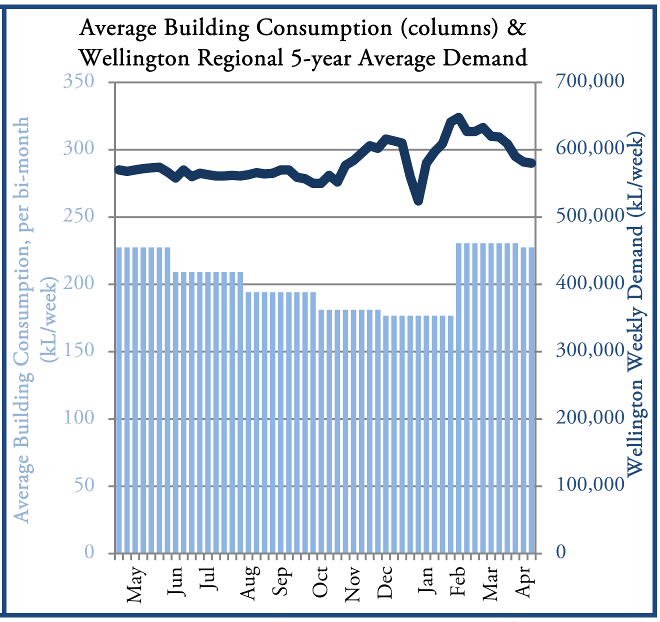

Figure 10.2: Average Weekly Consumption in Buildings Surveyed (column) & Wellington 5-year average Weekly Demand (line) (Source: Gribble, 2009)

However, for the buildings of interest, during the summer (Christmas) holiday period when the buildings are likely to be either closed or with reduced staff numbers for up to three weeks (~67% of the billed period in Auckland or ~35% of the billed period in Wellington), there is only a small dip in the billed water use. This is in contrast to the significant dip in the water demand lines. However, the dip in building water use is more prevalent in Auckland, most likely due to the smaller intervals between meter readings.

On a first view this would appear to suggest that the office building water use is driven not by the presence or absence of occupants, but rather by the water using features of the building itself.

After further discussions with a number of building managers it was identified that most HVAC and automated urinal flushing schedules are not altered to allow for these reduced occupancy periods. In most cases, where ground floor tenants are either retail or hospitality, and rely on the building HVAC as opposed to independent heat pumps, the building HVAC systems are left running to achieve comfort for these one or few spaces which are continuously occupied during this period.

An average daytime (8am to 8pm) temperature was calculated for each of the periods stated, which is assumed to coincide with the operating times of the buildings. The results of this are displayed in Figure 10.3 and Figure 10.4 below; showing local water demand, with the averaged daily temperature sourced from the *NIWA* climate database (NIWA, 2012).

Please note: in both the above Figures (Figure 10.1 and Figure 10.2) and the below Figures (Figure 10.3 and Figure 10.4), due to the difference in land area for the water demand line (Auckland CBD vs. Wellington region) there is a difference in the left-hand scales.

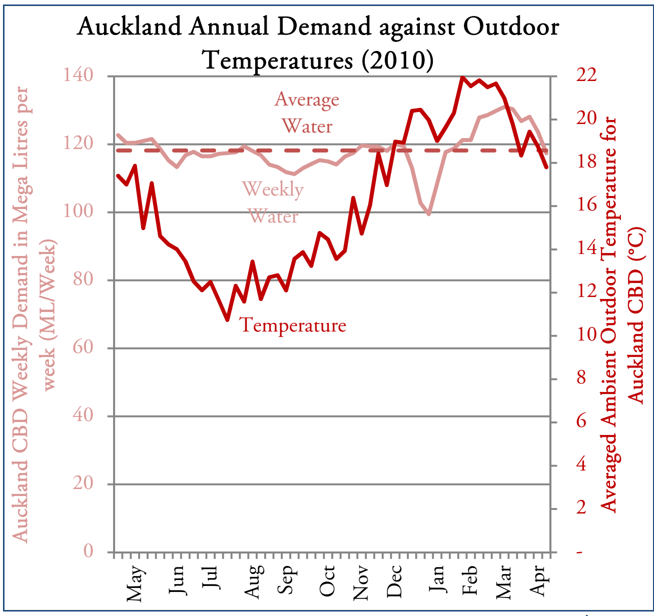

Figure 10.3: Auckland CBD Weekly Demand (pink) & Auckland CBD Weekly Ambient Outdoor Temperature (red) (Source: Reed, 2011; NIWA, 2012)

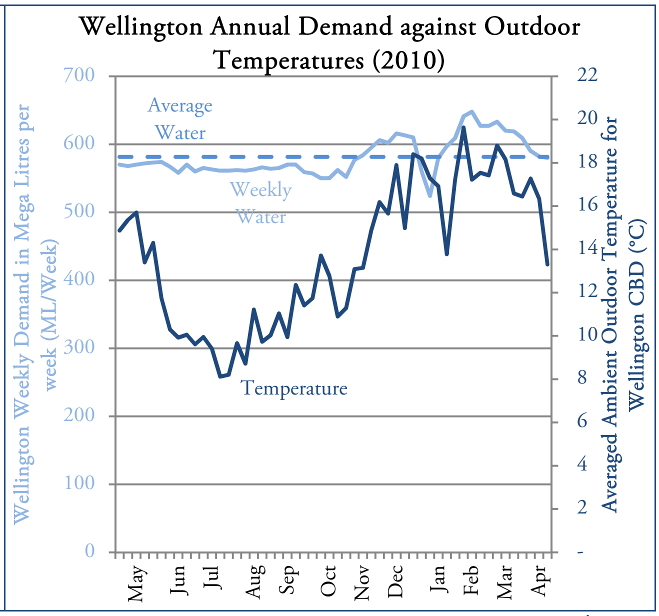

Figure 10.4: Wellington Weekly Demand (pale blue) & Wellington CBD Weekly Ambient Outdoor Temperature (dark blue) (Source: Gribble, 2009; NIWA, 2012)

Figure 10.3 and Figure 10.4 show peak temperatures correspond to peak water demand. There appears to be a strong relationship between total water demand, and the average ambient outdoor temperatures for the same period of time. However, a coefficient of determination of $r^2 = 0.47$ in Wellington, suggests only a moderate relationship.

While a similar (graphical) outcome is occurring in Auckland, the relationship also presents a low coefficient of determination of $r^2 = 0.13$. This shows that there is a weak (statistical) relationship or that for Auckland only 13% of the variance in water use can be explained by the variance in ambient temperatures. When considering the temperature of only the summer months, i.e. when the water demand rises above the annual norm, no significant relationships are found. Likewise, when considering the temperature and demand of all seasons except summer, no significant relationships are found.

When the winter months are considered, the trough is not as significant in the water demand line. This could be indicating that the increased need for cooling and irrigation is that demand above the average demand of ~575 ML/week in Wellington, or ~120 ML/week in Auckland CBD.

10.1.2. MANUAL WATER METER READINGS

During the SLWA phase, manual meter readings were recorded to see if the data could provide any information about individual water use. Two buildings in which water meters are publicly accessible (i.e. not secured by locks, codes, or other restricted access measures) were selected for this analysis. These buildings had their meters read at least once per day over a 9 day period from Sunday 6 December 2009 until Monday 14 December 2009.

Of the two buildings selected, one was a larger water-cooled building (W42), and the other was a smaller naturally ventilated building (W18). Readings were collected at approximately 8.00am for the water-cooled building, and approximately 8.00am and 8.00pm for the naturally ventilated building.

The monitoring was done to identify if there were any differences in water consumption during periods when the building is occupied, i.e. weekdays, as opposed to when the building is assumed to be closed/non-occupied, i.e. the weekend and weeknights.

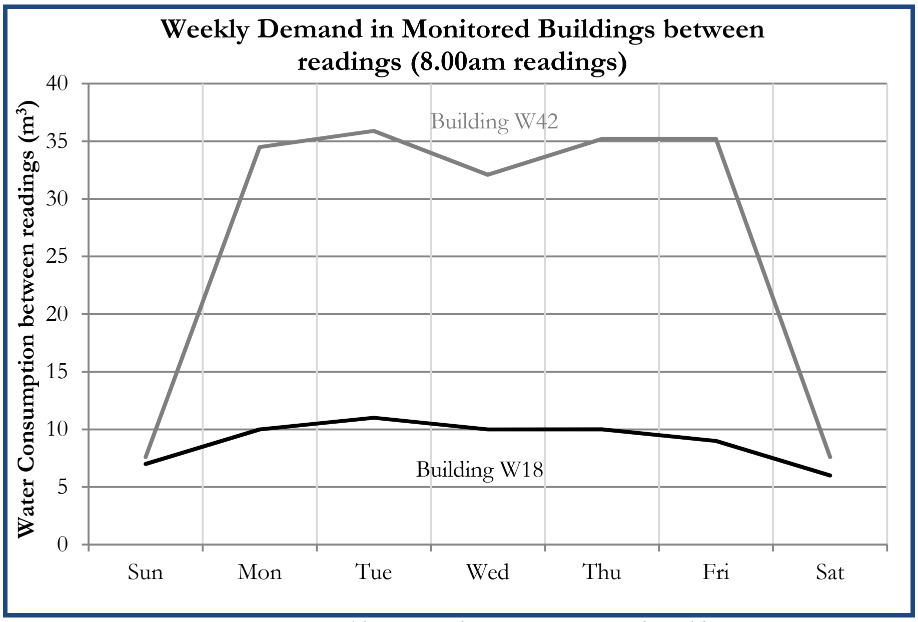

Figure 10.5: Weekly Demand in Two Monitored Buildings

In Figure 10.5 above, both buildings had a reduced consumption over the weekend (Saturday and Sunday) periods, which could be assumed to be due to the lack of occupants and reduced need for mechanical cooling (in the water-cooled building), etc.

Below in Figure 10.6, the water meter was able to be accessed and read twice per day in the smaller naturally ventilated building (W18), therefore this is showing the difference in day and night time usages. Readings took place at approximately 8.00am and 8.00pm each day during the 9 day monitoring period.

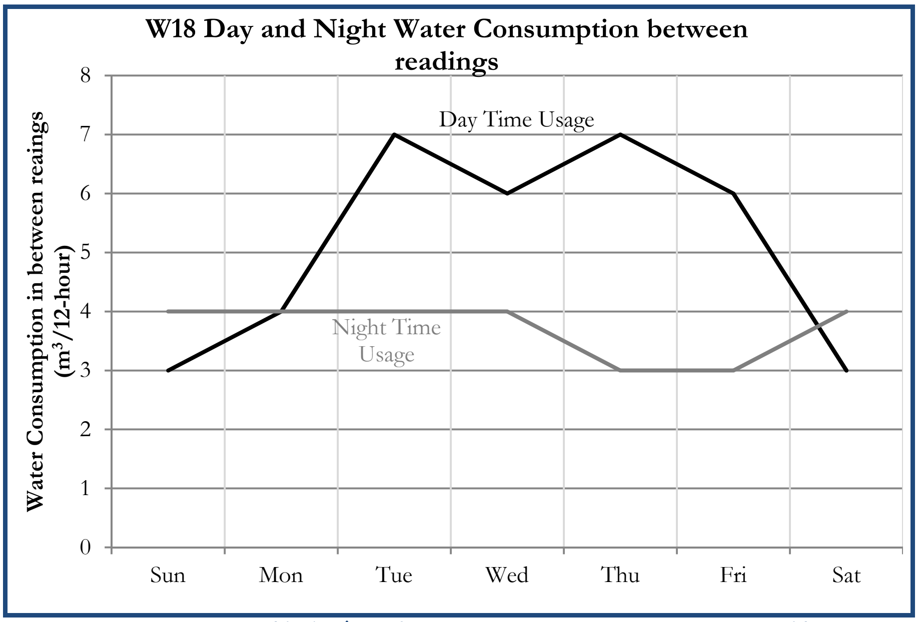

Figure 10.6: Day (black) & Night (grey) Water Consumption in One Building

This shows that daytime usage (6.5m^3) is on average twice the night time usage (3.5m^3). This also shows that during the weekend the night time consumption is higher than the daytime readings, which is a little peculiar.

It would be advantageous to have monitoring/data logging equipment installed on and within buildings to measure daily load patterns and to enable end-use fingerprint analysis. This would also allow more study in depth on whether water consumption is actually influenced by the presence or absence of the building occupants, and/or ambient temperatures.

The manual meter reading exercise is however a simple demonstration of how minimal effort and investment in meter reading can give informative and interesting results.

10.2. FULL WATER AUDITS (FWA)

Four FWAs were undertaken on a non-random sub-sample of Wellington buildings. These buildings were selected on the basis of their existing (council registered) water meters, and their compatibility with available pulse sensors.

At the completion of the SLWA, it was identified that compatible pulse sensors were available for this study, through the *BEES* project led by *BRANZ*. Therefore the building owners were once again approached for consent to install the proposed equipment. In order to do so, *Arthur D. Riley & Co. Ltd*, who are contracted for reading the water meters for *WCC* billing were also notified, along with *Capacity Ltd*.

After the pilot trial (14 May 2010 to 18 June 2010), another three buildings were fitted with monitoring equipment progressively from 21 October 2010 to 6 April 2011, and all equipment was removed on 10 February 2012. Below in Table 10.1, the four buildings, their monitoring specifications, and basic SLWA characteristics are outlined.

	W39	W3	W14	W18
FWA Details				
Equipment Installation	14 May 2010	6 April 2011	21 October 2010	4 April 2011
Equipment Removal	10 February 2012	10 February 2012	10 February 2012	18 January 2012
Total Duration	637 Days	310 Days	477 Days	289 Days
Water Meter	Sensus 620 series	Elster-Kent PSM-T	Elster-Kent PSM-T	Elster-Kent H4000
Pulse Sensor	HRI 620	PSM-T Reed	PSM-T Reed	PR7
SLWA Details				
NLA (m^2)	4,737	5,141	5,110	2,750
Cooling	Heat Pump	Air-Cooled	Air-Cooled	Natural
FTE Occupants	188	171	105	136
Storeys	16	17	7	6
Annual Billed Water (m^3/year)	6,298	4,788	4,274	520

Table 10.1: FWA Building Details

However, building W18 had such a low water demand, that either: the equipment failed to record any useful readings; or the equipment was malfunctioning. It was therefore concluded that it would not be possible to obtain worthwhile readings without sensitivity adjustment in the pulse sensor, or water meter calibration or replacement (to allow for low flow traces).

Building W18's water meter size is 40mm, and due to the building size and annual consumption averages, the water meter may be too large to be tracing any low flows. As the building fits the 'normal' profile in terms of occupancy, and appliances (other than being naturally ventilated), in contrast to the remaining buildings; it is expected that it would be using around 2,000 m^3/year.

Based on the information in Chapter 4.2, it would be ideal for a combination meter (such as *Sensus Meitwin*, or *Elster-Kent C4000*) be installed in place of the existing *Elster-Kent H4000*. This would have a high sensitivity (pulse per litre rate) with the compatible pulse sensor. A combination meter has the ability to record both low and high flow traces.

As identified through the pilot study (refer Chapter 7.3.2), the first five weeks were recorded at 10-second intervals, while the remaining time was set to record at 10-minute intervals. A single battery, such as the 'D-size' batteries used in the data loggers, had an estimated life of 6-months when recording at 10-minute intervals, so each battery was clearly labelled with the installation date, to avoid battery failure.

Once the monitoring equipment had been installed, due to the battery storage capacity, each building was re-visited every 5 to 6 weeks for data-logger changeovers. This was selected as the optimum period for mitigating the risk of battery failure, unauthorised tampering/vandalism, and/or equipment malfunction. In such an event, the period of loss was restricted to a maximum of six weeks. If the pulse sensors were connected either to a BMS or a central monitoring system, similar to what *Outpost Central* offer (SIM communications to live dashboard over the internet), the visits would not be necessary, and any failure would have instantaneous detection. This might be an option for future studies.

The data recorded from the buildings were analysed to determine if any periodic (including daily, weekly, and annually) patterns or relationships were occurring, and to see if the data could be developed into a generic model for future benchmarking reference and load calculations.

10.2.1. DAILY WATER USE

The charts below provide a visualisation of every day of September 2011, with the average week-day and week-end days highlighted in bold. September was chosen as it is an average month, as opposed to February (summer) or August (winter), so should therefore be neutral to any extreme climate. Also, as it is not near any major statutory holiday periods it should also remain neutral to any occupancy fluctuations.

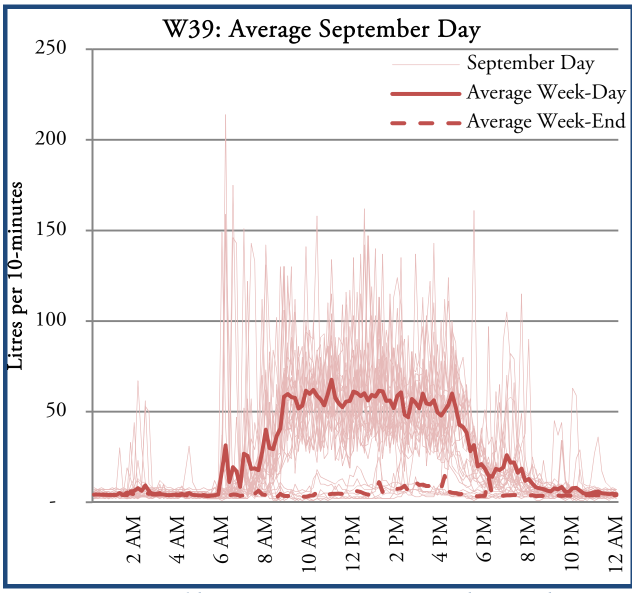

Figure 10.7: Building W39 Average Monitored September Day

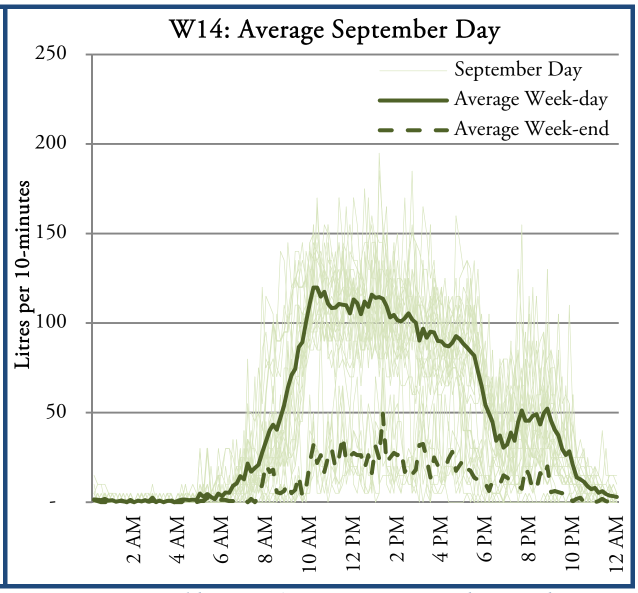

Figure 10.8: Building W14 Average Monitored September Day

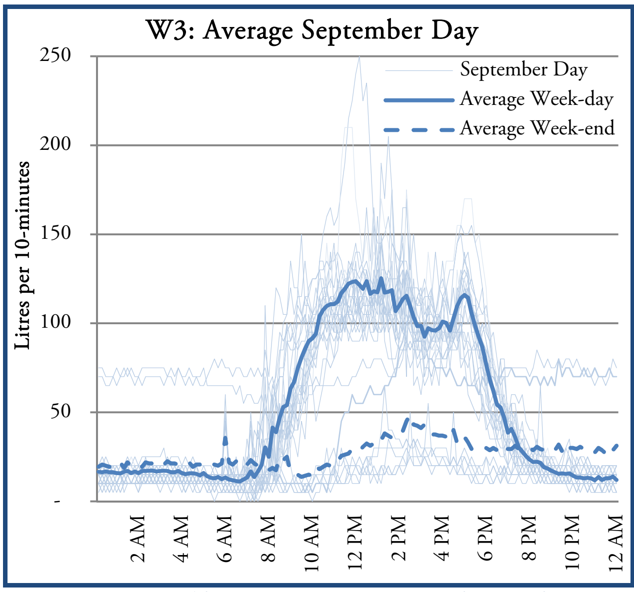

Figure 10.9: Building W3 Average Monitored September Day

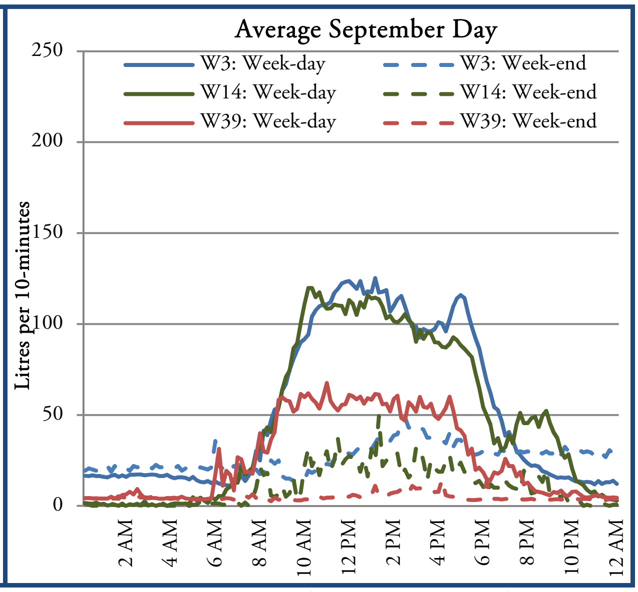

Figure 10.10: FWA Buildings Average September Day

As each building differs in the quantity of water used, and is different independently in a number of aspects, i.e. cooling mechanism, number of storeys, etc, they cannot be accurately compared until after the benchmark analysis has occurred. However, they can still be described and analysed individually.

These daily profiles show a very clear pattern, where night time usage is visibly identified. For each building, a daytime trend is appearing, beginning around 6-8am, and reducing again by 6pm during the week. In order for this peak (of 120 L/10-minutes) to occur, in building W14, ~17 of the 28 toilets would need to be flushing simultaneously (assuming each toilet is 7L/flush).

Although the three buildings monitored are all similar in size and occupancy, the variation in daily use patterns is not. W3 shows a large number of days where the base load is around 70 L/10-minutes, while the majority appear to be around 25 L/10-minutes, while W39 has a more constant baseflow of 10 L/10-minutes, and lower overall peak profile. W14, as noted above, does in fact reduce to near zero usage at times overnight using 10 L/10-minutes. However, building W14 is the only building with cyclic flushing; the other two have sensor activated flushing.

Building W3 however, has a call centre operating 24 hours a day, seven days a week, on one floor of the building. This floor also has the highest occupant density in the building. There is no other activity or appliance timed to operate outside normal working hours.

All three buildings have a second peak late afternoon/early evening, this is hypothesised to be caused from several things: cleaning processes; the urinal heavy-duty flushing cycles, after normal working hours; and possible end of day restroom rush. This consistent spike at the end of each working day may also be seen during the weekly analysis.

If the installations in the three buildings are considered, the end-use breakdown can be approximated based on the information found in Figure 3.7 and Chapter 9.4. This is given in Figure 10.11, Figure 10.12, Figure 10.13, and Table 10.2 below.

It was estimated that restrooms and HVAC are the biggest consumers of water based on the conclusions found in Chapter 3.2. However, based on the predicted (i.e. based on *BIA* (Stewart, 1995) study usage rates, and currently installed appliances) pie-charts below, it appears that the restrooms are likely to be the highest users of the two. It should be remembered that none of these three buildings employ water as their HVAC heat rejection mechanism, and also contained no water feature or garden areas requiring irrigation.

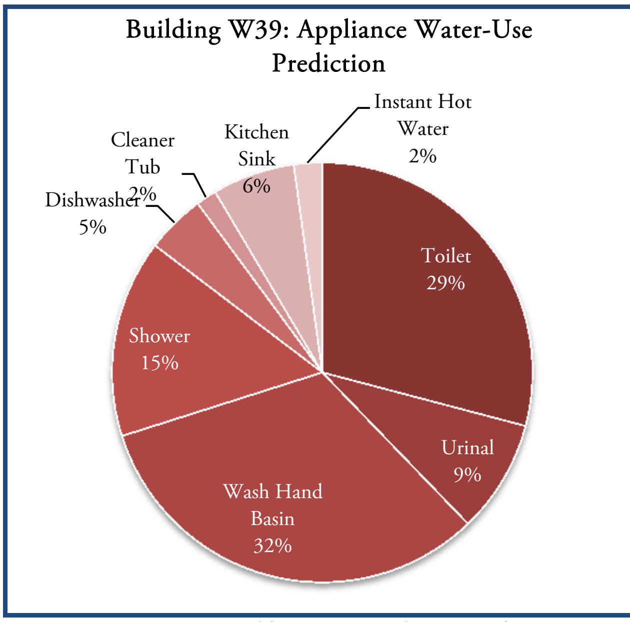

Figure 10.11: Building W39 Appliance Prediction

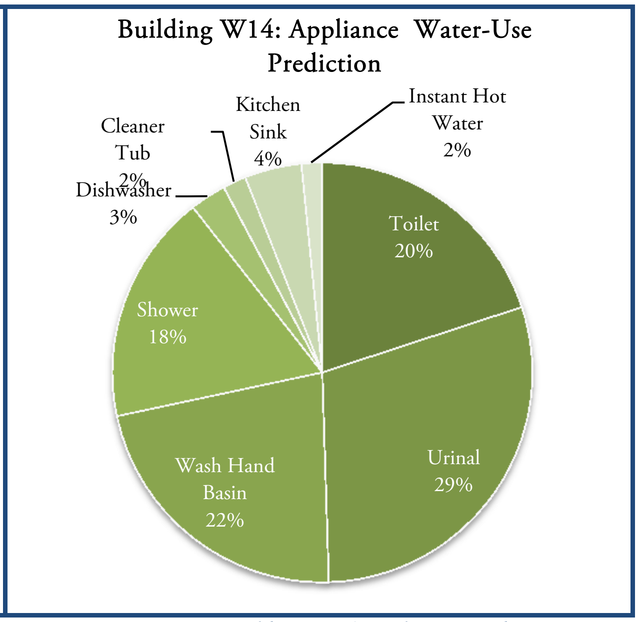

Figure 10.12: Building W14 Appliance Prediction

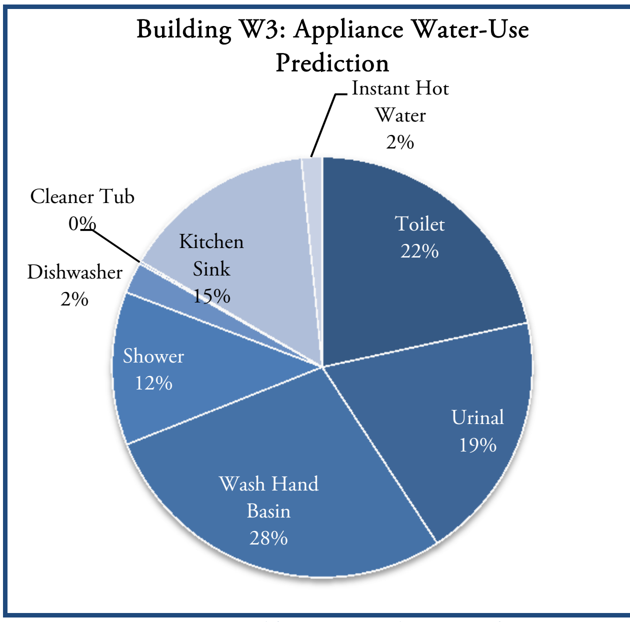

Figure 10.13: Building W3 Appliance Prediction

Appliance	Count by Appliance Type		
	W3	W14	W39
Toilets	44	28	39
Urinals	14	7	8
WHB	58	28	34
Shower	3	-	8
Sink	17	9	18
DW	10	8	16
Tub	1	7	7
Zip	15	7	15
Other	-	8	3
Total	162	102	142
HVAC	Air-Cooled	Air-Cooled	Heat Pump
Hours	M-F	M-Sat	M-Sat
FTE O	171	105	188

Table 10.2: FWA Buildings Appliance Details

These appliance predictions show that toilets, urinals, and wash hand basins are the biggest users. Building W14 clearly demonstrates the presence of the cyclic flushing urinals. Due to the increased level of occupancy in building W3, it is assumed that the kitchens have a higher usage rate than would be in the other two buildings.

The data analysis indicates that the day time portion of the water use is influenced by the presence of the occupants (due to obvious time/water relationships); however the baseflow periods are not.

10.2.2. WEEKLY WATER USE

Figures 10.14 to 10.17 display an average September 2011 week, for each of the three monitored buildings and overall. Over an entire week it is interesting to note the distinct day/night and weekday/weekend pattern that is occurring, with clear daytime peaks, as noted in the daily water use analysis and clear troughs overnight. It is also interesting to note a slight increase in weekend use in contrast to the baseflow. Buildings W14 and W39 both have hospitality facilities within their ground floors which are operational on a Saturday morning, possibly explaining the weekend use patterns.

Figure 10.17 compares the average September weeks with all buildings demonstrating a clear daily pattern. All three are peaking around 150 L/10-minutes, with the exception of W3, with a large Friday peak of 200 L/10-mintues. W39 shows the most variance in water use, while W3 shows the most stable line.

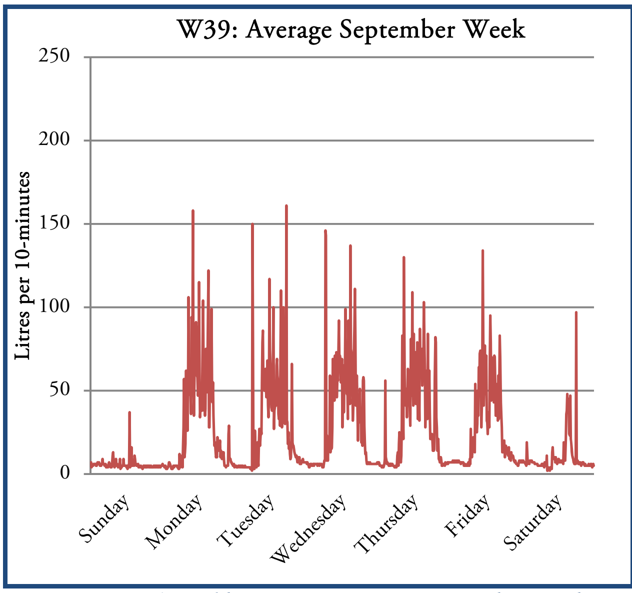

Figure 10.14: Building W39 Average Monitored September Week

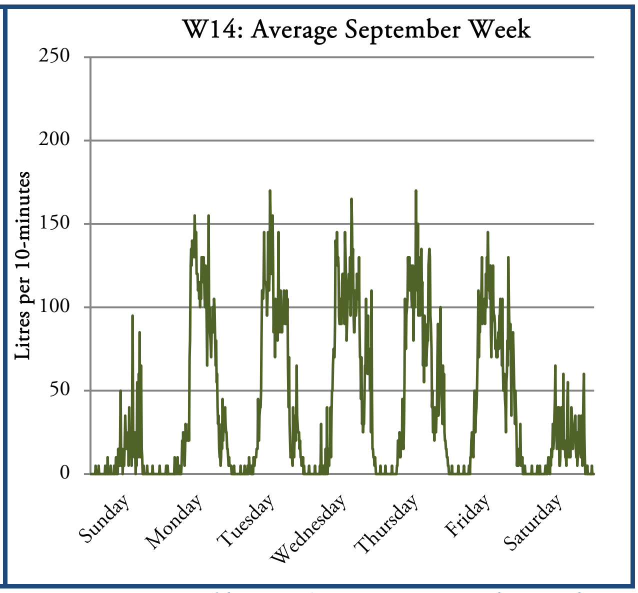

Figure 10.15: Building W14 Average Monitored September Week

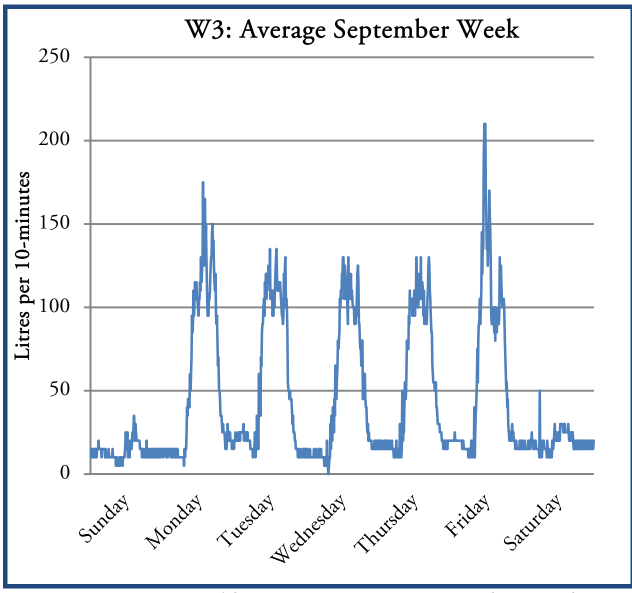

Figure 10.16: Building W3 Average Monitored September Week

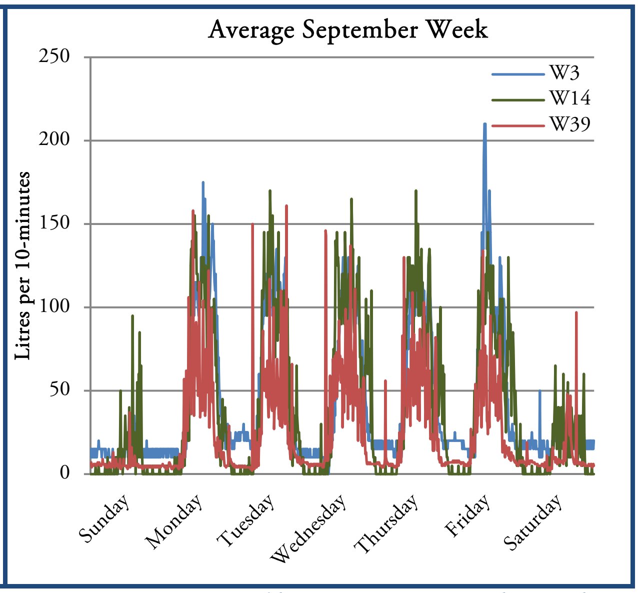

Figure 10.17: FWA Buildings Average Monitored September Week

The baseflow periods are clearly visible here over the duration of the week; W14 appears to reduce to zero consumption regularly, only once did W39 reduce to zero during the week, while W3 did not. In W39, the average flow is identified as 23 L/10-minutes. In W3, the average flow is 43 L/10-minutes. In W14, the average flow is 39 L/10-minutes. This is further discussed in Table 10.3.

Again, the conclusion is that while occupied times influence high consumption periods, water is still being used outside these periods. It would be interesting however, to compare this September week with all other weeks of the year.

10.2.3. ANNUAL WATER USE

As each building's monitoring period differed, and did not reach more than one consecutive year, only the overlapped data can be directly compared. Figure 10.18 displays the annual water consumption for the three monitored buildings in kilo-Litres per week (kL/week). They have been overlapped on one chart to determine if there are any patterns or similarities in seasonal use.

It was expected that there would be a summer peak and a winter trough, when there may be an increase/decrease in evaporative losses. However, as none of the three monitored buildings used water-cooled HVAC systems, there was not expected to be a huge variance off the norm.

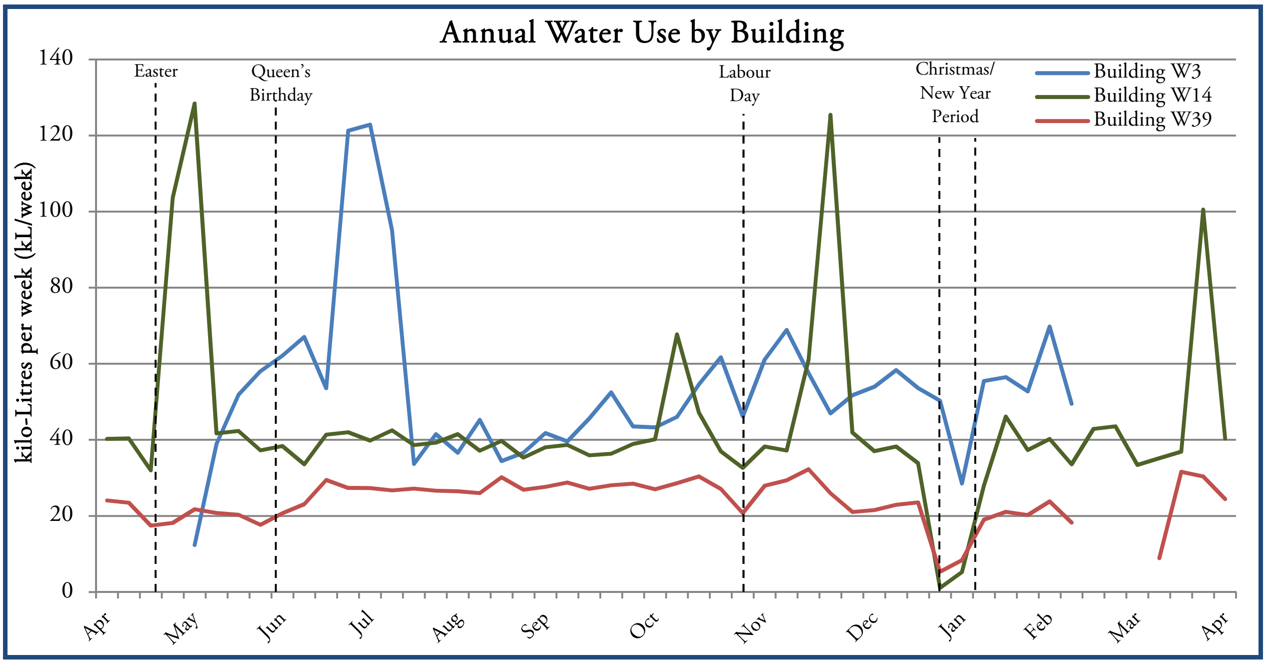

Figure 10.18: Annual Water Use by Monitored Building

In W14, a number of leak occurrences have created a large spike in March/April, April/May, and November/December 2011 and there is another large effect during June/July 2011 for W3. Please refer to Chapter 10.2.4 for further detail on these irregular occurrences. Both building W3 and W14 appear to consistently consume about 40 kL/week, while building W39 sits quite a bit lower. Again, there are numerous peaks; these are discussed later, in Chapter 10.2.4.

What Figure 10.18 shows is that over the summer holiday period (discussed in Chapter 10.1.1), the consumption does in fact significantly drop-off, and then increases again very soon after (10th January). In fact, the consumption drops off for each of the statutory holidays throughout the year. Easter and Anzac Day can be seen in late (22nd-25th) April, Queen's Birthday can be seen in early (6th) June, and Labour Day can be seen in late (24th) October, notably in buildings W14 and W39.

The highest recorded day for each building is set out in Table 10.3, along with the lowest and average recorded details. This of course is calculated with the irregular occurrences (such as leaks) removed. The lowest period appears to fall in December for both Building W14 and Building W39, and June for Building W3, while the peak periods are January for Building W3 and Building W14, and November for Building W39. It is noted that in all three cases there is at least some water being used every day.

Building	Average Day (L/day)	Peak		Trough	
		Rate (L/day)	Date	Rate (L/day)	Date
W3	7.833	14,826	30-Jan-12	775	12-Jun-11
W14	6,265	15,010	18-Jan-12	55	22-Dec-11
W39	3,479	6,854	15-Nov-10	764	30-Dec-11

Table 10.3: Annual Average, Peak, and Trough for Monitored Buildings

The average daily demand appears to be quite consistent throughout the year in all three buildings, with the exception of Building W3. All of the monitored buildings appear to peak during the summer months, while a clear trough over summer holiday break (December/January) is present in the three buildings, although at times during the year weekend usage is similar. Other than the summer holiday period, there does not appear to be a very low usage period during the year.

10.2.4. LEAKAGE

Coincidentally, during the FWA monitoring study, building W14's toilet valve malfunctioned causing the storage tanks to stay empty for a period of 3 days, a similar occurrence happened one month later. This can be seen in the weekly profile displayed below in Figure 10.19. Please note the average working day profiles, with the leak using approximately four times as much as the typical peak-day amount.

This can also be seen in Figure 10.18, where a number of weeks show largely higher usage. In building W14, the average daily peak is normally between 150 L/10-minutes and 200 L/10-minutes. During this recorded week (28 April 2011 to 4 May 2011), the malfunctioning toilet valve was not reported until the following Monday. This left the cisterns and storage tanks to empty, and continue to be emptied until the issue was reported and effectively pouring more than 400L of clean potable water down the drain over each ten-minute period.

Fortunately for the building owner, the cost of water in Wellington is so low (NZD\$1.715/m^3) that the leak cost no more than NZD\$300 for the highlighted period. If this leak were to occur in an Auckland building, the bill would have been in excess of NZD\$750; which in the scheme of the daily running of the building of this scale is still not high.

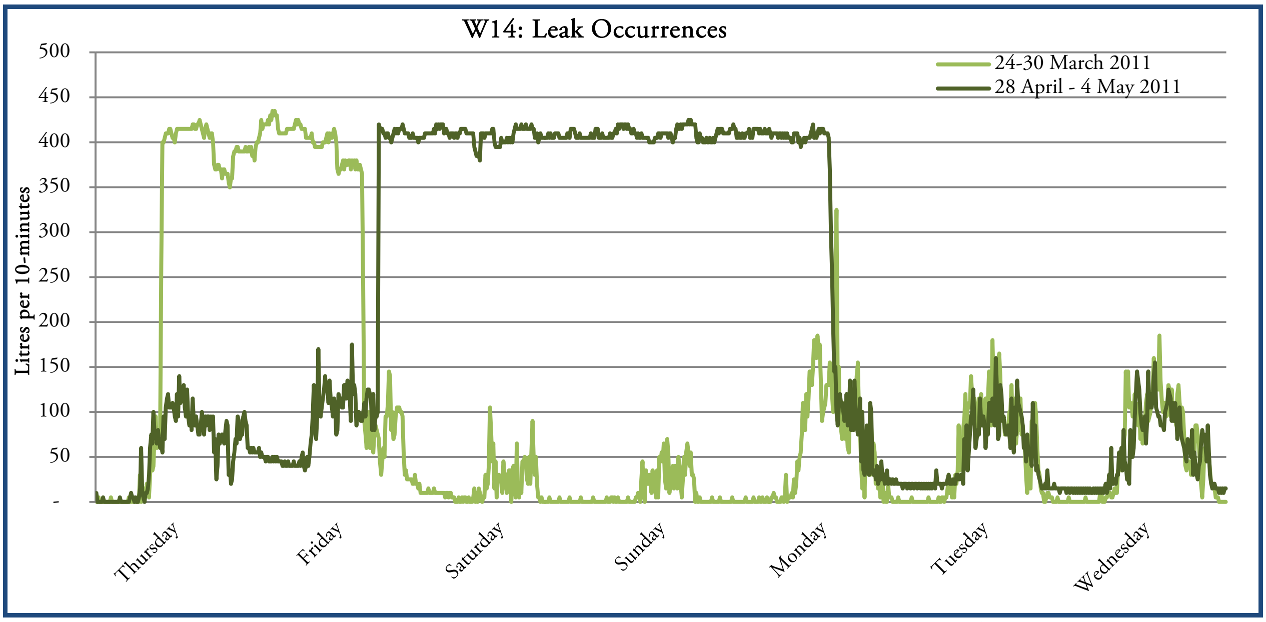

Figure 10.19: Building W14 Leak Occurrence during Monitoring Period

The building data were downloaded a few days after the fixture of the identified leak. The building owners were contacted and questioned to unearth the reasoning, reporting period, and inform them on water lost (~174,000L or 174 m^3), as well as the benefits of leak detection systems.

By looking at Figure 10.19, an irregular pattern can be identified in the period building up to the valve malfunction, thus the entire leak could have possibly been avoided. If the monitoring equipment was connected to a BMS, or other central (live) monitoring system with programmable alarm limits, the leak could probably have been detected much earlier.

In another interesting observation, in W3, a visible increase in water use, outlined by the increase in baseflow, occurred during June 2011. This caused the water use to be increased by around 50 L/10-minutes at all other times of the day.

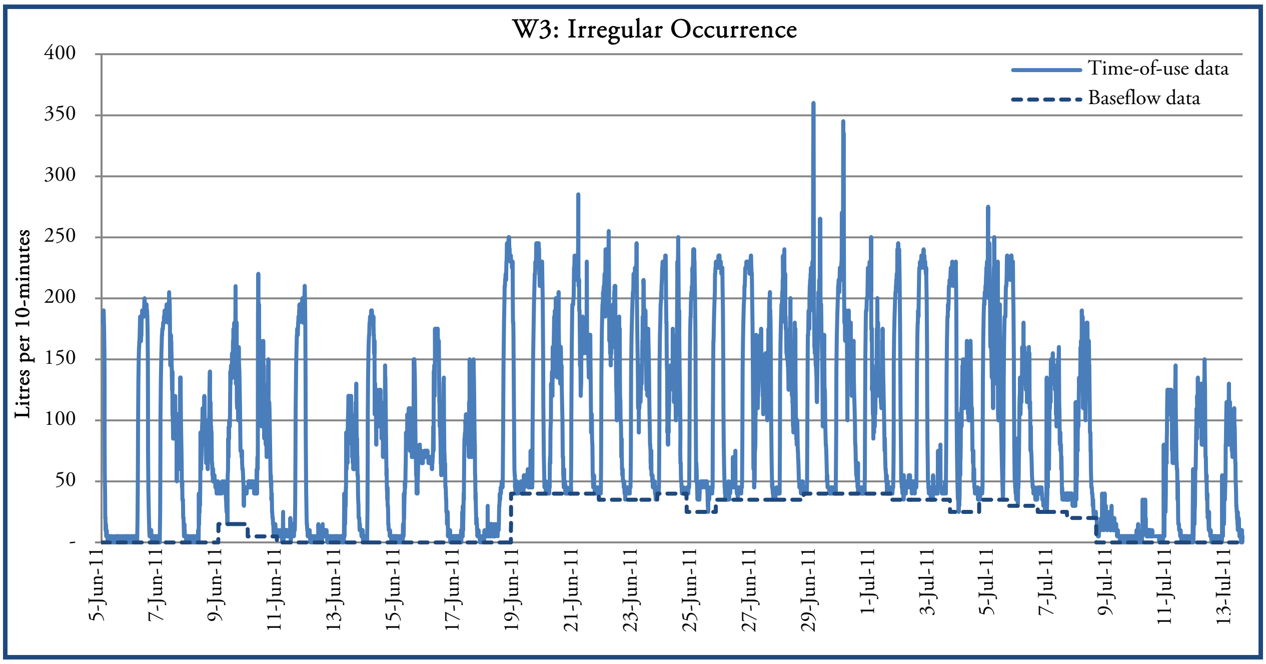

Figure 10.20: Building W3 Irregular Occurrence during Monitoring Period

After discussing this with the building owner, it was identified that the building was washed down prior to the repainting of the exterior; thus the increase in water use. This increase however, is significantly higher than expected and has affected the consumption during all hours of the day, most likely due to the rate at which the storage tanks are refilled in combination with the normal daily usage patterns. Note the return to normal weekly patterns from 9 July 2011.

10.3. SLWA vs. FWA

The effects of actually monitoring water data have been analysed as a comparison against the monthly or bi-monthly billing data gathered under the SLWA phase. In Figure 10.21 to Figure 10.24 the bi-monthly billed data in kL/week from the surveyed buildings (light coloured line) is compared to the monitored data (dark coloured line), also in kL/week, over the one year period. It was expected that the monitored data would entail much more variance, but be closely fitted in terms of quantity to the billed line.

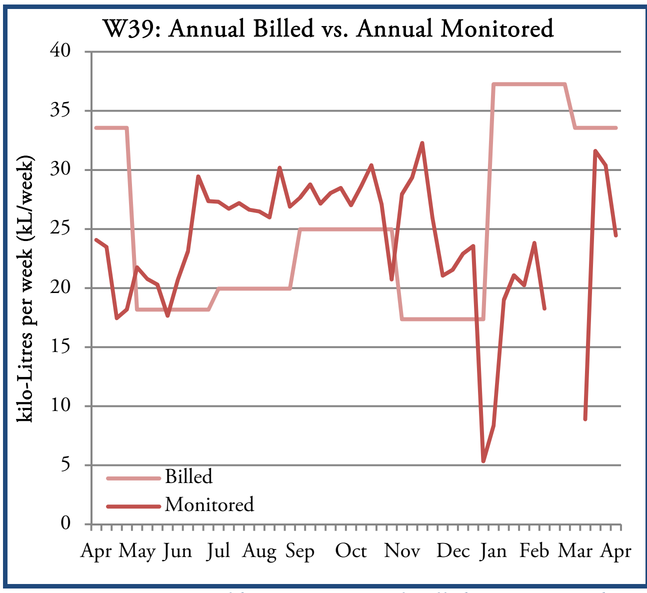

Figure 10.21: Building W39 Annual Billed vs. Monitored

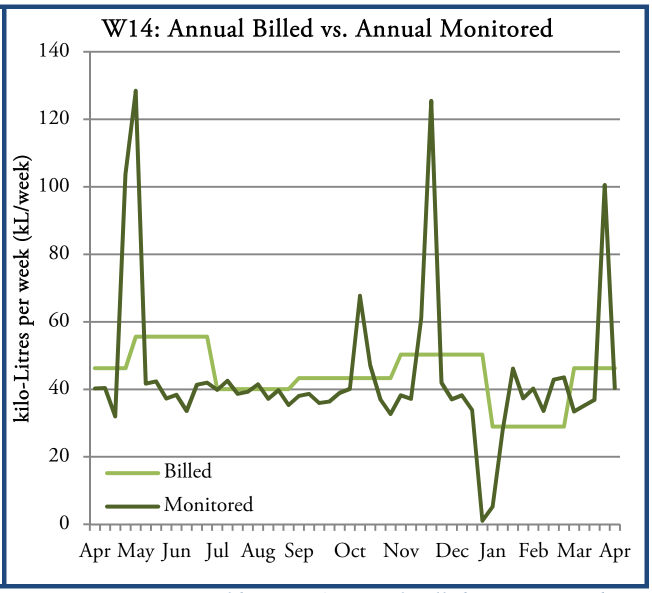

Figure 10.22: Building W14 Annual Billed vs. Monitored

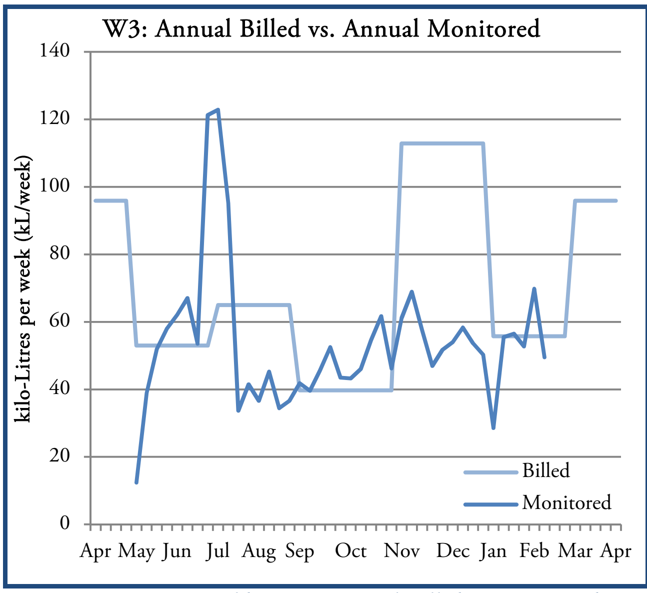

Figure 10.23: Building W3 Annual Billed vs. Monitored

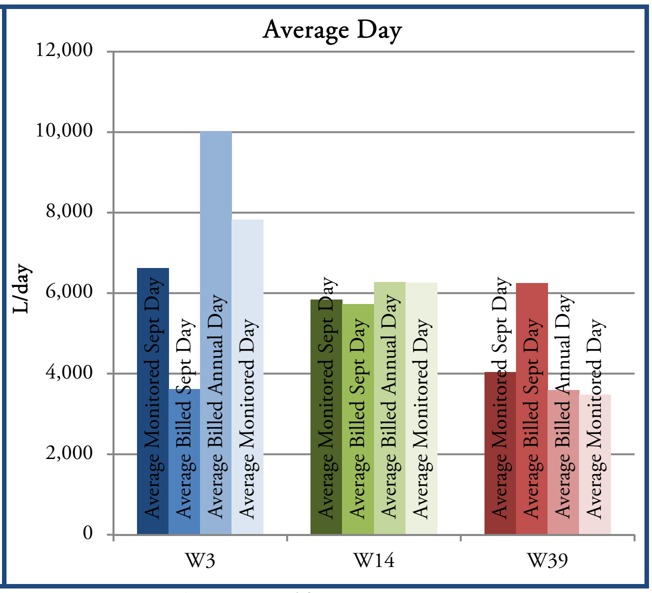

Figure 10.24: FWA Buildings Average Day Comparison

For each building, the weekly monitored data (52 points) shows greater variation as opposed to the bi-monthly billed data (6 points). Although the monitored data overall follows a similar trend to the billed data, it better enables seasonal variance to be examined.

In the billed data, the peak period appears to be in the spring season (September to November), with another clear increase during January/February in all three buildings. In the monitored data the peak is occurring more towards the summer months (December to March), except W39. The summer holiday period is also much more visible, and relatable to the water demand line, as shown in Figure 10.2. Thus it is concluded, from examining these three Wellington office buildings, that water use is marginally higher in summer, and average throughout the remainder of the year.

In Figure 10.24, a comparison of monitored and billed water data of an average September day, and an average (2011) day is shown. Building W14 and W39 display similar levels of consumption, while W3 appears to be less consistent, this is also clear in annual pattern in Figure 10.23.

It should be noted that no severe winter fluctuations have occurred; the water consumption remains relatively constant throughout the rest of the year (other than the irregular/leakage occurrences). The Wellington region total water demand line (as shown in Figure 10.2 previously) has been plotted against the monitored data from the three buildings, below in Figure 10.25.

The total Wellington demand line takes into account all types of users, which may or may not have climate influenced uses, the monitored data should show a more detailed comparison. Below in Figure 10.25, the Wellington water demand line has been plotted against the monitored buildings consumption, to explore if any relationships are occurring.

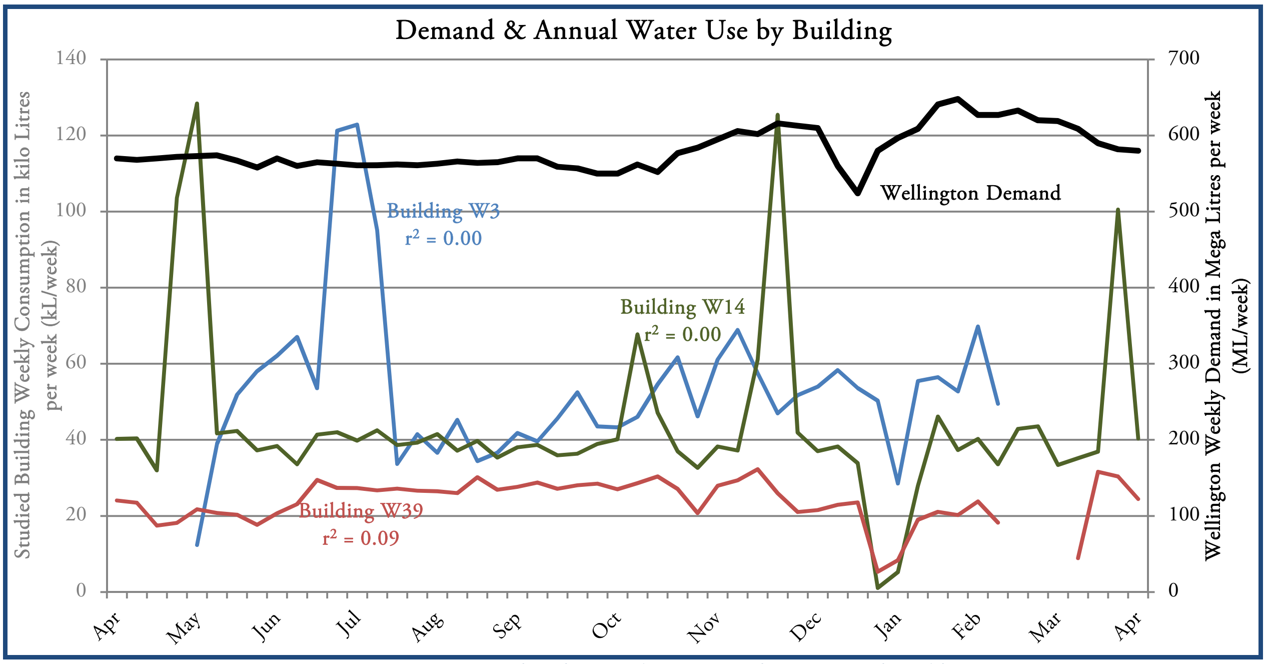

Figure 10.25: Demand and Annual Water Use by Monitored Building

No correlation is occurring, with a coefficient of determination of r^2 = 0.00, r^2 = 0.00, and r^2 = 0.09 for buildings W3, W14, and W39 respectively.

Previously, in Figure 10.4, the demand line was plotted against the coincident ambient temperatures for the same periods. Below the temperature is graphed against the buildings' monitored consumption. A similar, but weaker, relationship visible between ambient (daily) temperatures and monitored water data for Building W39 is occurring, with a coefficient of determination of $r^2 = 0.14$. There is no correlation between temperature and the monitored data for buildings W3 and W14, with coefficients of determination of $r^2 = 0.02$, $r^2 = 0.01$, respectively.

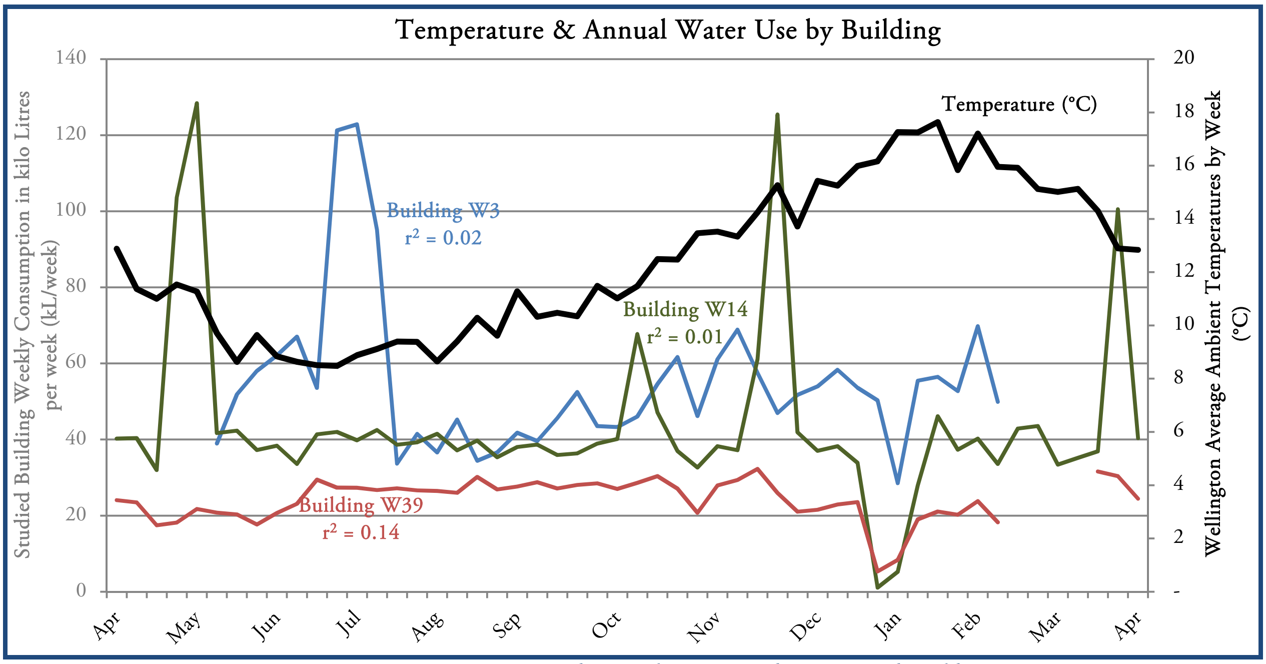

Figure 10.26: Temperature and Annual Water Use by Monitored Building

It was expected that there would be a much stronger relationship between water use and temperature. However, as mentioned earlier none of these three buildings had scope for any major evaporative losses, such as those from water-cooled HVAC systems or irrigation.

10.4. SUMMARY OF DETAILED WATER ANALYSIS

Overall there have been real benefits from undertaking the FWA, as not only have time-of-use flow patterns and loads been able to be identified, but also the benefits of leak detection have been encountered along the way.

From undertaking the daily profile analysis it is concluded that in these three buildings the base water loads are NOT determined by the presence or absence of people, but are driven by the building itself and/or its appliances. However, the daytime load, i.e. that above the baseflow load, is majorly determined by the occupants using the appliances, and thus is controlled by the presence of people.

It was also identified that leak detection may be able to reduce the risk of full malfunctions causing leakage. As in the case of building W14, the leak became subtly present in the days leading up to the appliance malfunction. With appropriate live monitoring, together with pre-set alarm limits, this leak could have been avoided.

This study has demonstrated the importance of undertaking water monitoring at the more detailed level, allowing daily profiles, weekly, monthly, annual, and seasonal analysis to be monitored, and leak detection. However, as the sample size is so small ($n = 3$), it should not be used as a representation for all New Zealand office buildings, rather as a guide based on the buildings described in this chapter.

11. BENCHMARK ANALYSIS

A Water Use Index (WUI) is the normalised consumption for an individual building. A benchmark is a calculated model representative of a group of buildings which share similarities (for example in occupancy type and/or location). This benchmark can be used as a target or Key Performance Indicator (KPI) for businesses, legislation, etc. This chapter outlines the development of WUIs for the collected dataset of 93 commercial office buildings studied, as a contribution to the establishment of benchmarks for water performance and efficiency.

The primary purpose of this benchmarking analysis is to determine whether the available data and water use models established can be used to develop an index of performance benchmarks for the comparison of water use between similar commercial office buildings within Auckland and Wellington.

As *SWC* (2007) state: "benchmark water consumption figures are a useful way to find out how water efficient your building is compared to others in the same industry. A benchmark helps you assess where there is room for improvement and if you can reduce your water use with cost effective measures. A benchmark can also confirm that your building is operating efficiently."

The collected data were entered manually into a spreadsheet to aid in visual and statistical analysis. The analysis firstly required understanding what (statistically) drives water use. For this, the normalisation process utilised a correlation analysis (refer Chapter 8.1). Then using another statistical technique, ANOVA, a category separation analysis took place, followed by the establishment of benchmarks.

11.1. NORMALITY OF DATASET

The normality (i.e. the data are normally distributed) of the outcome (water) variable dataset must first be tested to ensure the correct analysis methods can be applied. Both a histogram and a normal probability plot have been used as graphical techniques for assessing whether or not the dataset is approximately normally distributed. The histogram is used to demonstrate the range of normalised annual average water use. It is important to view this visually to inspect appropriate averages, as this gives an indication of the spread of data between best and worst case water users. If the dataset lacks normality in distribution, i.e. is binomial, it will need to be analysed differently.

The histogram (Figure 11.1) shows that the majority of the annual water consumptions are falling between 4,000 m^3/year and 14,000 m^3/year. An estimated visual midpoint would be around 10,000 m^3/year, with fewer buildings at either end of the scale. The normal curvature demonstrates a less than perfect 'normal' distribution; while a calculated skew of 1.16 confirms that the data is skewed to the positive (right) side of the distribution.

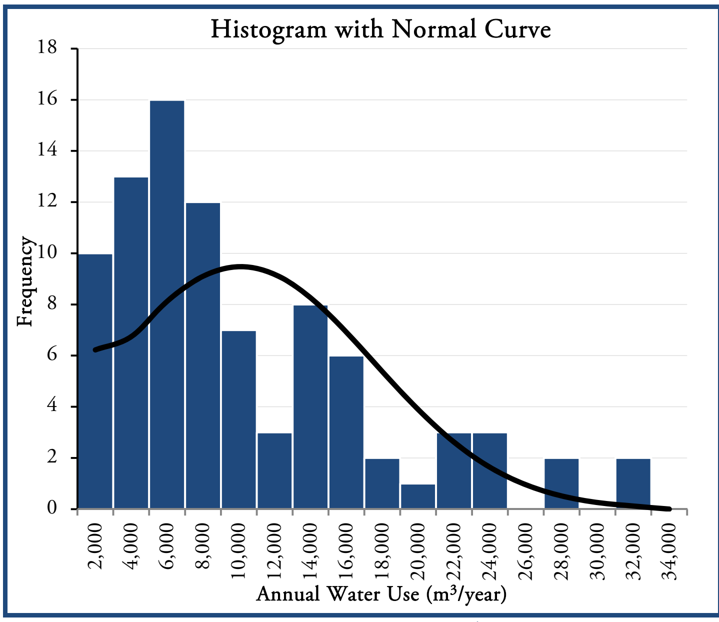

Figure 11.1: Histogram[1]

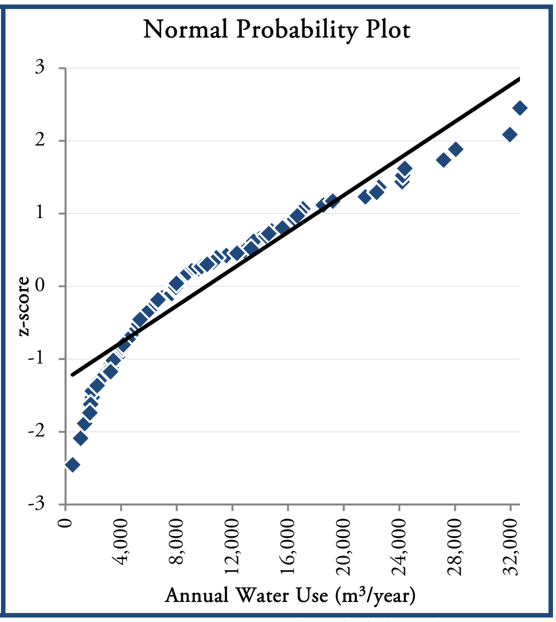

Figure 11.2: Normal Probability Plot

The normal probability plot (Figure 11.2) shows a strong linear pattern, but there are deviations from the line fit to the points on the probability plot at both tail ends. In either case, as the dataset is large in size (n >30), the CLT can be applied to aid in providing normality for the following analyses. The normal distribution appears to be a good model for these data.

Below are some basic descriptive statistics from the normalised dataset. Values are in m^3/year, where appropriate.

Univariate Statistics Annual Water Consumption (m^3/year)			
Count	88	1st Percentile	1,025
Average	10,116	25th Percentile	4,924
Median	7,953	50th Percentile	7,953
Mode	N/A	75th Percentile	14,068
Minimum	520	99th Percentile	32,043
Maximum	32,671	Interquartile Range	9,144
Range	32,151	t statistic (mean = 0)	12.85
Standard Deviation	7,386	t statistic p-value	0.00
Variance	54,548,087	lower 95% c.i.	8,551
Standard Error	787	upper 95% c.i.	11,680
Skewness	1.16	sign test p-value	0.00
Kurtosis	0.86	Wilcoxon p-value	0.00

Table 11.1: Univariate Statistics for Total Dataset

The calculated median water consumption intensity across the entire dataset is 7,953 m^3/year, which is relatively close to the visually estimated midpoint of 10,000m^3/year using the histogram. The majority of buildings (95.4%) falling within two standard deviations of the mean. The Kurtosis is a measure of the 'heaviness of the tails in the distribution' (Berk et al, 2010). The Kurtosis of 0.86 indicates a higher number of

[1] In Figure 11.1 above, only 88 counts have been used – the reason being that in some cases multiple buildings share the same water meter, therefore only the total values can be used (unless sub-metering is installed to accurately divide their water use).

extreme values than expected in a normal distribution. It is concluded that the dataset is suitable for simple linear regression.

11.2. WATER USE INDEX MODELS

For buildings to be compared accurately, a common driver must be used to normalise the water use, which will be relevant to the types of buildings, and any other influencing factors. Each building will be given a WUI (based on the normalisation process), which then contributes towards the development of overall benchmarks for the dataset(s).

As discussed in Chapter 3.3, it was found that water consumption per NLA and FTE occupancy are the most commonly used normalisation factors. However, all possible demand drivers identified within this study were tested for their correlation strength and significance. To aid in this process, the key variables selected were split into categories, of building influenced, people influenced, and equipment influenced variables, such as those outlined in Table 11.2 below.

Building Influenced	People Influenced	Equipment Influenced
NLA (m^2)	FTE Occupants	HVAC Mechanism
Storeys	Hours of Occupancy	Domestic Amenities
Footprint (m^2)	Tenancy Types	Hours of Operation
Building Age		

Table 11.2: Predictor Variables grouped by Type

To assess the relationship between water consumption and the possible drivers of water use, it is necessary to consider the strength of these relationships and the probabilities of each relationship occurring by chance. This is called a simple linear regression (or correlation) analysis, which is then followed by a multiple regression using numerous variables to predict water consumption, refer Chapter 8 for more detail.

11.2.1. SIMPLE LINEAR REGRESSION

First the building variables were tested using the multivariate descriptive statistics function in *MS Excel* add-in *StatPlus*. NLA came out as the strongest correlation to water consumption, with the lowest (best) significance value. Next the people variables were tested, where FTE occupants came out on top. Then the equipment variables were tested, where the number of domestic amenities was the strongest driver. The coefficient of demand (r^2) and significance values (*p-value*) are shown in Table 11.3 below.

Building Variables			People Variables			Equipment Variables		
	r^2	p		r^2	p		r^2	p
NLA (m^2)	0.58	0.00	FTE Occupants	0.50	0.00	Domestic Amenities	0.53	0.00
Storeys	0.51	0.00	Occupant Density	0.02	0.16	HVAC mechanism	0.15	0.00
Footprint (m^2)	0.12	0.00	Hours of Occupancy	0.00	0.63	Hours of Operation	0.06	0.03
Building Age	0.02	0.17						

Table 11.3: Regression Analysis of Specific Demand Drivers for Water Use

Finally, the strongest, most significant output from each of the above three tests were tested visually against one another. These are shown in the correlation matrix in Figure 11.3 below. The correlation matrix is made up of: the upper-half showing visual relationships (scatter-plots); and the lower-half showing numeric relationships (coefficients of determination, and *p*-values). This is a quick visual method of identifying any obvious patterns, relationships, or outliers (if any).

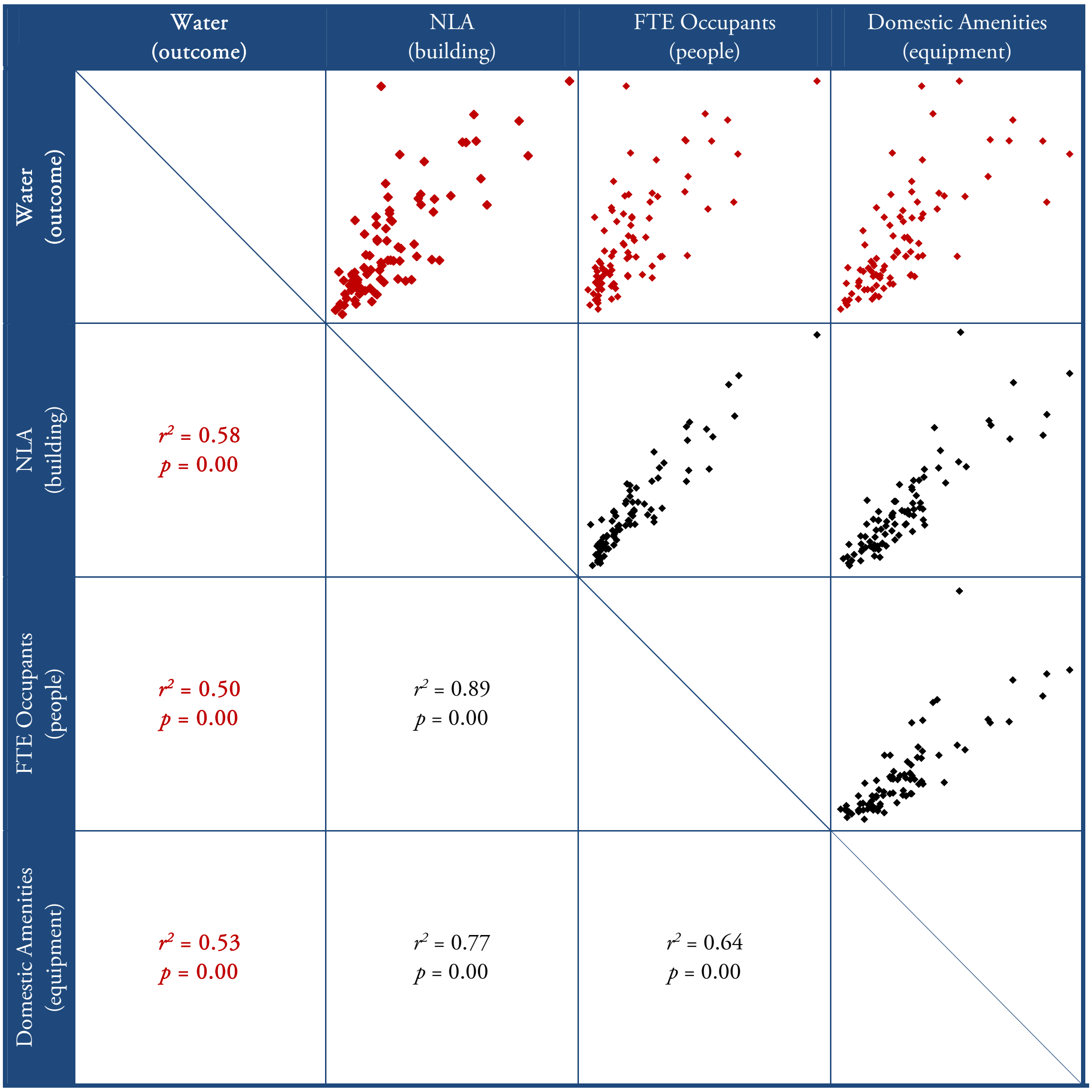

Figure 11.3: Correlation Matrix

This shows that the NLA appears to be the most (visually and numerically) correlated, while all of these characteristics present some correlation with one another, hence the r^2 >0.50 in all cases. As FTE occupants is a function of floor area, as is domestic amenities with both floor area and FTE occupants.

Figure 11.4 below is a scatter-plot of all buildings surveyed, in both Auckland and Wellington, showing the regression line between annual water consumption and NLA. For the regression line Equation 11.1: $y = a + bx$, where a is the total annual water consumption where the driver is zero, and b is the increase in total annual water consumption per one value increase (or decrease) in the driver.

This equates to $y = 0.7868x + 1833.9$. This means that with every increase in x (floor area) of 1.00 m^2, y (water consumption) can be expected to increase by 0.79 m^3/year, with a base use of 1,834 m^3/year.

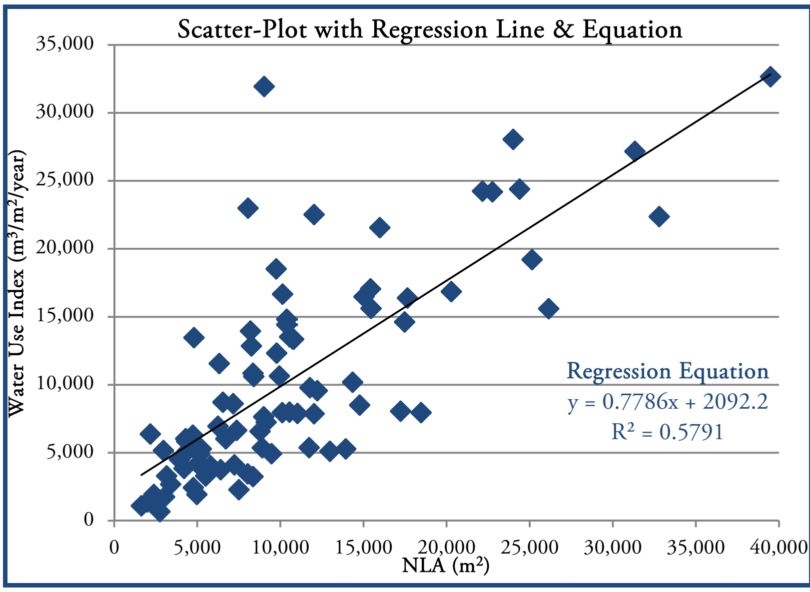

Figure 11.4: Most Statistically Appropriate Demand Driver Scatter-Plot

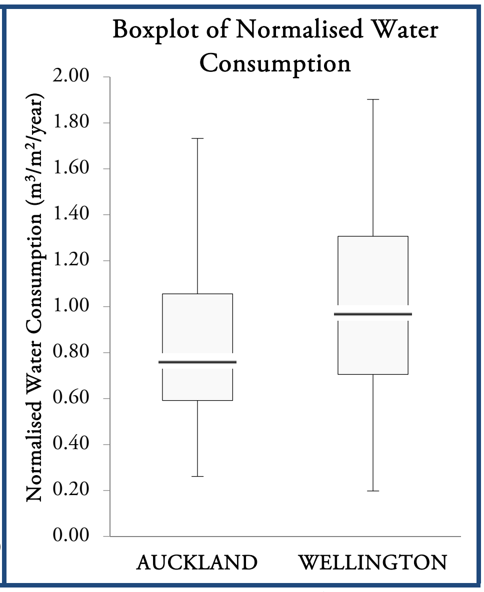

Figure 11.5: Boxplot

The box-plots in Figure 11.5 demonstrate the range of normalised water use in the sampled buildings, showing Auckland to be lower in almost all aspects, including Upper Quartile (UQ), Lower Quartile (LQ), Inter-Quartile Range (IQR), Maximum, and Median variables; while Wellington's Minimum value is slightly lower than Auckland's Minimum value.

Before the WUI model can be confirmed, the dataset will undergo a multiple regression analysis, where more than one (i.e. a group of) predictor variables are used to predict the value of the water consumption (Berenson et al, 2010).

11.2.2. MULTIPLE REGRESSION

This technique analyses multiple predictor variables at once, to determine if there is a group of predictors as opposed to a single predictor variable. This very much follows the same format as the simple linear regression beginning with the correlation analysis, and ending with the regression equation.

This analysis was undertaken using *MS Excel* add-in *Data Analysis, Regression* function. This took the form of two steps. First, the strongest predictor variables from the grouped simple linear regression were tested; these were NLA, FTE occupants, and number of domestic amenities. Table 11.4 below demonstrates the output from this test.

	Coefficient	Standard Error	*t* statistic	*p*-value	Lower 95%	Upper 95%
Intercept	1,163	1,076	1.08	0.28	-978	3,304
NLA	0.63	0.23	2.75	0.01	0.17	1.09
FTE Occupants	-0.22	2.91	0.08	0.94	-6.00	5.56
Domestic Amenities	11.03	8.08	1.36	0.18	-5.05	27.11

Table 11.4: Multiple Regression Output

The next step involves analysing the *p*-values of these three predictor variables, and removing anything greater than 0.05 ($p>0.05$), thus cleaning the data from any insignificant detail. Therefore, the final model only includes one variable, NLA, which mimics the simple linear regression analysis result. This is further outlined in Table 11.5 below.

	Coefficient	Standard Error	*t* statistic	*p*-value	Lower 95%	Upper 95%
Intercept	1,833.94	833.76	2.08	0.04	76.48	3,591.40
NLA	0.79	0.07	11.47	0.00	0.65	0.92

Table 11.5: Regression Model

The coefficient is used to estimate the water consumption by using Equation 11.1, below. The NLA standard error is low (0.07), which is the best outcome for the model (Berenson et al, 2010). Thus the normalisation measure for this study (for existing buildings) will be NLA, with the WUI measured as cubic metres of water per square metre of NLA per year (m^3/m^2/year).

$$y = a + bx$$
$$Water\ Use = 1{,}833.94 + (0.79\ \times NLA)$$

Equation 11.1: Regression Equation

Again as in Figure 11.4, the prediction is that with every increase of one in NLA (or $1m^2$), the water consumption will increase by 0.79 m^3/year, with a base use of 1,834 m^3/year.

Where evidence of irregular data was found, and where the data were used for determining the regional benchmark calculation, any outliers identified (both visually and numerically) were excluded, but not discounted. As five years' worth of historical water meter readings were retrieved, annual analysis was still made possible by using the remaining, assumed to be accurate, years from the service providers. However only those outliers classed as 'Extreme Outliers[2]' were excluded.

Visually Identified	Value m^3/m^2/year	Moderate Outlier >UQ + 1.5 IQR <LQ – 1.5 IQR	Extreme Outlier >UQ + 3.0 IQR <LQ – 3.0 IQR	Removal?
Building W4	3.54	> 2.22 < -0.29	> 3.16 < -1.23	Yes
Building W10	2.81			No
Building W44	2.93			No

Table 11.6: Outlier identification[3]

After the extreme outlier removal, the NLA has a coefficient of determination of r^2 = 0.71 with annual water consumption. This is a strong relationship, and should be taken as the most statistically appropriate driver for water use in this instance.

However, when considering these relationships with pragmatism in mind, NLA is also assumed to be the most sensible normalisation measure for this study – as it is a measure that is known for most buildings. FTE occupant numbers, as collected from this study, have been found to be very inconsistent, and at times difficult to calculate accurately – even for the managers of each tenancy. The number of storeys cannot accurately represent the building scale, i.e. tall/skinny vs. short/wide buildings. For other key variables outlined, the relationship between NLA and these variables is expected to be high, as FTE occupant number is a function of NLA, as is the number of domestic amenities and so on.

[2] Refer Equation 8.3.

[3] As sourced from Berk et al (2010).

11.2.3. ANALYSIS OF VARIANCE (ANOVA)

'While the estimated statistical models of water use can be used to derive benchmarks for average levels of water use, it is helpful to examine the variability of water use directly from the data' (Dziegielewski et al, 2000). For this reason, another statistical technique called ANOVA has been applied, which involved determining whether the overall sample should be separated for any reason, for example by location, presence (or absence) of cooling, size, etc. Refer to Chapter 8.1 for more details on ANOVA.

The datasets were separated and tested for any statistically significant differences which could mean that two (or more) resultant benchmarks would stand independent of one another. This tests a null hypothesis (H_0), and an alternate hypothesis (H_A):

$$H_0: \mu_1 - \mu_2 = 0 \text{ (i.e. the means (μ) come from the same population)}$$

Equation 11.2: Null Hypothesis

$$H_A: \mu_1 - \mu_2 \neq 0 \text{ (i.e. the means (μ) come from a different population)}$$

Equation 11.3: Alternate Hypothesis

The strength or the significance is represented by the probability value, or *p*-value, where $p<0.05$ demonstrates that a significant difference is occurring (reject the null hypothesis (H_0) and accept the alternate hypothesis (H_A)), which in this case means that the two datasets come from two different populations. Table 11.7 below shows the significance of a specific separation characteristic, and the best identified split for each separation.

Variable	Median Benchmark		*p*-value (significance)
Size	<13,000m^2 0.90m^3/m^2/year	>13,000m^2 0.83m^3/m^2/year	0.03
HVAC	Water Cooled 1.05m^3/m^2/year	non-Water Cooled 0.79m^3/m^2/year	0.74
HVAC	Mechanical 0.90m^3/m^2/year	Natural 0.73m^3/m^2/year	0.74
Location	Auckland 0.76m^3/m^2/year	Wellington 1.03m^3/m^2/year	0.01
Location	CBD 0.90m^3/m^2/year	non-CBD 0.58m^3/m^2/year	0.03
Building Age	Pre-1980 1.13m^3/m^2/year	Post-1980 0.89m^3/m^2/year	0.21

Table 11.7: Statistical Significance of Benchmark Separation

The study looked at size separation, with the strongest separation being found by splitting the cumulative floor area in half (above and below 13,000m^2), but as the median values are not very dissimilar, the significance still does not warrant any benchmark separation. Building age demonstrated a large difference in the proposed medians (between pre- and post-1980). However, again the significance did not necessitate benchmark separation.

It has been suggested that the cooling systems are responsible for a large proportion of the total annual water bill (SWC, 2002). Analysis of the sample comparing water- and non-water-cooled buildings, as well as mechanically- and naturally- ventilated, found no statistical significance in either of the two tests.

Location (Auckland or Wellington) demonstrated a statistically significant reason for benchmark separation, at the 95% confidence level. Therefore, it is concluded that separation by geographic location (Auckland vs.

Wellington) is the best suited method of benchmark separation. CBD vs. non-CBD also showed some significance, but not enough to warrant separation.

This process was repeated for the Auckland and Wellington datasets separately with the above hypothesis tests, however no further conclusive separation was accepted.

As a result of the ANOVA, it is assumed that the established benchmarks may be used for all sizes of buildings, all ages of buildings, with all HVAC system types (or no types), and whether located within the CBD or not. The following benchmarking analysis will utilise these results and analyse Auckland and Wellington as two separate datasets.

The distribution of the two datasets has been charted below. This is a method of assessing the distribution and variance of the results, and visualising this difference in the two datasets side-by-side, for median and standard deviations (showing one and two standard deviations from the median).

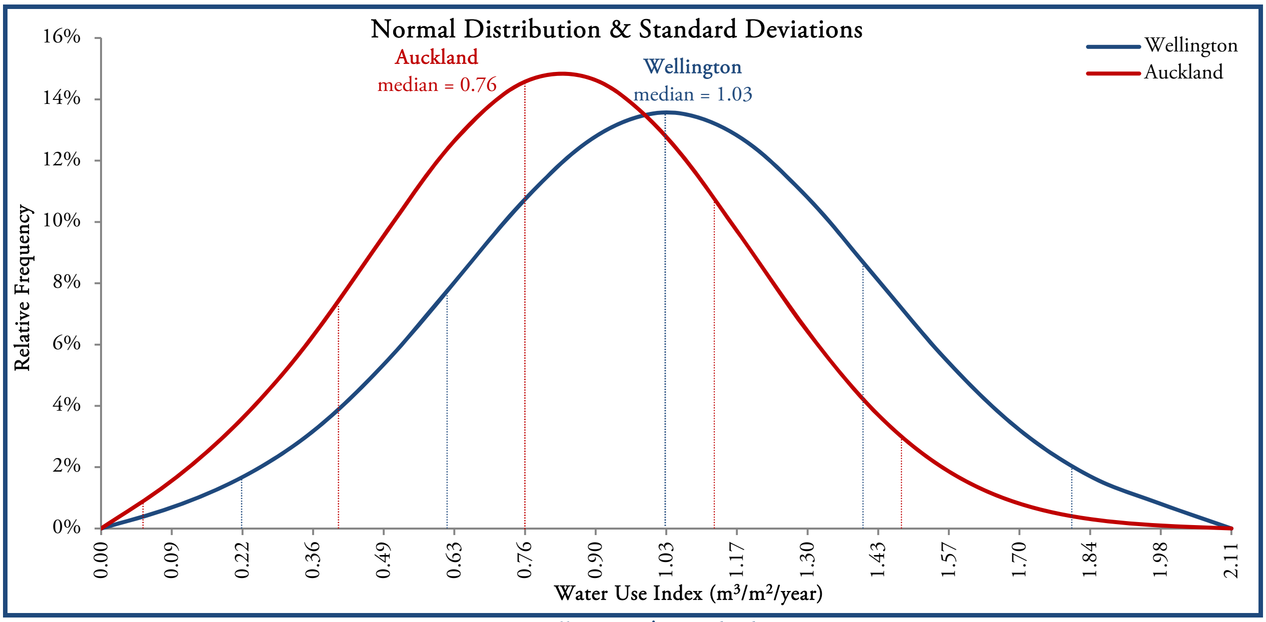

Figure 11.6: Bell-Curve & Standard Deviations

Figure 11.6 demonstrates the standard normal distribution of both regions WUIs; showing that 95.4% of the time the WUI will fall within ±39% (or 2 standard deviations) of the 0.76m^3/m^2/year median benchmark if in Auckland, or ±47% (or 2 standard deviations) of the 1.03m^3/m^2/year median benchmark if in Wellington. The shape of the distributions shows a longer positive tail (towards the right side of the chart), for both datasets, however is more visible in the Auckland distribution line than the Wellington one.

After examining the Wellington top 5% of buildings (outliers), the reasons still appear unexplained. All these buildings (W4, W10, and W44) utilise non-water cooled HVAC systems, while also having no evidence of visible leaks or cyclic flushing urinals. Building W4 has been excluded since having been identified and calculated as an extreme outlier. However, buildings W10 and W44 also appear much higher than any other building in the dataset, and as they were each very close to being classified as an extreme outlier, they have also been excluded from further benchmark calculations. They will be brought back into the analysis AFTER the benchmarks have been calculated.

Figure 11.7 below shows the cumulative distribution of the two datasets, with the [three] outliers plotted for the Wellington dataset. From simply looking at this, Wellington's normalised water use appears to be consistently higher than Auckland; especially at the 95th percentile, where the outlier buildings are showing abnormally higher water use than the overall sample.

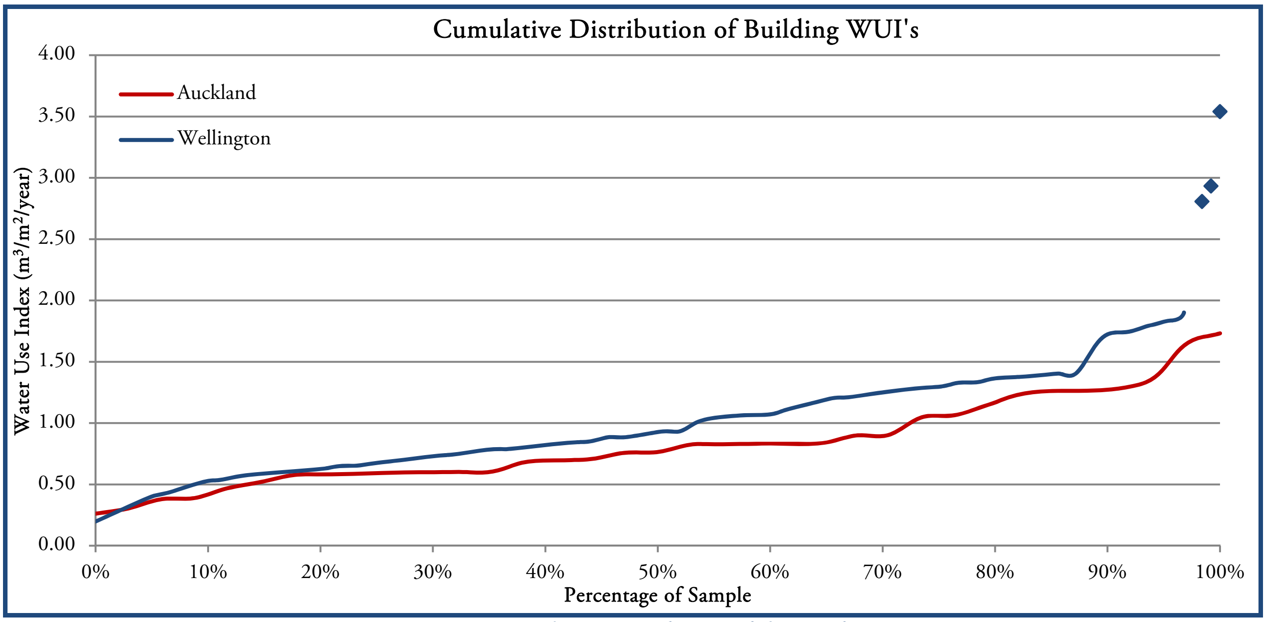

Figure 11.7: Cumulative Distribution of the two datasets

In terms of the overall difference, in spite of the suggestion that benchmarks would be influenced by climatic differences by region (Bloomfield et al, 2010), it appears that the opposite effect is occurring here (also shown under the correlation analysis), with Auckland being somewhat warmer and more humid than Wellington, but Wellington is the higher water user.

Climate Variable	Auckland		Wellington	
	2010	2011	2010	2011
Temperature (dry-bulb)	16 °C	16 °C	14 °C	14 °C
Temperature (wet-bulb)	14 °C	14 °C	12 °C	12 °C
Relative Humidity	85 %	84 %	80 %	79 %
Absolute Humidity	15.0 hPa	15 hPa	12.5 hPa	12.4 hPa
Annual Precipitation	959 mm	1390 mm	1057 mm	981 mm

Table 11.8: 2010 & 2011 Climate Data (Source: NIWA, 2012)

In Chapter 9.4, where the level of efficiency in domestic amenities and HVAC equipment was considered, Auckland is more efficient in terms of toilets, urinals, and faucets, and in general has newer HVAC systems.

After discussing this significant difference between Auckland's and Wellington's water use with a building owner with portfolios in both cities, they stated that they effectively pay four times as much for water in Auckland than they do in Wellington. So it makes economic sense for them to put water efficient measures in the place where they can achieve the most financial benefit.

However, as cited in Chapter 9.6, Auckland pay ~3% less for water than Wellington overall. But Auckland have the incentive and opportunity to reduce their wastewater portion, on top of just ingoing water reduction; whereas Wellington's wastewater charges are annual rates-based.

To explore this, Table 11.9 shows the results of considering a building identical to building W45 in both Auckland and Wellington, and assuming that 60% of the 327 FTE occupants are male (Stewart, 1995), who utilise the urinals twice per day, 249 days of the year. The building currently has thirteen (13) multi-user trough urinals flushing (9L) every 20-minutes on a cyclic automation. These urinals will have the flushing mechanism upgraded to a Zurn Waterguard flushing system (microwave sensor activation). This changes the flushing rate to user activated as opposed to time-activated – nothing else changes. The cost of this installation is NZD$4,407 and as Table 11.9 shows, the payback period is less than six months in Auckland, but over one year in Wellington.

Location	Cost of Installation[4]	Savings (m^3/year)	Savings (NZD$/year)	Payback Period (years)
Auckland	NZD$4,407	2,195	9,532	0.46
Wellington			3,765	1.17

Table 11.9: Water Efficiency Implementation Cost-Benefit Analysis

Therefore it is hypothesised that due to the lack of visible (in terms of pricing) incentives to save water in Wellington, their water use is higher. On the other hand, Auckland see the real-time opportunity to reduce their water use, behavioural influences and awareness are higher in Auckland, driving water conservation practices.

Further discussions in the industry suggest that due to the recent (1994) drought, and the introduction of both universal metering and volumetric wastewater charging in Auckland, Auckland's regional water demand has dropped (Auckland Council, 2010). This is demonstrated in Figure 11.8 below, from the *2011 Auckland Regional Water Demand Management Plan*. The blue line represents the total demand in kL/day, and the red line represents the gross per capita demand, in L/person/day – thus allowing for population growth.

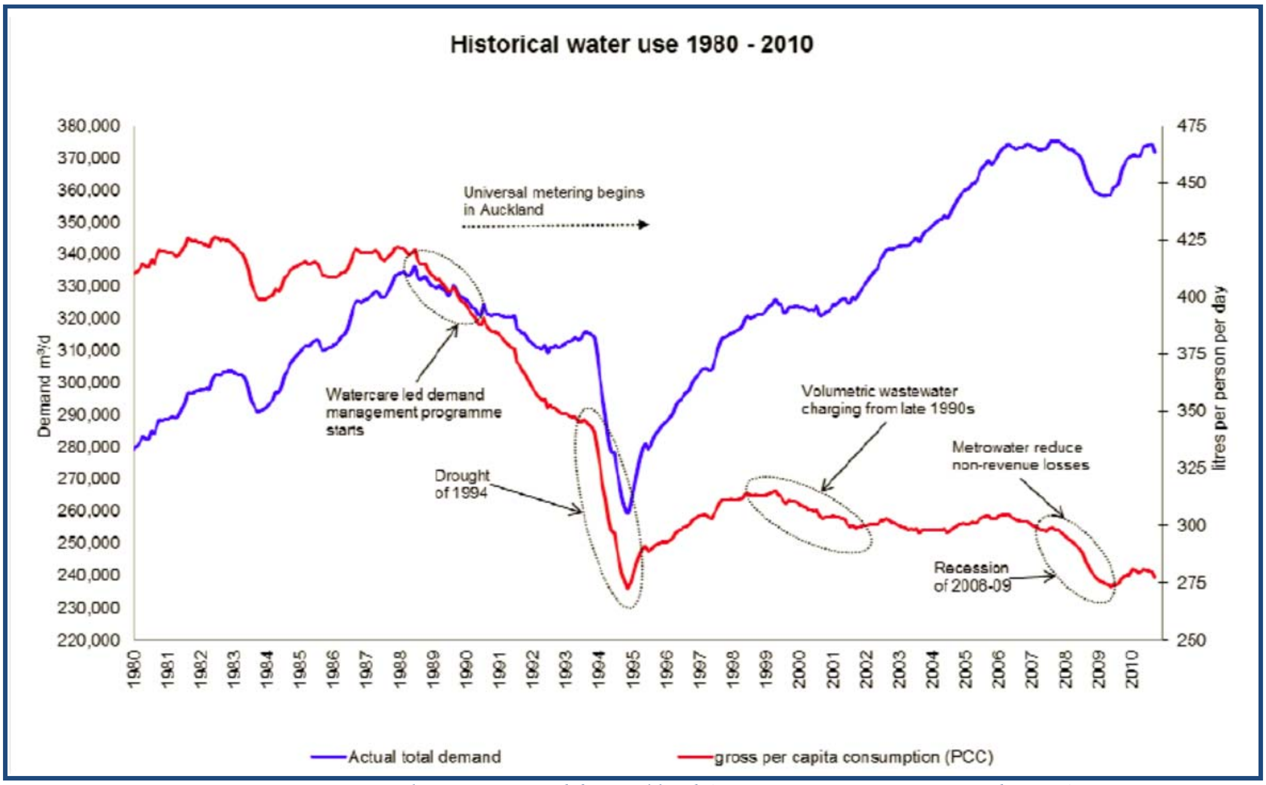

Figure 11.8: Historical Water Demand for Auckland (Source: Watercare Services Ltd, 2010)

[4] Unit Price NZD$209; source: Joseph, 2011. Installation Price NZD$130/unit; source: Smith, 2011.

A similar reduction in demand has been described in Tauranga and Nelson, since the introduction of residential volumetric charging (Jaduram, 2009; NCC, 2012). It is also assumed that this behavioural change would be carried through to the workplace, thus aiding in reducing overall water demand. In addition there is a higher focus and awareness from building owners and managers on reducing their water consumption, and therefore costs.

Without volumetric charging (both for residential customers and commercial tenancies – i.e. end-users) the end-user cannot fully appreciate the cost of water. One method is for the building manager to install sub-meters for each tenancy, or divide the water invoice by proportion of tenanted NLA. In either case, the tenants can begin to appreciate the cost of water, through periodic charging based on those readings, i.e. cost recovery.

However, without visual tariff incentives in Wellington, the building managers lack the awareness and opportunity to implement cost-effective water efficient measures. A recent British study showed consumers lack the knowledge and action related information, both on their water consumption and environmental issues, which was described as the [lack of] inspiration behind people making water efficient changes (Doron et al, 2011).

Therefore it is hypothesised that the reason for the difference in behaviour is primarily due to volumetric charging for both water and wastewater – promoting an understanding of their consumption, the experience of water shortages first-hand, and tariff incentives in Auckland, which has prompted this benchmarking separation, rather than climate influenced benchmarking.

Now that the category separation has been concluded, with Wellington and Auckland providing significant reason for separation, the two datasets can be translated into performance benchmarks.

11.3. MARKET-BASED BENCHMARKING

For a benchmark to be meaningful and accurate, it must take into account the whole population, the rating method needs to be simple, and the ratings need to be easily obtainable. For this reason, a market-based benchmarking approach has been selected (see Chapter 8.2). Three tiers of performance have been used; these tiers are 'Best Case', 'Typical', and 'Excessive Use'.

As shown in Table 11.10, the 'Best Case' benchmarks were calculated using the twenty-fifth percentile of the dataset, or the LQ, of $0.57m^3/m^2$/year in Auckland, and $0.73m^3/m^2$/year in Wellington. The 'Typical' benchmark uses the fiftieth percentile, or median value, of $0.76m^3/m^2$/year in Auckland, and $1.03m^3/m^2$/year in Wellington. The 'Excessive Use' consumption benchmark uses the seventy-fifth percentile, or the UQ, of $0.97m^3/m^2$/year in Auckland, and $1.33m^3/m^2$/year in Wellington.

In relation to Bannister et al's (2005) rules outlined in Chapter 5.1, this market-based approach has used the median value to form the 'Typical' benchmark. It has encompassed 75% of the sample population without change (where 75% of buildings would achieve a WUI of less than the 'Excessive Use' benchmark). The bands are not linear by value, but by percentage of sample. And finally, the 'Best Case' benchmark is represented by 25% of the sample, a level of water use which is obtainable with effort.

This approach enables comparison with other similar studies and their benchmarks, while still providing a simple method for industry uptake.

AUCKLAND (m^3/m^2/year)	MARKET-BASED BENCHMARK (percentile)	WELLINGTON (m^3/m^2/year)
0.57	Best Case (25%)	0.73
0.76	Typical (50%)	1.03
0.97	Excessive Use (75%)	1.33

Table 11.10: Proposed Consumption Benchmarks

This suggests that a water efficient office building would be consuming less than 0.57m^3/m^2/year in Auckland, or 0.73m^3/m^2/year in Wellington. It is also interesting to note that the 'Best Case' benchmark in Wellington is very close (within 4%) to the 'Typical' benchmark for Auckland.

As these benchmarks become established (if implemented) in the industry, they should be reviewed periodically to ensure they encompass the current population. It should be noted that if an efficiency-based approach were to be used, the fiftieth percentile from the market-based approach would only achieve one out of five – the lowest rated value. This is explained in greater detail in Chapter 11.4 below.

11.4. EFFICIENCY-BASED BENCHMARKING

Efficiency-based benchmarks follow the same principles as the market-based benchmarks, where their bands are determined by percentiles. Efficiency-based benchmarks are included into some building sustainability rating tools – such as *NABERS* (Quinn et al, 2006). Refer to Chapter 5.1 for a more detailed discussion.

These efficiency-based benchmarks do not require the same level of attainability, but still need to be portrayed with simplicity. The benchmarks given in Table 11.11 and Figure 11.9 have also applied Bannister et al's (2005) rules as follows. 80% of the sample population has not been encompassed (as it only covers the better 50% of the population). The median value has been used to determine the Typical value. The best score is represented by only 1% of the sample population (and is therefore obtainable but significant effort should be made). And the bands are spread equally apart (by value). This has also caused an anomaly, where the Wellington values are generally larger than the Auckland values, except the highest rating (5), where the Wellington value is lower than the Auckland value. This is due to the wider distribution in the Wellington dataset. This is best visualised using the line chart below, where the shaded region shows the buildings not achieving any rating (Figure 11.9).

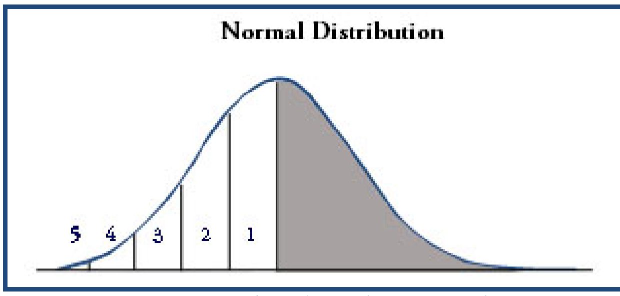

Figure 11.9: Benchmark Levels on Normal Curve

AUCKLAND (m^3/m^2/year)	EFFICIENCY-BASED BENCHMARK %	Rank/5	%	WELLINGTON (m^3/m^2/year)
0.76	50%	1	50%	1.03
0.64	37%	2	33%	0.81
0.51	14%	3	12%	0.60
0.39	8%	4	3%	0.40
0.26	1%	5	1%	0.20

Table 11.11: Proposed Water Efficiency Rating Bands

The percent rank in the samples differ, this is because the distribution of the two samples differs.

The benefit of undertaking this method of benchmarking is it only rates buildings in which their managers are actively involved in water efficiency efforts, or which have effective water conservation systems in place. It will not rate inefficient buildings, i.e. if a building is to be rated, it must be performing better than average.

The disadvantage with this system is it automatically excludes [the water inefficient] 50% of the population, which reduces the market uptake and success; but it could drive more innovative measures and larger savings if implemented. This index would also need to be updated, as for the market-based benchmarks, periodically to ensure ratings are accurate for the current population.

For the reasons surrounding the percentage of population exclusion, and added complexity and understandability which could potentially influence a negative market impact, in the remaining analyses and discussion only the market-based benchmarks will be used and commented on.

11.5. TRANSLATION

Using these benchmarking results, together with the detailed water analysis data, a normalised comparison can now be formulated. The buildings outlined under the detailed water analysis are shown using the normalisation process, and market-based benchmarking.

Building ID	Water Use (m^3/year)	NLA (m^2)	WUI (m^3/m^2/year)	Rating	Percentile (%)
W3	4,788	4.141	0.93	Typical	44
W14	4,274	5,110	0.84	Typical	35
W39	6,296	4,737	1.33	Excessive Use	74

Table 11.12: Monitored Building Ratings

In reference to Chapter 10, if the water use is now normalised, the buildings can then be compared. The WUIs for each of the individual buildings are shown in Figure 11.10 to Figure 11.13, below.

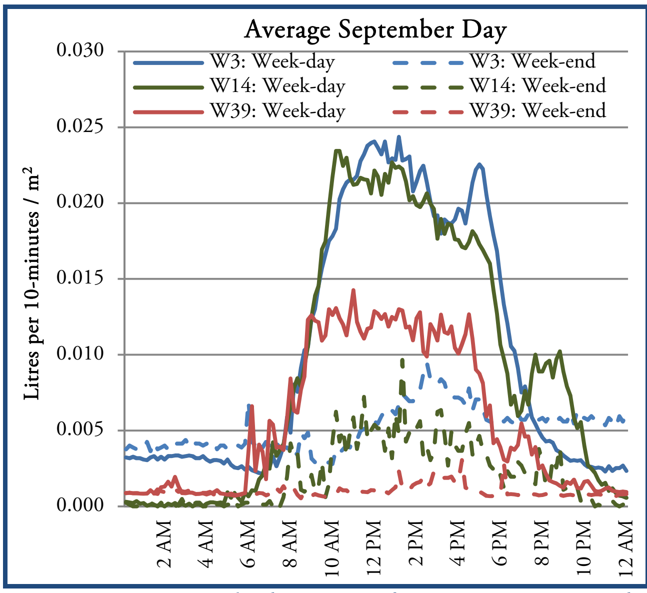

Figure 11.10: Normalised Water Use for an Average Monitored September Day

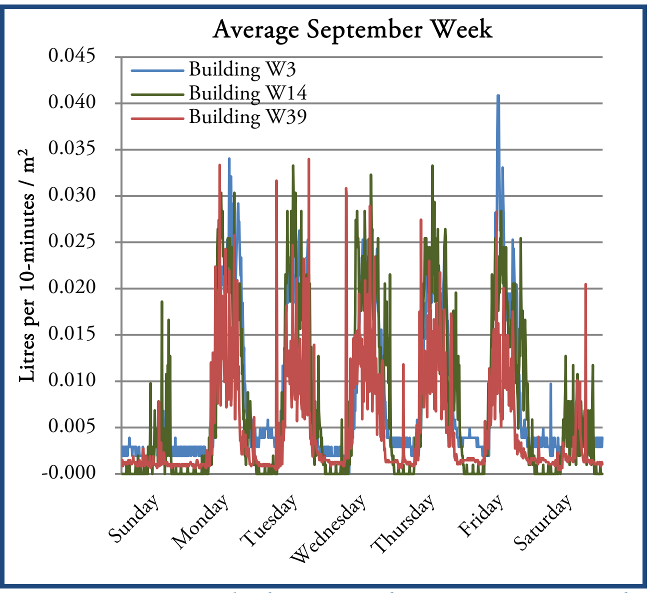

Figure 11.11: Normalised Water Use for an Average Monitored September Week

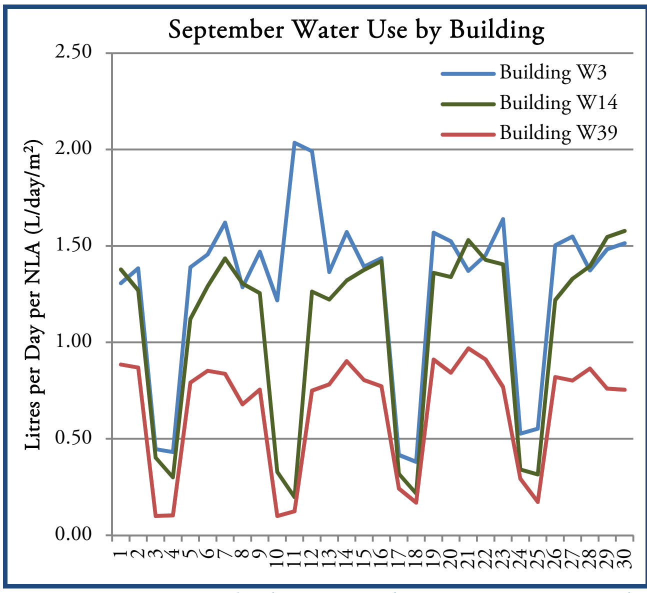

Figure 11.12: Normalised Water Use for an Average Monitored September Month

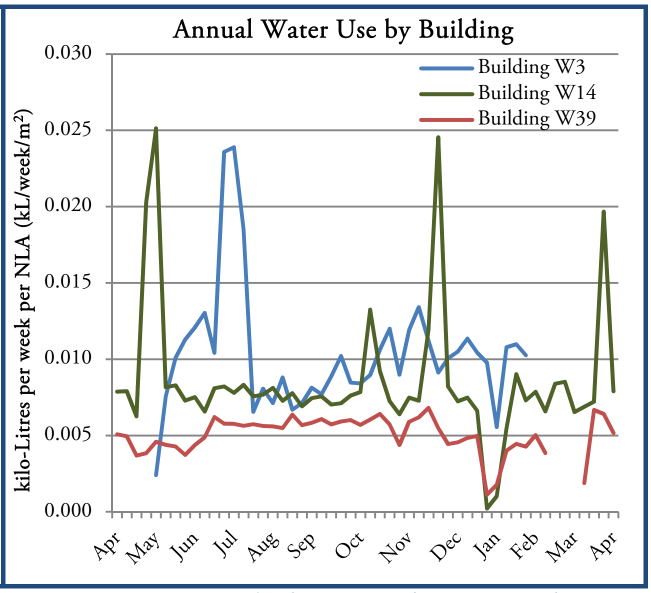

Figure 11.13: Normalised Water Use for a Monitored Year

These compare the buildings' normalised water use. However, as all three buildings were similar in size, the difference between the above charts and those in Chapter 10, is negligible other than the scale. Please also note the difference in scales (or time intervals) between the four Figures above (11.10 to 11.13).

As can be concluded from Figure 11.10, Figure 11.11, Figure 11.12, and Figure 11.13, it would be expected that these three building all have a relatively low WUI. However, when analysing the five years' worth of data, building W39 appears in Excessive Use, but for the analysed September month appears to be much lower. Which means either a leak had been remedied, or a change in occupancy, behaviour, or appliance efficiencies had occurred over the last five years.

11.5.1. INTERNATIONAL COMPARISON

Internationally very little work has been published with regard to water consumption and water performance benchmarking, other than those studies outlined in Chapter 5. Those which have been published do not always present the exact percentiles for their rating bands, for this reason, only the 'Typical' benchmark or 50th percentile can be accurately compared.

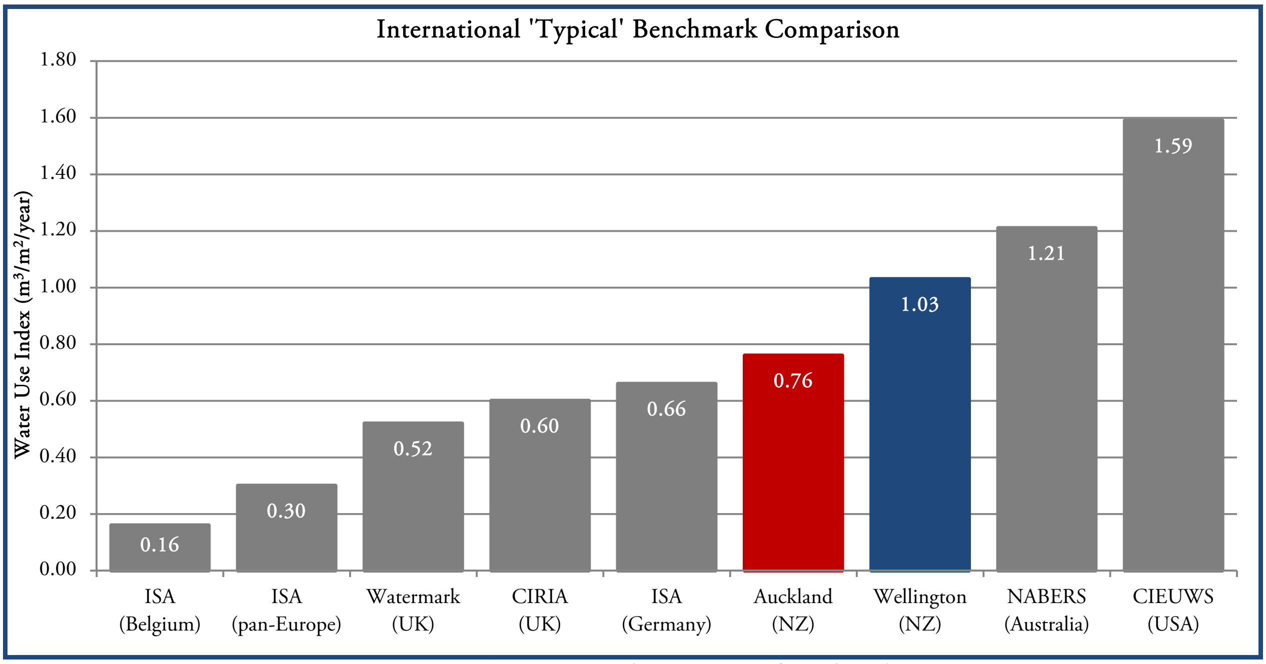

Figure 11.14: International Comparison of Benchmarks

Figure 11.14 shows that the New Zealand buildings that were studied, on the world scale, are performing about average, sitting between the United Kingdom and Australia. As the *ISA* studies have not publicly released any literature surrounding these benchmarks, their accuracy has not been confirmed.

Figure 11.14 shows that the Auckland commercial office buildings examined under this study use less than half as much as those examined under the *CIEUWS* in the USA (although the *CIEUWS* study was based on only 5 buildings from across the country). The UK's benchmarks appear to show their typical usage to be less than that of New Zealand, Australia, and the USA.

Theoretically commercial building water use should not widely differ between regions for any reason other than cultural ways of using water and any climatic influenced evaporative losses. Water in office buildings is generally used for the same reasons, i.e. sanitation, domestic activities, and for environmental conditioning. However, due to the difference in evaporative losses caused from differing climates, a climate normalisation adjustment has been used to see effects neutrally.

In Australia, the "office building water consumption benchmark has been established on the basis of a normalised water consumption intensity figure that corrects for climatic impacts" (Bannister et al, 2005), across their [large] country. However, as Australia is very large in size, which in turn means climates can be very different in varying states a climate normalisation was applied to the different states.

When the benchmarks are climate normalised for each state, the benchmarks should not differ from one another. The normalisation equation used in this Australian study, and which will be applied to the international benchmarks outlined above, can be found in Equation 5.1.

Using those studies in Figure 11.14, their contributing variables have been examined, and are outlined in Table 11.13, below. This means the climate has been adjusted by the number of degrees that each day's average temperature is above 15°C (wet-bulb), over an entire year.

Study	Existing WUI (m^3/m^2/year)	CDD_{15wb}	W_{corr}	Climate Normalised WUI (m^3/m^2/year)
Bint (Auckland)	0.76	740	-0.20787	0.55
Bint (Wellington)	1.03	330	0.21845	1.25
NABERS (Australia)	1.21	1519	-1.01788	0.19
CIEUWS (USA)	1.59	387	0.15918	1.75
Watermark (UK)	0.52	305	0.24444	0.76
CIRIA (UK)	0.60	305	0.24444	0.84
ISA (pan-Europe)	0.30	467	0.07599	0.38
ISA (Belgium)	0.16	397	0.14878	0.31
ISA (Germany)	0.66	467	0.07599	0.74

Table 11.13: International ['Typical'] Benchmarks after Climate Normalisation Adjustment

Table 11.13 and Figure 11.15 show that once the climate adjustment formula, as developed by Bannister et al (2005), has been applied, the New Zealand benchmarks appear to be much better in Auckland than in Wellington. Wellington is now second to highest, while Auckland has stayed much the same, in terms of international ranking.

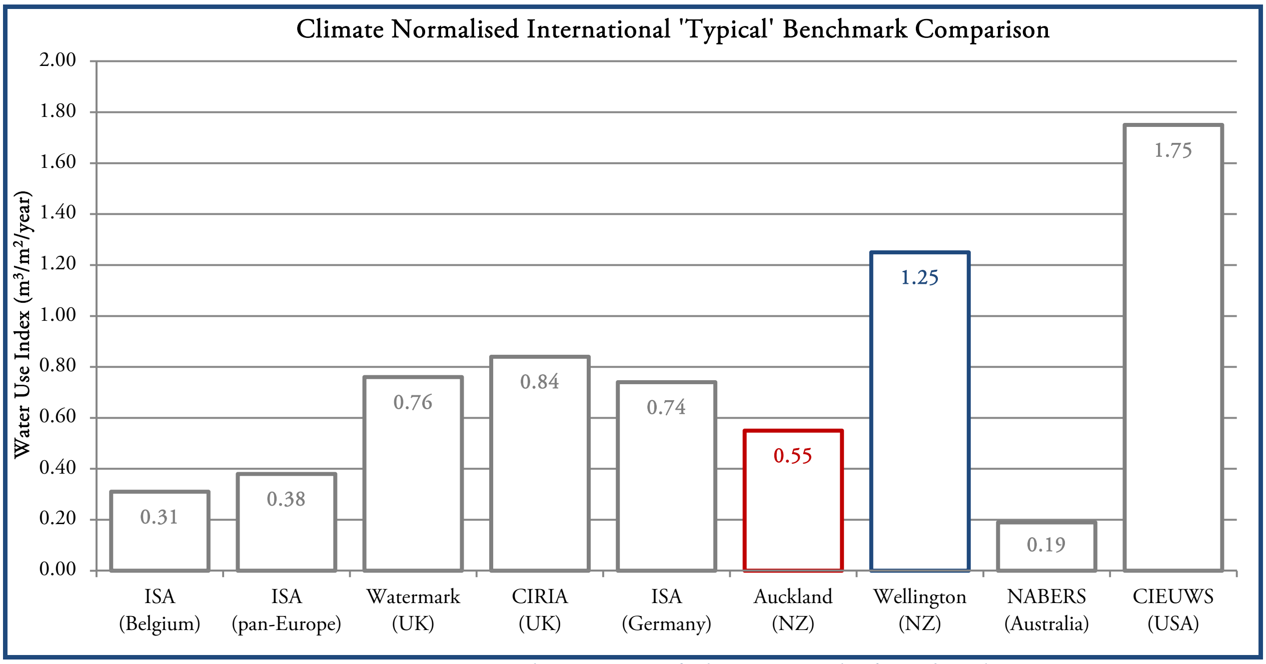

Figure 11.15: International Comparison of Climate Normalised Benchmarks

Bannister et al (2007) highlight, the relationship to climate is "particularly important when considering water consumption figures for tropical and sub-tropical regions, as the climate is more extreme and thus one would expect a larger difference to be present."

In conclusion, the Auckland office buildings studied appear to be performing relatively well in contrast to similar international buildings studied. While the Wellington buildings are amongst the worst. Overall, New Zealand has a lot to learn from both Auckland and other foreign studies. The next steps include actioning water efficiency or demand management means and incentives in New Zealand.

11.5.2. EXTRAPOLATION

The *BEES* analysis of the total number of office buildings by size quintile (refer Table 3.1), can be used to estimate the total annual water usage of all office buildings falling within the Auckland and Wellington regions.

If the remaining regions are calculated based on the overall (Auckland and Wellington combined dataset) sample median of 0.84m³/m²/year, the approximate water use by region in the office buildings sector can also be estimated.

Region	Office Building Count	Cumulative Floor Area (m^2)	Proposed Benchmark (m^3/m^2/year)	Total Water Use (m^3/year)
Auckland	1,791	3,093,221	0.76	2,350,848
Bay of Plenty	387	308,402	0.84	262,142
Canterbury	850	896,154	0.84	761,731
Gisborne	66	33,025	0.84	28,071
Hawke's Bay	256	149,533	0.84	127,103
Manawatu-Whanganui	499	356,210	0.84	302,779
Marlborough	68	32,780	0.84	27,863
Nelson	102	50,822	0.84	43,250
Northland	220	122,529	0.84	104,150
Otago	330	231,249	0.84	196,592
Southland	197	117,417	0.84	99,804
Taranaki	340	185,852	0.84	157,974
Tasman	58	15,732	0.84	13,372
Waikato	725	457,748	0.84	389,086
Wellington	553	1,554,412	1.03	1,601,044
West Coast	94	40,411	0.84	34,349
Total	**6,536**	**7,645,557**		**6,500,128**

Table 11.14: Benchmark Extrapolation

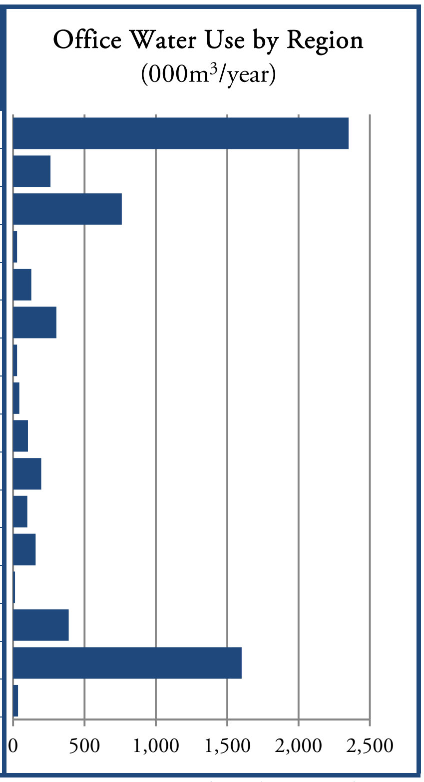

Figure 11.16: Benchmark Extrapolation

However, it should be emphasised that the benchmarks established are only representative of the Auckland and Wellington office buildings studied herein, and further research is needed to formulate an accurate benchmark for each of the other regions and buildings. The following calculations determine the number of office buildings required to achieve a statistically representative sample for office buildings in New Zealand.

11.5.3. SAMPLE SIZE STATISTICS

Based on the results of this benchmarking study, and the population size as given by the *BEES* reports (Isaacs et al, 2010a) and in Table 11.14 above, the optimum sample size for the most accurate results can now be estimated. This is done using Dziegielewski et al's (2000) equation, as outlined in Equation 11.5 and Equation 11.6 below. The margin of error has been set at 5%, while the desired confidence probability interval has been set at 95%.

The calculation is performed using Equation 11.4, where n_o is the first approximation of the needed sample size, t is the confidence probability (95%), r is the margin of error (5%), $\bar{y}$ is the sample mean (0.93), and s is the sample standard deviation (0.39).

$$n_o = \frac{t^2 s^2}{r^2 \bar{y}^2} = \frac{(1.96)^2 (0.39)^2}{(0.05)^2 (0.93)^2} = 270$$

Equation 11.4: Sample Size Calculation

Because n_o/N is not negligible, the finite population correction needs to be applied.

$$n = \frac{n_o}{1 + n_o/N} \qquad = \frac{270}{1 + 270/6536} \qquad = 260$$

Equation 11.5: Sample Size Correction

Of the 6,536 office buildings in New Zealand, 2,344 are within the combined Auckland (1,791) and Wellington (553) regions. In order to create a suitable national/sub-regional WUI, a total of 260 buildings need to be studied for a representative sample, based on the studied sample mean and standard deviation.

11.6. SUMMARY OF BENCHMARK ANALYSIS

Based on the demand drivers in Chapter 3.3, and the methods in Chapter 8, the benchmarking index model has been trialled. This showed that NLA was the best (both statistical and pragmatic) driver for water use in this sample of office buildings.

Both the single and multiple regression analyses produced the same formula (Equation 11.1) for predicting water use. The ANOVA tests showed that a separation of the benchmarks by geographic location was necessary, using the market-based approach. However, if the efficiency-based approach was to be used, a single benchmark, the median of the totalised dataset (0.84m^3/m^2/year), for all of New Zealand could be argued more appropriate.

Internationally these benchmarks situate both Auckland and Wellington between the UK and Australia in terms of benchmarking by NLA. When allowing for climate normalisation (although Chapter 10 found very little correlation between water use and ambient temperatures) the two regions' benchmarks move in opposite directions; Auckland being better than the UK, and Wellington being just ahead of the USA.

Based on the data found and created herein, it must not be used as statistically representative of New Zealand. As shown in Equation 11.5, a sample size of 260 office buildings is needed for complete statistical representation. However, as these results are statistically significant, their implementation in the current New Zealand industries is possible.

SECTION FIVE: TOOL DEVELOPMENT

This fifth section provides a discussion on the reality of implementing the changes outlined in the previous section into the New Zealand market environment. Its intention was to primarily provide an interface to this research study through an interactive database/tool, and to consider the barriers which might prevent implementation of such a system. This provides a response to one research question posed in Chapter 1.2.2:

- What is needed to provide the support for higher levels of water efficiency and conservation?

The design and development of the Water Efficiency Rating Tool (WERT) are discussed in Chapter 12. Database/Tool Design. Strategies and issues are discussed within Chapter 13. Implementation. This also includes possible collaboration techniques with current BSRTs, such as the *GSNZ rating tool*.

12. DATABASE/TOOL DESIGN

Following the development of the water benchmarking index model, the next step in the process is providing that model with some form of implementation medium to ensure usability, and to demonstrate the value of its use as a publicly available tool. As Gleick (2003) states "long-term sustainable use of water does not require drastic advances in technology or heroic or extraordinary actions. Instead, it requires an ethic of sustainability and the will to continue expanding positive trends that are already underway."

From researching the water supply and demand situation in New Zealand, it was identified that there was a large market gap which a rating tool could fill. This would allow industry and public to understand their water performance, what water use efficiency is, how to achieve it in new design or existing buildings.

For these reasons a Water Efficiency Rating Tool (WERT) has been developed and demonstrated to the industry, based on the data and benchmarks established in this study. The WERT has not yet been trialled by industry as issues surrounding the intellectual property needed to be resolved prior to its release. The WERT is proposed to be developed into an online software calculator.

12.1. PURPOSE

The main objective of an efficiency rating tool is to provide a single, intelligent, and interactive database driven system offering users the opportunity to manage their site details, add billing data, and view benchmark details via an interactive tool (Kitchen et al, 2003).

The aim of creating and implementing this WERT, was to enable awareness and understanding of both water issues and performance, and to promote water efficient approaches. As this tool was targeted at a segmented market, communication methods were vital to its application and success.

A number of development criteria were established to ensure that: the tool had an aim; the tool had something to be critiqued against; and the tool was appropriately suited its target markets. The tool is planned to work as both a performance (analysis) tool, and a prediction (design) tool. The performance method rates existing buildings, while the prediction method aids in water efficient design and retrofit, however they work together in one tool.

Three targeted end-user categories were identified, which have differing requirements in terms of the WERT purpose and use:

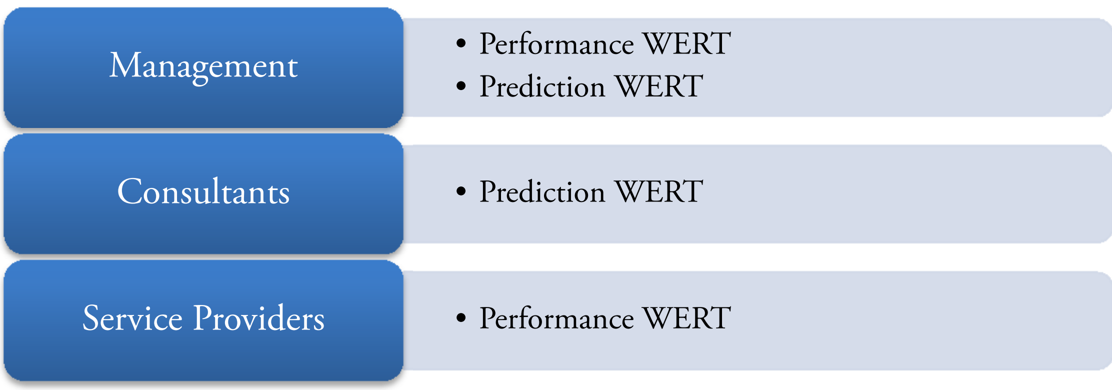

Figure 12.1: Target Market

Under the 'management' category, property owners and managers, building managers, facility managers and co-ordinators, or anyone with a vested interest in understanding a commercial building's water performance are targeted. These personnel generally would have a tertiary qualification in property management or business studies, and/or be trained professionals. The most useful piece of information from a management perspective would be how their building performs, what they can do to improve it, and what the financial viability is of doing so.

'Consultants' refers to designers, engineers, and Environmentally Sustainable Design (ESD) consultants. Again, these personnel are assumed generally to be qualified or trained professionals. The most useful piece of information for this group would be performance benchmarks and targets, and how to predict performance based on design, prior to construction.

The 'service providers' category refers to water agencies and local/regional authorities. The most useful part would be the ability both to determine benchmarks and to help their customers understand improvement potential. Also, as noted in Chapter 10, where a meter had been under-reading for some time, such a tool could help to resolve the issue.

12.2. DEVELOPMENT CRITERIA

From previous research undertaken on the development of end-user tools and calculators (for any purpose, e.g. energy, lighting, accounting, etc), the following criteria were used to aid in the decision making processes.

Although these tools are not directly related to the WERT, they have been selected to simply demonstrate user interface criteria choices and the level of importance they played in their study. These studies share a commonality, being self assessment tools designed for public, non-specialised use. The water specific data has been established and discussed previously in Chapter 10 and Chapter 11, now the user interface/medium will be considered.

TOOL/CALCULATOR	CRITERIA					
	Relevant	Realistic	Practical	Accurate	Promote action	Objective
NABERS[1]	✔	✔	✔	✔		✔
NZ ALI[2]	✔	✔	✔	✔		✔
NZBC G7 Compliance Tool[3]			✔	✔		
HHC[4]		✔	✔		✔	
BQI[5]	✔	✔	✔			✔

Table 12.1: Existing Tool Development Criteria

The above stated criteria were selected based on the published information for each study. Each study did not state that they would not comply with the non-checked criteria, rather just which criteria they would strive to achieve.

[1] National Australian Built Environment Rating System (Bannister et al, 2005)
[2] New Zealand Liveability Index (Bennett, 2010)
[3] New Zealand Building Code G7 Compliance Tool (Stewart, 2009)
[4] Housing Health Checklist developed by Hasselaar (as cited by Bennett, 2010)
[5] Building Quality Indicator (as cited by Bennett, 2010)

Based on the targeted industry and end-users of this WERT, the following six criteria have been set for the development of this WERT:

TOOL/CALCULATOR	CRITERIA					
	Relevant	Realistic	Practical	Accurate	Promote action	Objective
WERT	✓	✓	✓	✓	✓	✓

Table 12.2: WERT Development Criteria

It should be noted that 'Objective' has been included in the WERT development criteria, although there may not be room for much subjectivity. Objectivity is a criterion which can severely influence inaccurate results, i.e. if the user enters bias inputs to alter the result in some way, so will be built into the WERT to minimise subjectivity. Each of the selected criteria for the WERT are further outlined below in Figure 12.2.

Accurate

- As this tool should have the ability to estimate the actual happenings based on factual data, the accuracy level for the outputs from the tool (i.e. margin of error) need to be within ±10% of actual. However, until the implementation level has been conducted this cannot be FULLY measured.

Realistic & Relevant

- The data and results must be realistic and relevant. It must represent the population of data, therefore it is based on the performance data of the 93 office buildings audited as part of the field study. The relevance will be achieved through the communication method, and by working with the targeted end-user industries, to determine the most desired resultant information.

Practical

- The tool must be simple, easy to use, and the results must be communicated in a way which promotes understanding. It must be user friendly and non-complex, and offer practical suggestions.

Promotes Understanding & Action

- The results provided in the tool must be positively informative, in order to promote not only an understanding, but also actionable to be carried forward through to implementation.

Objective

- Any subjective opportunity must be minimised as much as practically possible.

Figure 12.2: Criteria Definitions

The overlying criterion for all of the above listed criteria is effective communication. Does it have the ability to promote understanding in the target industry (trained, qualified building and/or water professionals, and/or the average layperson), from a range of fields? Effective communication is detrimental to the success of such a system, as the system needs to be able to clearly communicate on behalf of the criteria in Figure 12.2.

As Onwuegbuzie (2008) rightly points out "the way we think about what and how and why we are generating data must be addressed in a large way so that countless decisions can be made to move the ball forwards in terms of real lives." This highlights the importance of being very clear in understanding the purpose and method in the [tool] development, if the WERT is to be implemented and used in the industry.

For this reason, communication, practicality, and relevance are highly ranked criteria and have been incorporated throughout the assessment method and outcomes, along with the other outlined criteria.

12.3. ASSESSMENT METHOD

There are two methods for using the WERT, a prediction (design) assessment method and a performance (analysis) assessment method. The two methods have been combined into one tool, to allow for comparison – what IS happening vs. what SHOULD BE happening, as well as using the two independently if desired. This tool has been discussed, demonstrated, and critiqued against the above criteria, in the discussion to follow.

There are four levels in the WERT process (refer Figure 12.3 below), three of which can be performed using the WERT itself, ranging from the simplest and least intensive, to the most complex. During the development of this tool, a business model was also attached to each of the four levels of the performance WERT model. The AIDA model has been applied:

A - Attraction
I - Interest
D - Desire
A – Action

The AIDA is "a consumer behaviour that traces the sequence of cognitive events leading to a purchase decision or action; also called the hierarchy of readiness" (All Business, 2011). This model is most commonly used in marketing strategies, which of course could be applied in the same context here as well. As the key purpose and the final outcome proposed from the use of WERT is to help buildings become water efficient (i.e. Step 4 – Implementation), this model can theoretically also be applied to WERT. This is demonstrated below in Figure 12.3.

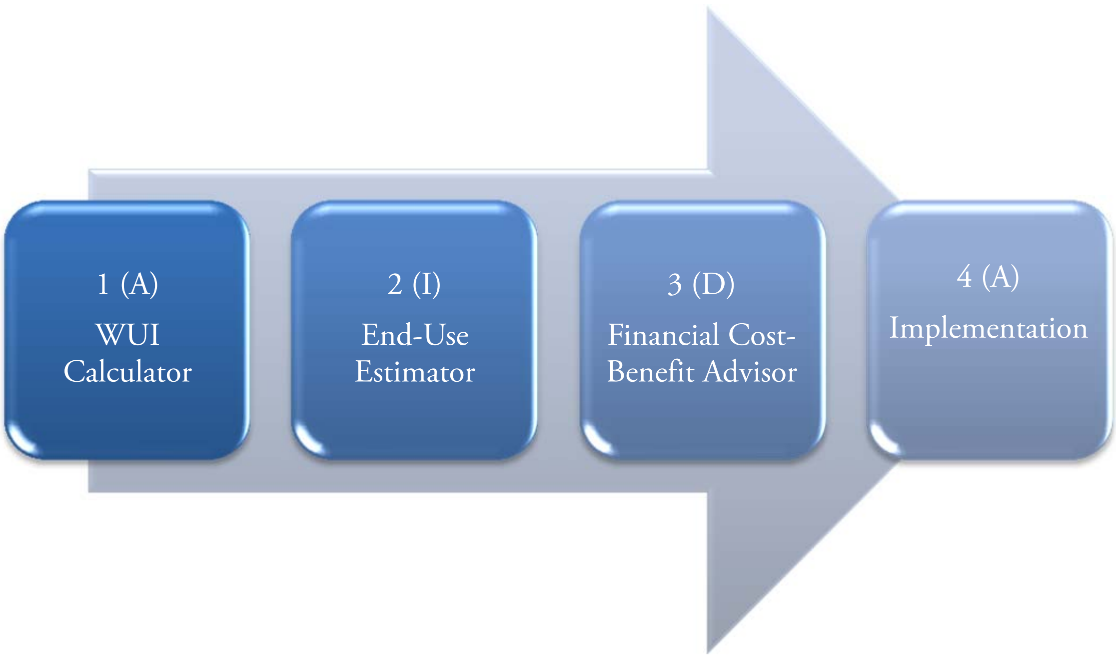

Figure 12.3: Performance WERT Model

The user first becomes aware of WERT and completes Step 1 – WUI Calculator. This spurs an interest, and provides some information. Step 2 – End-Use Estimator, engages that interest and interprets the user's building(s) data into an understandable form. Next, Step 3 – Financial Cost-Benefit Advisor (FCBA), creates the desire by providing cost-effective solutions specific to the entered building, visualises possible savings, calculates a new a WUI, and promotes action. The users of the tool now have almost all of the information needed to act. Step 4 – Implementation is the action of going through with the recommendations and implementing the systems recommended by the FCBA.

12.3.1. PHYSICAL TOOL DEVELOPMENT

The WERT was designed and developed using *MS Excel* spreadsheets. A number of standard macros (using *Visual Basics* or *VBA*) and formulae were used. The data and spreadsheets were locked, or 'protected' to prevent user error or deletion of any formulae. The WERT was designed to be dynamic and automatically updates with each change of any variable within the tool. Please refer to Appendix E for WERT example.

12.3.2. WATER USE INDEX (WUI) CALCULATOR

The very first step needed to be the simplest, and easiest to use of all steps to promote attraction. The information provided in this step is very basic, but very informative in a single value. This information is provided by calculating the NLA and annual water consumption, and the results are provided as a column chart – in comparison to the regional benchmark. Figure 12.4 below shows the screen-grab of this step.

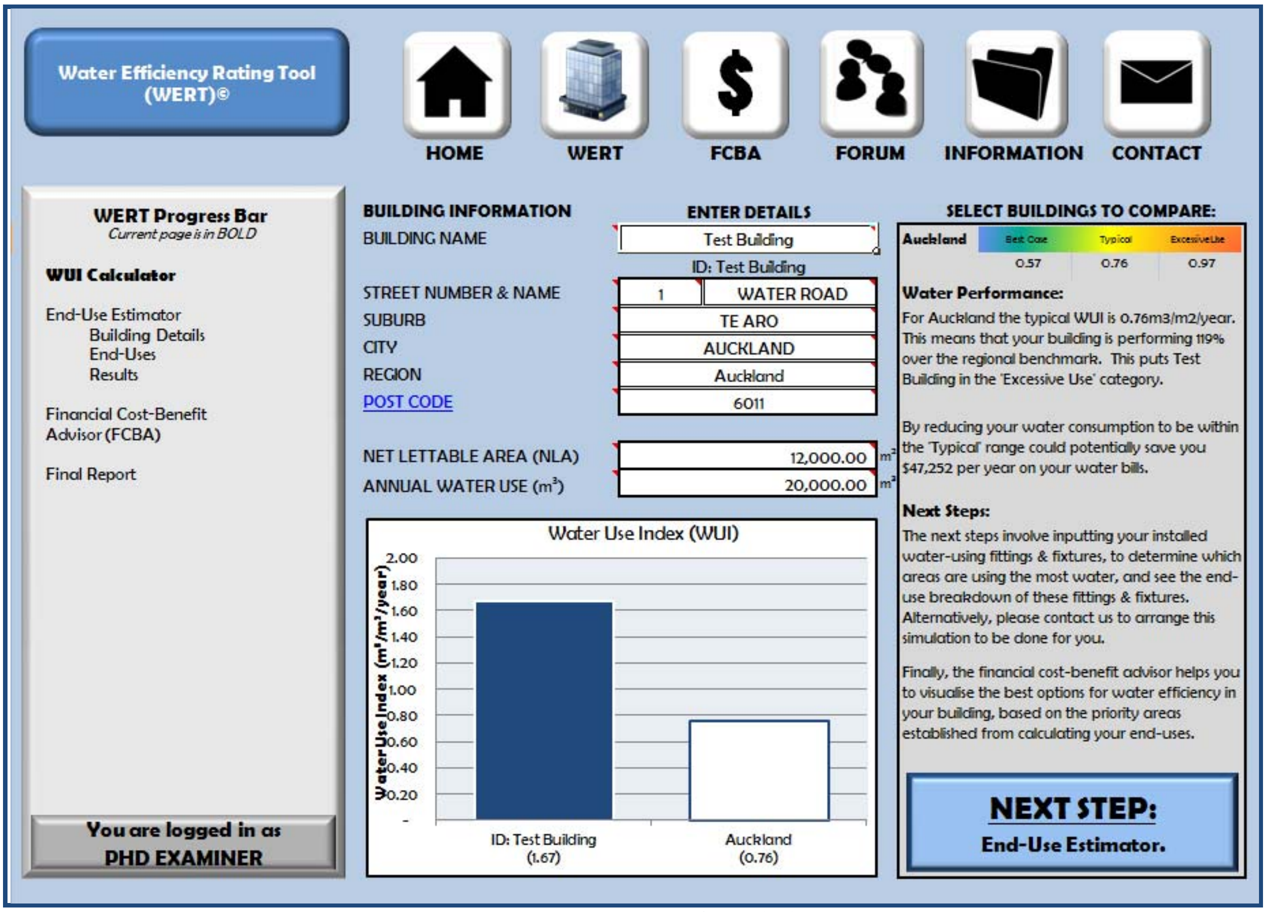

Figure 12.4: Water Use Index Calculator

The WUI calculator step is simple, easy to use, the results are dynamic (i.e. automatically updated), and are on the same page as the entered data. On the right hand information panel, an explanation of the meaning of the results can be found, along with action-related advice, and the appropriate next steps. The next level is the end-use estimator.

12.3.3. END-USE ESTIMATOR

The end-use estimator takes the details from the WUI calculator step (shaded grey on the "Enter Details" column in Figure 12.5), and allows the user to enter the current or proposed appliance schedule. The input information required here includes: number and type of appliances, *WELS* rating (if any), and if the flow rate is known the default values can be overwritten.

This step is the most intensive and complex of the three under the model, as it requires the user to supply significant detail of the fittings and fixtures schedule. There are two sub-steps: building characteristics; and end-uses. The end-use estimator part of the tool takes data on the currently installed water-using appliances and estimates the proportion of annual billed water going to a single appliance type within the building. These estimates are based on previous studies on restroom usage published by *BIA* (Stewart, 1995) and Vickers (2001), and research from this study. The *WELS* standard (Standards New Zealand, 2005), which was introduced to New Zealand recently as a voluntary appliance labelling scheme, has also been used.

The first sub-step is an extended version of the WUI step. This level also allows the user to enter and store a number of buildings in their portfolio or customer sample. This can then be revisited for comparison as further buildings are entered, or upgraded.

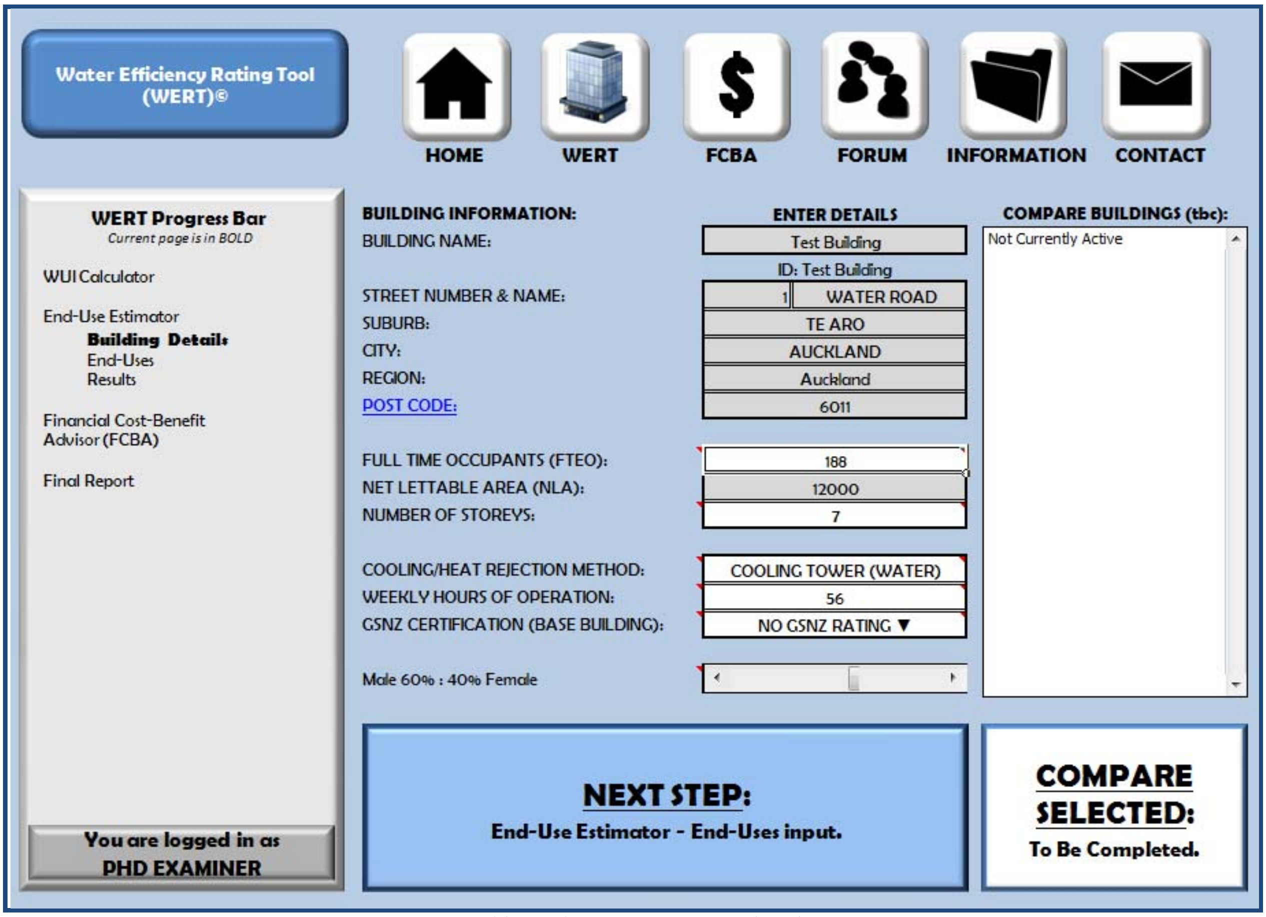

Figure 12.5: Building Characteristics page of End-Use Estimator

The number of FTE occupants is required, however if the WERT is to be used solely as a predictor tool (i.e. for pre-construction design), the maximum number of occupants (as per *NZBC*) can be used. This input is required for the calculation of the number of domestic appliances. This also sets up the male to female ratio, which can be adjusted using the slide bar below the "Enter Details" column in the centre of the screen – it is currently set at a default of 60% male to 40% female (Stewart, 1995).

The number of storeys is required to provide a general idea of the shape and scale of the building.

Then, the heat rejection method needs to be specified, using a drop-list of options. If "COOLING TOWER (WATER)" is selected, an additional input area appears on the following screen to aid in calculating the HVAC water use. The weekly hours of operation for that method of heat rejection also need to be estimated.

And finally, whether or not (and to what level) the building is *GSNZ* certified is input. If this option is used, then an additional screen will appear to aid in calculating the split between the mains water, rainwater, and grey water use, if any.

The next sub-step requires information on the installed (or proposed) appliances, such as the count and type of appliance, *WELS* rating (if any), and if the flow rate of a particular appliance is known the default value can be overwritten. The general categories of appliances are toilets, urinals, wash hand basins, and other. The flushing or use mechanism is generalised into a drop-list of options for each category.

On the "Cooling Tower" row (lower of screen in Figure 12.6, because "COOLING TOWER (WATER)" was selected as the method of heat rejection in the previous sub-step), additional input is required to determine the amount of water used in this area.

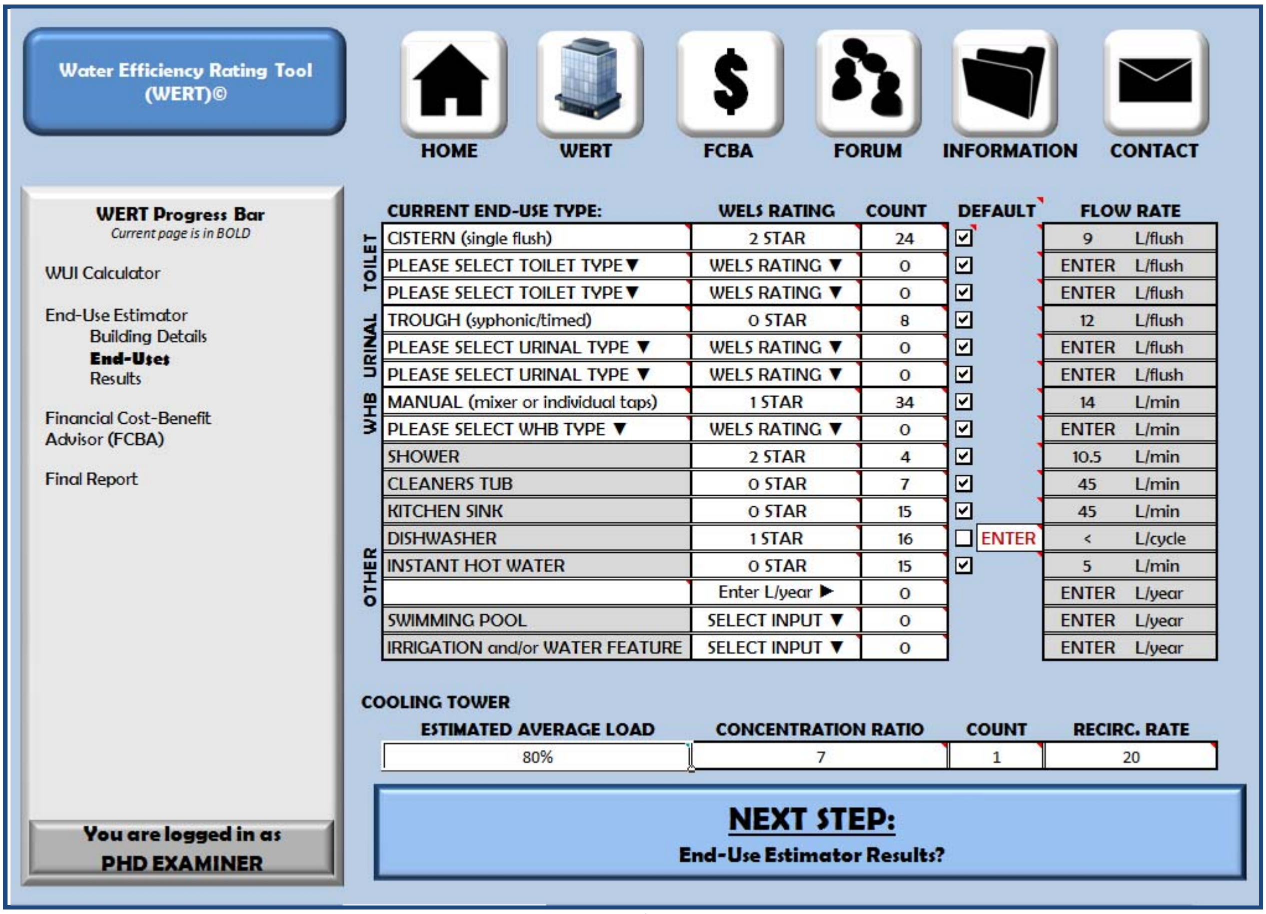

Figure 12.6: End-Use Estimator

For the cooling tower, the estimated average load refers to the approximate percentage of the hours of operation that the units will be running at full capacity. The concentration ratio is the difference in the suspended solids of the water in the cooling tower basin water and the make-up supply water, typically seven in New Zealand (Symons, 2011). The recirculation rate is somewhat more complex to find if the information is not readily available. The best way to determine this is to check the pumps feeding the cooling tower, and then contact the manufacturer for the 'pump curves', which will provide the recirculation rate (Symons, 2011). The default recirculation rate for this model is 20 L/second. Finally, the count is the number of units.

The results [both performance and prediction] are given as a stacked column chart (shown in Figure 12.7), and compared against the relevant benchmark for that region. The WUI for the proposed building and the regional benchmark are displayed both on the chart (as a graphical output), and above it (as a numeric output). To the right, in the information panel, the total estimated consumption and annual charges appear. Information on the next steps, including potential savings opportunity, and methods for prescribing this are also outlined.

If the stacked column is selected with the mouse pointer, a pie-chart is created outlining the indoor water use disaggregation (in Figure 12.8). This enables high-usage (priority) areas to be identified visually via the pie-chart.

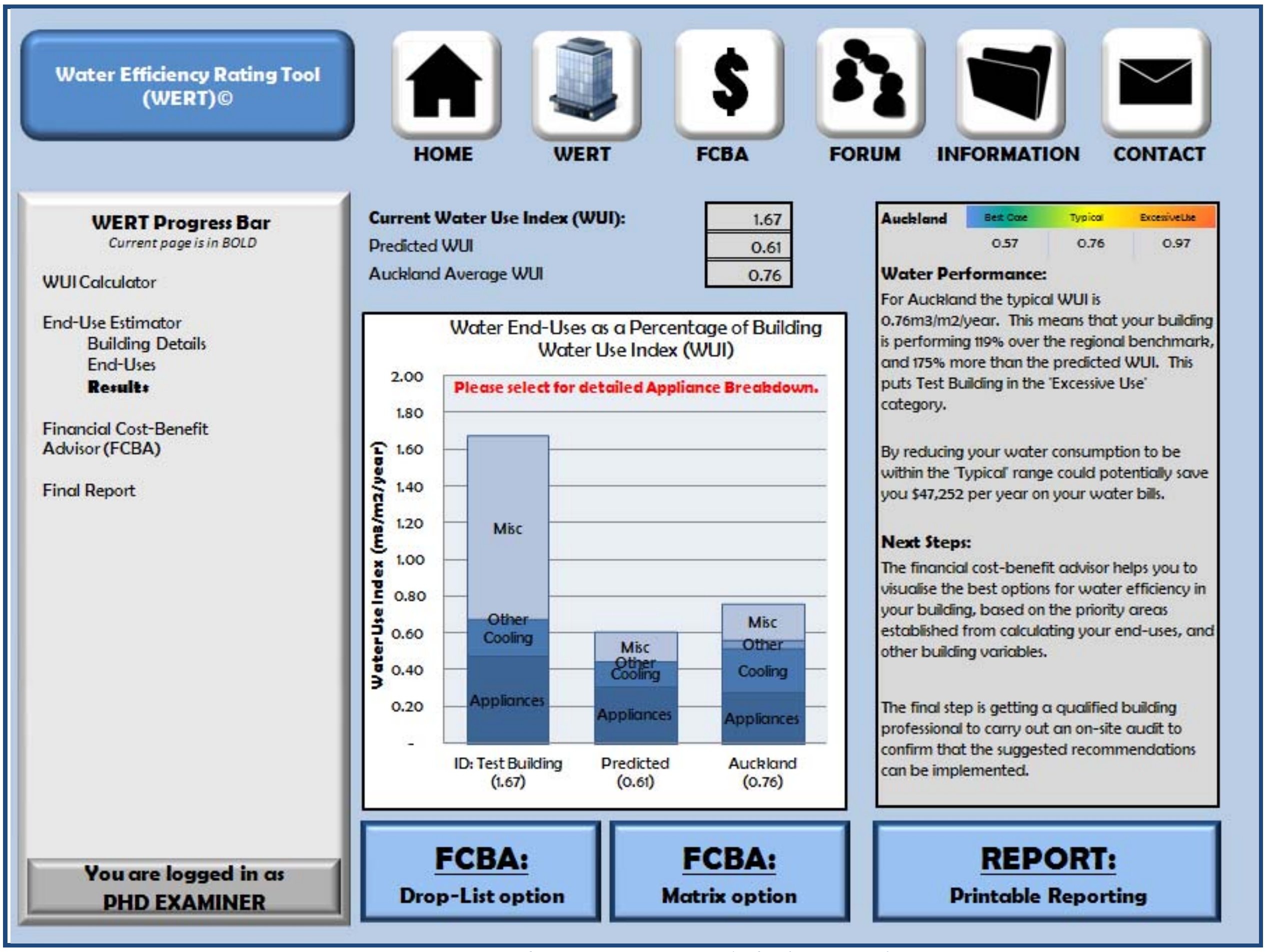

Figure 12.7: End-Use Estimator (Stacked-Chart) Results

Again, the right hand information panel interprets some of this data and advises on the next steps of action and any significant recommendations. As this end-use estimator step is relatively complex (especially in contrast to Step 1: WUI Calculator), pop-up help boxes appear as you select or hover over each input field.

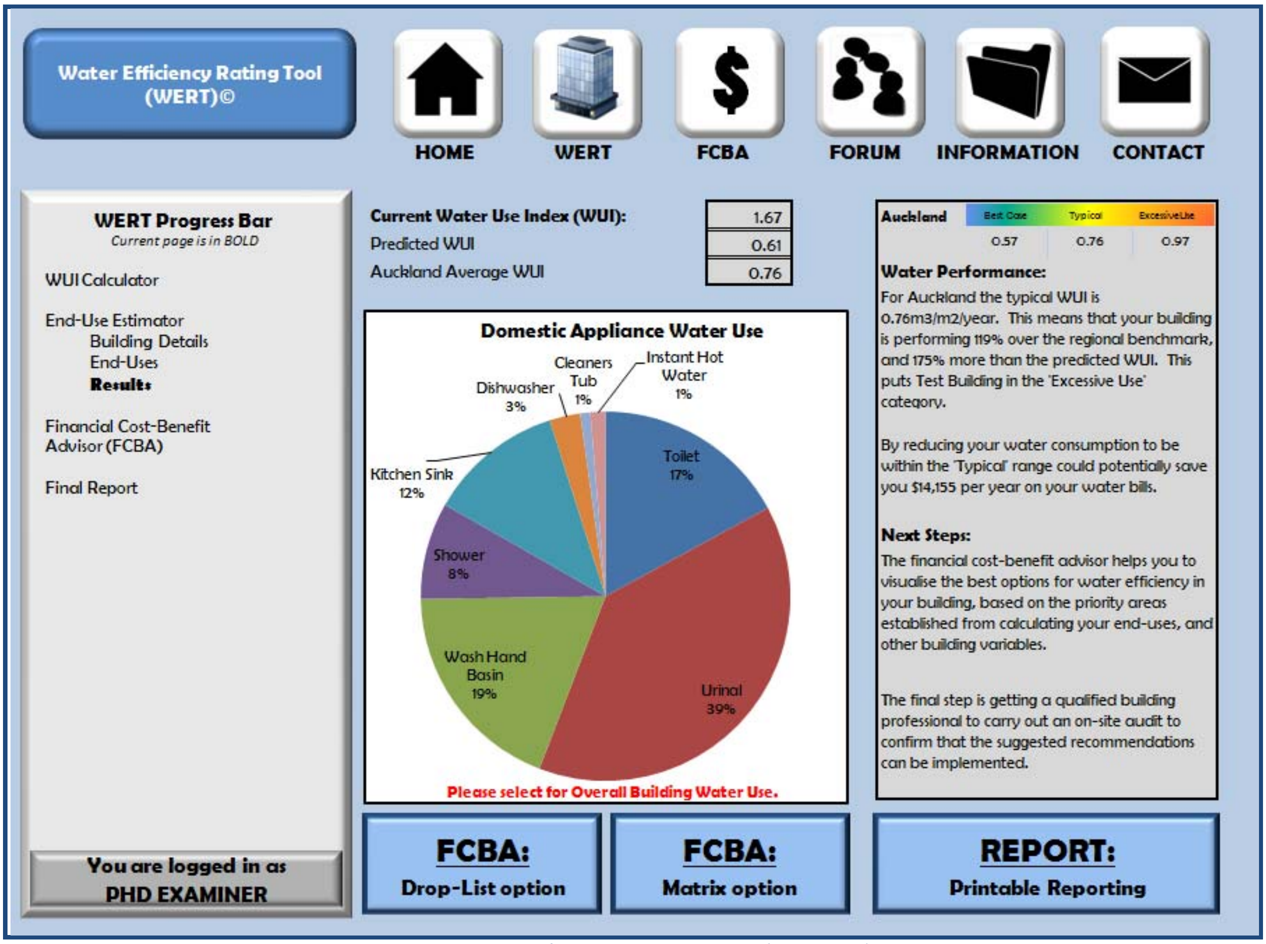

Figure 12.8: End-Use Estimator (Pie-Chart) Results

Based on entering all 93 of the studied buildings in Chapter 11, the accuracy of this end-use estimator (i.e. the difference in total calculated water use from the end-use estimator, from the billed water use) is within ±8.5% of total water use (this ranged from 0% to ±69% (in the case of the outliers described in Chapter 11.2.2). A printable report can be generated which shows the input and output data, allowing it to be stored within the business filing system.

12.3.3.1. FINANCIAL COST-BENEFIT ADVISOR (FCBA)

The FCBA aids in the user's decision surrounding types of appliances to install as part of a water saving proposal. It offers the baseline WUIs, and computes a new WUI based on the improved or suggested implementation package.

This step has two options, the first utilises a cost vs. efficiency matrix creating overall packages (Figure 12.9), while the second uses drop-lists of budget preferences (low, medium, high), for each specific appliance (Figure 12.10). The purpose of this step is to allow the user to interact with different options for appliances. The user will be able to select the most appropriate type of appliance based on budget and consumption specifications.

As each user of the WERT may have a different mechanism for aiding in decision making, the results have been expressed in terms of differing measures of financial viability, such as Net Present Value (NPV), Internal Rate of Return (IRR), or payback period – with the initially entered data as the baseline for comparison. The results also outline the overall per unit costs (both in terms of installation and water tariffs), and any other suggestions or issues.

The first input involves selecting which is the preferred financial term: NPV; IRR; or payback period (although this can be changed at any time). Then the current interest rate must be set (with the *Reserve Bank of New Zealand (RBNZ)* 5-year average as the default (RBNZ, 2011)). Then the budgetary preferences are explored. Based on these inputs, a water efficiency package is formulated. This then calculates a new WUI for the building. The pie-chart from the previous step is shown on the left navigation panel to aid in determining priority areas for water efficiency.

By using cost estimates and flow rates provided by *MacDonald Industries* and *Davis Langdon*, together with a range of other estimates for comparison, the results are made to be directly relevant to the building being studied. The two options (cost vs. efficiency matrix, and drop-list) are displayed as screen-grabs in Figure 12.9 and Figure 12.10.

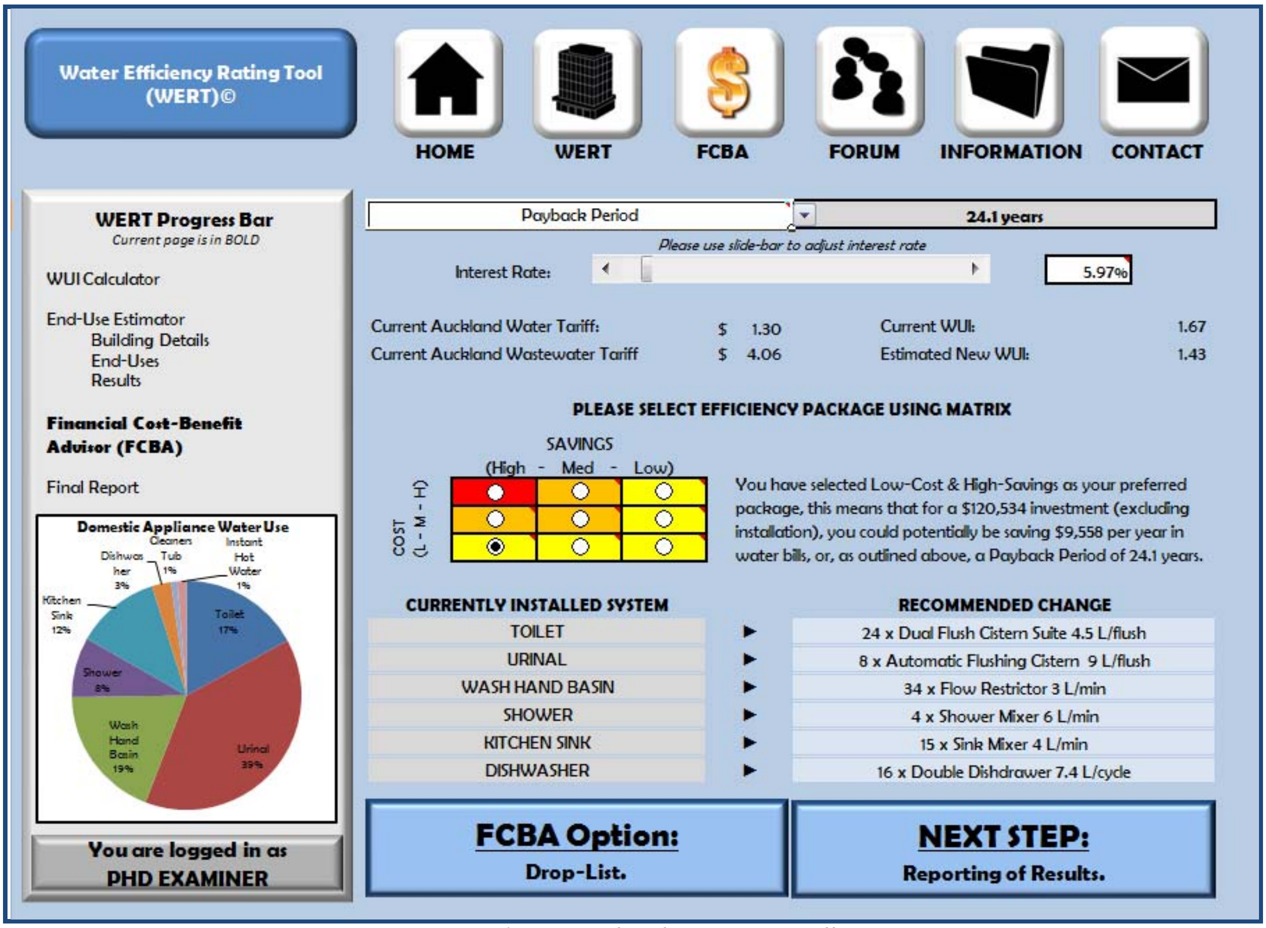

Figure 12.9: Financial Cost-Benefit Advisor (Cost vs. Efficiency Matrix)

This step creates promotion of action by communicating the calculated package through the preferred monetary term. This step is the most interactive and dynamic. The outputs are in three parts: financial viability; total costs; and details of selected appliances. Additional support and advice is always suggested on each of the results screens.

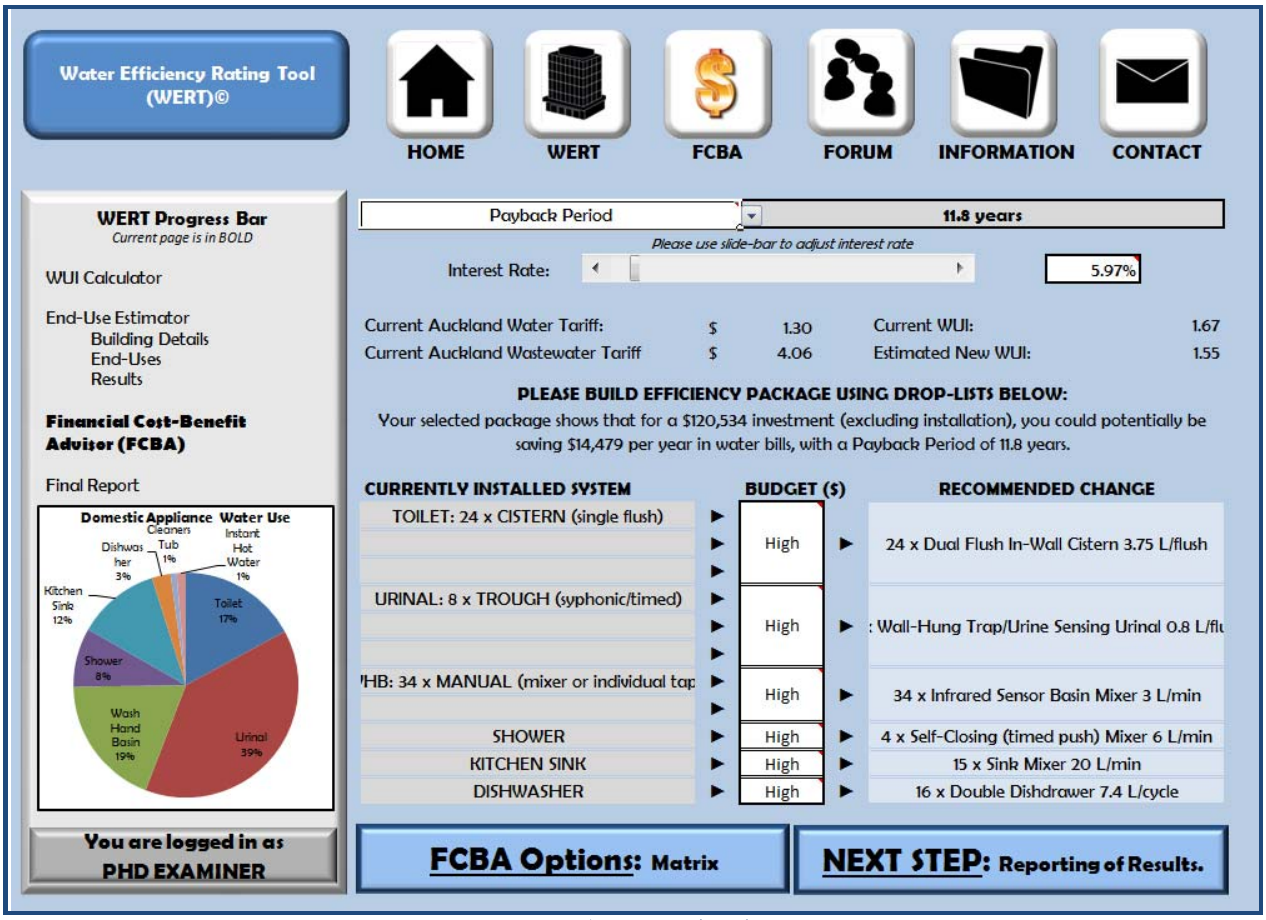

Figure 12.10: Financial Cost-Benefit Advisor (Drop-List)

All input and output fields are featured on the same page. This implies simplicity and ease of use, without having to switch between views and wait for page loads.

12.3.4. IMPLEMENTATION

As every building is different, in size, reticulation, drainage specifications, age, and other ways, each building must be assessed by a qualified person prior to the installation of appliances designed to reduce water consumption. The implementation process should be guided by a trained professional. These disclaimers are clearly stated throughout the use of the tool, to ensure that the users are aware that the tool output is purely an expression of estimates; in some cases they may be 100% spot on, but others may be out quite significantly. These results must only be used as a guide, and must be confirmed against as-built conditions.

For example, Joseph (2011) highlighted some older buildings which have had ultra-low flush toilets or other appliances installed, and subsequently have had to deal with blockages further down the drainage line. This is due to the drainage slopes being designed to current standards at the time of construction, and therefore they did not have enough gradient to carry away effluent and sludge in the piping network when the flow of water was reduced. Therefore, it is emphasised that consultation is required during the planning stage.

It would be ideal to include into the WERT the drainage slopes, or age of building – and therefore drainage standards of that specific era – as a method for improving the accuracy of the suggested results.

This step seals the action of understanding the implementation, as it is achieving the overall aim of helping buildings become more water efficient.

12.3.5. OTHER FEATURES

In order for the tool to be fully self-sufficient, there are other aspects which will be included into the future web-site based software. These include:

- Interactive forum;
- Online library;
- Contact details of partnered Project Managers and Product Suppliers; and
- Live monitoring dashboard.

The interactive forum is designed to allow common questions and answers between users (and administrators) as it is believed that discussion can be more informative than published documents, for some users. It also allows topics not included in the tool to be addressed.

The online library offers other documents, guides, and links for water use and associated topics which may be of interest to the users of the tool and/or website. The contact details of partnered Project Managers and Product Suppliers aid in providing implementation details and independent advice, if required.

The live monitoring dashboard is a proposed future addition, which will complete the monitoring package by providing up-to-date information on usage and leak identification. An example of this already exists through *Outpost Central* (www.outpostcentral.com).

12.4. VALIDATION

As one of the initial aims for this research was to provide something practical that has the potential for industry implementation to promote understanding of water use, the tool must be validated and tested in the industry. This sub-chapter tests the functions and outcomes of the WERT, and also tests it in an industry example in Wellington.

First, each of the 93 studied buildings in previous chapters, have been entered through each step of the tool, and the results compared and analysed. This provides an idea of the level of accuracy in contrast to the original dataset and benchmarking results. These have been done separately for the performance method and the prediction method. Secondly, the WERT has been used on a building with a potentially under-registering (under-performing) water meter to test its accuracy.

12.4.1. PERFORMANCE METHOD

Using the performance method of WERT, all 93 buildings were each entered. The following output is averaged for steps one through three. The performance WERT was designed to calculate, rate, and advise on how the subject building is performing as is, and its next steps of action.

Step 1 (A): Water Use Index Calculator

The below Table shows the WUI calculation output, as an average of all sampled buildings in each region. This includes any outliers previously excluded from the benchmarking analysis, as it is ideal to show all outputs in this instance.

	WUI ($m^3/m^2/year$)				
	Minimum	Lower Quartile (Best Case)	Median (Typical)	Upper Quartile (Excessive Use)	Maximum
Auckland	0.30	0.54	0.77	0.89	1.80
Wellington	0.24	0.69	0.97	1.29	3.43

Table 12.3: WUI Calculator Output

It is noted that there is a small (<6%) difference between the outputs above, and the benchmarks established in the previous chapter (Auckland 'Typical' of $0.76m^3/m^2$/year and Wellington 'Typical' of $1.03m^3/m^2$/year). This is both due to the fact that all buildings have now been included, and the WERT is based on the most recent billed year as opposed to the five year average used in the benchmark development.

Step 2 (I): End-Use Estimator

The end-uses for both Wellington and Auckland buildings have been averaged, and then combined to create the pie-chart in Figure 12.11. The outcomes were generally more consistent in Auckland than Wellington, hypothesised to be due to the greater level of focus placed on the efficient running of equipment in Auckland.

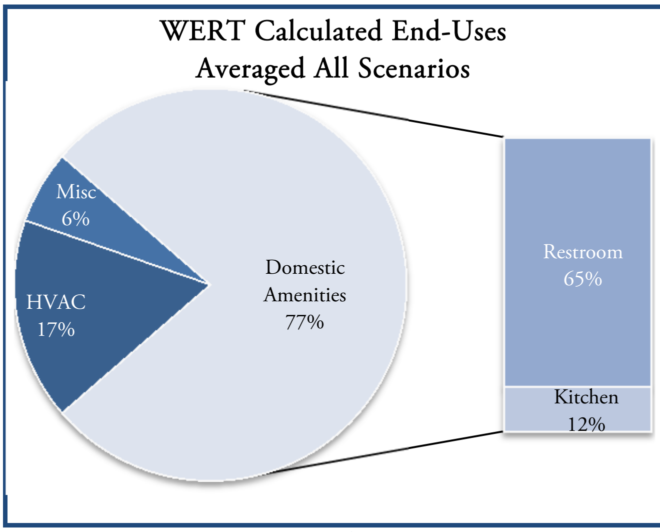

Figure 12.11: WERT End-Use Estimator Output

	Auckland	Wellington
HVAC	**29 %**	**21 %**
Domestic Amenities	**90 %**	**97 %**
Toilet	26 %	24 %
Urinal	16 %	24 %
WHB	32 %	26 %
Shower	10 %	13 %
Cleaners	0.9 %	0.7 %
Kitchen	16 %	15 %
Miscellaneous	**9 %**	**8 %**

Table 12.4: WERT End-Use Estimator Output

Table 12.4 has been calculated using all buildings, whether using HVAC or not; therefore, these percentages are averages, and will not add-up to 100%. These figures have been used to create the pie-chart in Figure 12.11. The breakdown of domestic amenities (non-bold in Table 12.4) are showing similar percentages as those shown in Figure 10.11, Figure 10.12, and Figure 10.13 for buildings W39, W14, and W3, respectively.

This shows that the highest usage areas are calculated to be in the wash hand basins, toilets, and urinals, as well as in the HVAC (overall, between both cities). The miscellaneous usage areas are hypothesised to be due to the unidentifiable leakages or appliances either being used or running inefficiently. This 'miscellaneous' figure is the difference between the most recent annual bill, and the annual consumption as calculated by the WERT.

When comparing the WERT results in Figure 12.11 with that of the Sydney example in Figure 3.7, the biggest difference is in the domestic amenities. The WERT miscellaneous usage is assumed to incorporate any leakages, or unknown uses in the building, not accounted for in the calculations. However, as the FWAs (see Chapter 10) did not measure leakage, nor is it predicted in the WERT, the percentages shown in Figure 12.11 could differ in reality. The Sydney example in Figure 3.7 shows 26% of the total water use can be attributed to leakages.

Step 3 (D): Financial Cost-Benefit Advisor (FCBA)

The FCBA takes the estimated end-use breakdown from step two, and the outputs from step one, and offers an efficiency package using the preferred financial term as the output. Again, all 93 of the studied buildings have been put through the FCBA, to formulate the details in Table 12.5 below.

Below are the [mean] averaged values for each output. These were tested using the 5-year average interest rate of 5% (RBNZ, 2011), and a 'low' budget for all items.

	New WUI	Payback Period	NPV	IRR	Investment	Savings	Savings
	$m^3/m^2/year$	Years	NZD$	%	NZD$	NZD $	% of m^3
Auckland	0.52	10.61	59,799.18	13	81,878.89	11,497.09	26
Wellington	0.68	27.25	-13,621.71	2	63,511.44	4,002.42	29

Table 12.5: Average FCBA Results

This shows a larger improvement potential in Wellington especially – with on average 29% savings by consumption (as opposed to financial savings). A reduced WUI, below the 'Best Case' benchmark, is achieved for both cities.

Seemingly less investment is needed in Wellington (assumed to be due to the bigger overall size of the buildings in the Auckland sample) for a higher percentage of savings by consumption. However, the financial viability of implementing these changes is severely worse off in Wellington. This is due to the tariff structures, as outlined in Chapter 9.6, limiting the cost savings from any water efficiency efforts.

12.4.2. PREDICTED METHOD

The prediction method takes all the details entered in the performance method, except the current water consumption, and calculates a WUI. This shows what the building should be using, or what it would be using without any leaks, etc, given the appliance schedule.

	WUI ($m^3/m^2/year$)				
	Minimum	Lower Quartile (Best Case)	Median (Typical)	Upper Quartile (Excessive Use)	Maximum
Auckland	0.04	0.47	0.62	0.75	1.15
Wellington	0.25	0.59	0.75	0.94	1.31

Table 12.6: WERT Predicted WUI Results

The difference between these results, and those in Table 12.3 under the current calculations, is primarily due to the difference in the calculation versus the measured reality. The scope of leakage has not been determined, and therefore cannot be calculated. Also, the calculation assumes that each appliance is operating correctly, without any human or mechanical error.

12.4.3. DEMONSTRATION

Chapter 10.2 noted that building W18 did not record any useful readings during monitoring and had a surprisingly low billed consumption in contrast to the overall sample. The water performance for this building was analysed, and then also predicted using the WERT. Table 12.7 shows that building W18 could be using up to 76% more than was being recorded through the water meter if the predicted WUI calculation is correct.

These recommendations were sent to the building manager and *Capacity Ltd* to see if a new water meter could be installed (such as that outlined in Chapter 10.2) and/or the existing meter be calibrated to double check the sensitivity.

Existing	Predicted	After Meter Calibration
0.24 m^3/m^2/year	1.04 m^3/m^2/year	1.01 m^3/m^2/year

Table 12.7: Building W18 Predicted WERT Validation

Upon calibration of the existing water meter, and receipt of the latest water bill, the building now produces a WUI of 1.01m^3/m^2/year. This is within 3% of the prediction method estimate, proving the accuracy of the WERT in an industry example.

12.5. SUMMARY OF DATABASE/TOOL DESIGN

This WERT has been designed for the targeted markets of management, consultants, and service providers. The WERT was required to be an accurate, realistic and relevant, practical, objective tool, which promotes action and understanding, and which could be implemented through effective communication.

These criteria were built into the tool through the WUI, End-Use Estimator, FCBA, and finally through implementation advice. Upon testing the tool, the prediction method proved to be within ~3% of the predicted WUI, demonstrating its relevance in a real industry application.

Several building managers and water service providers, as well as one council have expressed their interest to use this WERT for future analysis. Therefore, as this is seen as a potential real application, its implementation and business models are to be analysed, as well as other avenues of implementation. These form some of the next steps towards New Zealand becoming a water conscious country.

13. IMPLEMENTATION

Implementation considerations can be a determining factor in a product's success or failure, yet as Smith (2008) highlights, "relatively little consideration has been given to how the structure of a rating tool facilitates dialogue between different stakeholders in formulating and pursuing a project", or how it will actually function post-implementation.

This chapter considers the environment which the WERT is proposed to enter, and compares the tool to current New Zealand standards and measurements, and existing international calculators. The purpose of this assessment is to gauge where the New Zealand building and water industries are in terms of the market environment and preparedness to deal with demand-side management.

The implementation is discussed here in terms of methods, current industry challenges, and the theoretical views of these challenges. The barriers which may arise during any transition to 'water-use' thinking are outlined through analysing the current market environment. The most suited method of the implementation of WERT is then prescribed based on industry based workshops, and by taking this business concept and strategy through local business start-up support institutes, *VicLink* and *Grow Wellington*.

13.1. MARKET ENVIRONMENT

The market environment refers to the environment of the industry prior to any implementation of the WERT. The current situation is analysed in terms of issues and barriers, direct opportunities and competition, and alternate options. This situation can be considered from both a supply- and a demand-side perspective.

13.1.1. SUPPLY-SIDE MANAGEMENT

The supply-side focuses on providing water and related services. Supply-side management refers to actions taken to ensure sourcing and supply processes are conducted as efficiently as possible, to mitigate risks associated with peak demands, drought, loss of water quality, and any other foreseeable supply-side risks.

In New Zealand the "three waters:" stormwater, wastewater, and drinking water, are controlled by 67 local utility providers, and 12 regional councils (Land & Water Forum, 2010). However each of the three waters may not necessarily be under the same control – a situation which is highlighted in Wellington, where drinking water and wastewater utilise different charging mechanisms that are unrelated to one another.

At present, there is a lack of the uniform governance and management of water and its related services. There is a driving force coming from the water industry especially, outlined throughout the *Water New Zealand* conferences and publications released, for the need for governance and regulation at a national level.

A recent publication, the *Report of the Land & Water Forum: a Fresh Start for Fresh Water* (2010) highlights the New Zealand water issues:

> *"Water is also causing disputes – disputes about Water Conservation Orders and water infrastructure development; disputes about the intensification of farming and about run-off; disputes about water infrastructure in cities and towns, its discharges, and how it should be organised and paid for; disputes about who should be involved in its management, including the role of iwis"* (Land & Water Forum, 2010).

The report also goes on to describe the recent attempts to improve the national policies as being unsuccessful, ending with New Zealanders contesting one another through legal arbitrations (Land & Water Forum, 2010). The *Report of the Land & Water Forum* published in 2010, was the first step towards a national water strategy. It has identified that most effort and concentration is on water supply and rural infrastructure, with little effort being put into urban water demand or demand management. This is understandable as a national approach, targeting the biggest water users (estimated between 57% and 77% of New Zealand water is allocated for irrigation purposes (Counsell et al, 2005)) – the need for irrigation for food growth is also ever increasing. However, it might also be ideal to target the areas where the biggest opportunities may lie.

The lack of consensus on the supply-side is also affecting the demand-side. The lack of incentives and initiatives to promote water conservation and efficiency in buildings is neither a pressing concern nor emphasised to the extent to make people aware of the issues. This is not a problem unique to New Zealand. In a recent British study, participants claimed to understand that water conservation is a problem which everyone is responsible for, but did not know how to act (Doron et al, 2011).

13.1.2. DEMAND-SIDE MANAGEMENT

Demand-side is the source of demand, i.e. the individual consumers, post-supply. Demand-side management is typically "designed to shift the peak load to another time of day, cut the peak load, or reduce the total load by increasing end-use efficiency", by using "financial incentives, education, or other programs to modify the demand" for water (Government of Western Australia, 2012).

Demand management faces a number of barriers to its implementation, such as that of lack of education and involvement, and a lack of communication between and within businesses and staff. At present, the only form of end-user education in relation to commercial building water use is through the water invoice to commercial building owners, thus forming an administrative relationship. As Doron et al (2011) highlight, at this point "it is virtually impossible to relate the levels of consumption to the actual practice of it," and thus also, through lack of monitoring and accurate data collection, disables an in-depth understanding of how water is being consumed, other than in bulk through reservoirs – from the supply-side.

As the *Report of the Land & Water Forum* (2010) highlights, "volume related charging results in more efficient use of water … as price signals for supply act as a measure that can be used to encourage water efficiency." It is hypothesised that one of the most effective approaches to encouraging demand-side management (in all sectors) is through volumetric charging at a residential level – as well as at commercial level. This educates individuals at home and could aid in changing the relationship, from administrative to contractual (Wilde, 2011). For instance, water users in Auckland have been charged by volume for some time at residential level, and this shift in behaviour of water consumption is brought through to other sectors, also producing reduced energy demand through reduced pumping and treating requirements for water (Lawton et al, 2010).

This has been demonstrated through Auckland, Tauranga, and Nelson with the change to universal metering in their regions, as outlined in Chapter 11.2. "Those councils that apply volumetric charging tend to have much lower water use than councils that do not" (Land & Water Forum, 2010). Thus it is believed that individual education can affect the bigger picture in terms of water use.

While commercial buildings are already metered, cost-recovery from commercial building managers (to their tenants), educates end-users at work. In this thesis, in only one (building W4) of the 93 studied were cost-recovery mechanisms in place, based on the actual meter and sub-meter readings for that building.

Smith (2008) also points out that the integration of stakeholder and end-user values in the implementation phase enhances the ability of overall success, before the WERT can be introduced to the building industry. Industry feedback, collaboration, and critique are desired processes and characteristics, before the implementation.

13.1.3. INDUSTRY WORKSHOPS

Two industry based workshops were hosted in Auckland and Wellington during August 2011, which were supported by *VicLink*. These were undertaken for the purpose of understanding a number of things, such as current industry challenges from all angles, to gauge the effectiveness of the benchmarking study results and the tool from an industry perspective, and to understand any ideal future industry movements.

Personnel from the targeted industry categories (water service providers, building management, and consultants), among others, were invited to attend. Twenty-four participants in total attended the two workshops. Two forms of feedback were utilised: table discussions; and individual questionnaire feedback. Please refer to Appendix C9 for the template of the questionnaire that was used.

The industry personnel in attendance in Auckland appeared to be more senior in their respective companies, as opposed to Wellington. This is another indication that the level of importance placed on water as a valuable resource in Auckland is higher than in Wellington. The primary reason for attendance (as noted by participants) was to understand water efficiency potential for commercial buildings; by learning about benchmarking and understanding the appropriate steps of action.

The core of each workshop involved firstly providing feedback to the participants on the benchmarking study, as a way of gauging its usefulness and its effect on the targeted users. From these results, the most important pieces of information presented at the workshops were “benchmarking” and “details in fact” for the Auckland group, and “tariff differences” for the Wellington group. The least important piece of information presented was the general data (i.e. that without any real answers to problems) in both groups.

The next stage of the workshops involved more of an interactive setting, where the participants were asked to split into groups of three to discuss the challenges and struggles they (in their, and in other industries) were facing. This then took the form of table discussion and debate from the groups. What was really interesting here was the effectiveness of bringing a range of different industry personnel together to discuss these issues – this would not normally occur. The detailed results from both the table discussions and the individual questionnaires can be found in Appendix C10.

The common issue that arose in the workshops was the lack of customer (those paying for water) and consumer (those consuming the water) education, and the methods associated with increasing education. Also, the lack of incentives in Wellington to reduce consumption (through tariff structures) was queried more than once. The Wellington group were in favour of a tariff re-structure to match Auckland. This could benefit both building managers and water service providers. The building managers would have a much higher incentive to reduce consumption, which has the potential to reduce the demands on the supply network and postpone infrastructure investment.

This is supported by the financial analysis results outlined in Chapter 9.6 and Chapter 11.2, demonstrating higher financial savings opportunities in Auckland. Also, a key question put to the Auckland water service providers was “are there any incentives for buildings to implement monitoring or leak detection systems (i.e. sub-metering), as the capital cost can be very high?” This query provoked little response, but was recorded by all water service providers in the room for later thought.

When comparing the results from these two workshops to the British study by Doron et al (2011), the similarity in the lack of educational information being provided to both the customers and the consumers was strong.

The remainder of the workshop was occupied with the demonstration of the WERT, gaining feedback on its features, advantages, and benefits, while also highlighting any ambiguous or disliked areas. In regard to the three levels of WERT, the participants were asked to express their views on the usefulness and worth.

The questionnaire results found that Level 1: WUI "should be low-cost or free," as it is non-complex. Level 2: End-use Estimator is important, but Level 3: Financial Cost-Benefit Advisor, as an accumulation of the three levels, was the most desired as a "neat educational and informative tool." Please refer to Appendix C10 for more details on responses.

The participants were also asked to comment on which parts would be most useful to their industry, and other industries – and how they relate. The most prevalent comment, was questioning how it [the WERT] could be applied to *GSNZ*, and/or vice versa, to provide a more thorough, complete building performance package.

Seven of the attendees indicated that they would like to partake in pilot trials of the WERT, if and when it becomes available in the industry.

13.1.4. EXISTING PRACTICES

While Doron et al (2011) identify that the lack of educational information removes the direct decision support for water efficiency on an individual scale; this was also a common note in the industry workshops. The existing practices, in terms of standards, tools, and literature, will be assessed for their informative and implementation strategies.

In New Zealand there is no single legislation explicitly stating guidelines for water use in commercial buildings. The closest found comes from the *Building Act 2004*, as outlined in Chapter 4.1.2.4.

Other than this, there are currently no set targets for the consumption of potable water and its demand or supply rate in New Zealand, as there are for energy or GHG emissions. However, the benchmarking and WERT results from Chapter 11 and Chapter 12 can be discussed and compared to existing Energy Use Indices (EUIs) and *GSNZ*, among other national and international studies and performance guidelines. This is discussed further below.

13.1.4.1. ENERGY USE INDICES (EUI)

New Zealand standard *AS/NZS 4220:1982 Code of Practice in Non-Residential Buildings* is a guide for commercial property owners, designers, and engineers to use when considering the quantity of energy proposed or being used within their development/building. This standard also offers general guidelines for energy conservation in non-residential buildings. An EUI is similar to a WUI in that it normalises a common resource by NLA to allow rating and target setting.

Waggett et al (2006b) identify 'that information is available for energy use in offices and other buildings, and is regularly used at both the design and operation/management phases of the buildings to identify whether action is required.' Therefore, if water standards can match those of energy and/or emissions targets, their adoption and transition into the industry could be enhanced.

Building	EUI ($kWh/m^2/year$)		WUI ($m^3/m^2/year$)	
	Existing	New	Auckland	Wellington
Personal Services Consultants Technical Services Banks Office Buildings Retail Trading	200	100	0.76	1.03
Restaurants	400	200		
Wholesale Trading	150	80		
Classrooms	80	40		
Industrial Buildings				
with substantial process energy	100	0		
with little or no process energy	200	100		
Hospitals	500	250		
Laboratories	200	100		
Theatres	200	100		
Museums/Galleries	200	100		
Sports Buildings	200	100		

Table 13.1: Energy Use Indices and Water Use Indices (Source: Standards New Zealand, 1982)

Above in Table 13.1, the current EUIs for New Zealand are outlined, with the WUI benchmarking results from Chapter 11 inserted to the right. This shows the similarity in the models of measurement. Both are a measure of consumption against the building NLA, per year. Although it is not a performance tool, it still has the ability to be discussed as a sustainability model for implementation success in the targeted market, and also for collaborative opportunity.

BSRTs are seen as an excellent technique for demonstrating improved environmental effects on both buildings and the environment (Smith, 2008); however they have also been the subject of much 'greenwash' criticism in recent times. Smith (2008) also notes that they "allow owners, architects, building professionals, and authorities to select options, set targets, and establish goals, enabling sustainable development to take place in a more measured and accurate way."

The results this recent study showed were that sustainable building has a high marketing value, with few people opposing it (Smith, 2008), what is lacking is the balance of effective communication informing on how to move forwards toward the efficient use of water in New Zealand.

13.1.4.2. GREENSTAR NEW ZEALAND (GSNZ)

The *NZGBC* created *GSNZ* to: establish a common language and standard of measurement for green buildings; promote integrated, whole building design; raise awareness of green building benefits; recognise environmental leadership; and reduce the environmental impact of development (Smith, 2008).

The tool of interest here is the *GSNZ* for Offices. The water section of the *GSNZ* manual is categorised by four areas. WAT-1 Occupant Amenity Potable Water Efficiency (points are awarded for the reduction in predicted consumption through domestic amenities, heat rejection methods, and the use of non-potable water). WAT-2 Water Meters (use of metering and monitoring). WAT-3 Landscape Irrigation Water Efficiency (efficient systems or non-potable water use). WAT-4 Heat Rejection (either non-water or non-potable water systems). Please refer to Table 5.13 for more detailed information on these credits.

However, for the Energy section of the *GSNZ* for Offices tool, a compulsory maximum requirement of 105 kWh/m^2/year must be predicted for the building to be rated at all. It should be noted that this is higher than the EUI outlined in Table 13.1, under the *AS/NZS 4220* (Standards New Zealand, 1982). Due to the nature of the two resources (energy and water), it is suggested that a similar measure be implemented for water use also. Energy has a 25% weighting, while water has a 10% weighting contribution to the overall building rating.

EUI	WUI	
	Auckland	Wellington
105 kWh/m^2/year	0.76 m^3/m^2/year	1.03 m^3/m^2/year

Table 13.2: GSNZ EUI and Proposed WUIs

Since its implementation in 2007, fifty-two buildings have become *GSNZ* certified under the two versions: *Office 2009* and *Office Design & Built v1* (NZGBC, 2009). This tool has been used as an effective BSRT in New Zealand since its implementation, and is also seen as an effective marketing method for those buildings certified.

13.1.4.3. INTERNATIONAL RATING TOOLS

For the development of an interactive rating tool for water, three examples are used; the *Watermark* project (Kitchen et al, 2003), the *NABERS* tool (Bannister et al, 2005), and the *ADSM "Water Consumption Health Check"* tool (ADSM, 2009).

The *NABERS* tool assesses energy, water, waste, and the indoor environment (NABERS, 2011). Since its implementation, *NABERS* has been largely adopted throughout Australia. The tool allows the preliminary WUI to be calculated freely over the internet. The more detailed, full certification requires a FWA at a cost of approximately AUD$4,400 + GST (NABERS, 2011).

The *Watermark* project in the UK identified that the 'biggest barrier to the public sector in achieving savings in its water consumption was the lack of benchmarking and water management information across the public sector' (Parkinson et al, 2003). It has been stated that the *Watermark* is the most comprehensive study undertaken on water benchmarking (Quinn et al, 2006). On top of just a water performance calculator, a website was developed to:

- Provide a single information source for customers;
- Provide a focal point for communications;
- Provide easy access to reference material;
- Provide users with up to date news;
- Encourage use of a centralised database for disseminating information to customers;
- Facilitate a move away from email and phone as main means of communicating information to all customers and encourage staff to publish reference documents on the web and send links rather than copying the document to individuals;
- Facilitate customers awareness of Watermark and its associated services; and
- Develop an information sharing culture across the wider public sector (Kitchen et al, 2003).

After its implementation and research phase, the project found that the public water sector now had enhanced ability to achieve water savings by as much as 20% per building (Parkinson et al, 2003). However, the data has somewhat disappeared since the conclusion of the data collection and reporting of *Watermark*. It appears that the output is now administered by *ADSM* in the UK, who also have a simple online tool "*Water Consumption Health Check.*" The level of detail provided is not informative, and requires the user to enquire via a phone call to the company for further detail – a commonly avoided sales action by New Zealanders (Burns, 2011). There is no encouragement or advice for continuing with water efficiency, rather it just provides a 'pass' or 'fail' feature with no other detail.

While there is the attraction to build a quick and simple model, like the *ADSM* tool, long-term credibility can be potentially jeopardised (Larsson, 1999). However, two recently published studies on the development of performance tools in New Zealand identified the importance of simplicity, time intensity, and the establishment of design criteria to work towards, as key requirements from proposed tool users (Bennett, 2009; Stewart, 2008).

13.1.5. EDUCATION & AWARENESS

In both Smith (2008) and Doron et al (2011) studies, as well as the workshops for this study, a common outcome in the feedback was the lack of educational information being provided to the end-users (i.e. customers and consumers). In Doron et al's (2011) study, participants were wholly unaware of how much water they and their appliances were consuming.

Education and awareness go hand-in-hand, as one feeds the other. However, to enable educational promotion the method of communication is critical. Smith (2008) highlights that, "while communication of results is important at the end of an assessment, it is just as vital that communication between stakeholders (customers) and end-users (consumers) is created in the implementation phase of a rating tool."

A large proportion of the participants of Smith's (2008) study were not satisfied (31%) and hardly satisfied (30%) with the level of information currently available on sustainable building practices. Greater visibility of a rating tool's intentions and outcomes will naturally tend to generate effective information, benchmarking, and feedback processes (Bordass, 1997).

From a commercial tenant perspective, low staff awareness of resource efficiency is common. Envirowise (2009) highlight the "importance in raising awareness for the stimulation of staff participation and encourage others to become involved. To raise awareness and get buy-in, staff need to be given the facts about the true cost of waste, how the programme applies to them as individuals, and the benefits of resource efficiency to the business." This statement highlights the commitment requirement from senior management, while at the same time it reinforces the definitive need for volumetric charging (or cost-recovery) and thus, enabling consumers to be aware of their consumption.

Watercare Services Ltd already have in place an educational strategy by means of a simple graphic on their residential water invoice; where the blue droplet represents the current invoice consumption in contrast to the upper and lower band limits of dwellings of a similar occupancy (size) – in Figure 13.1 and Figure 13.2 below.

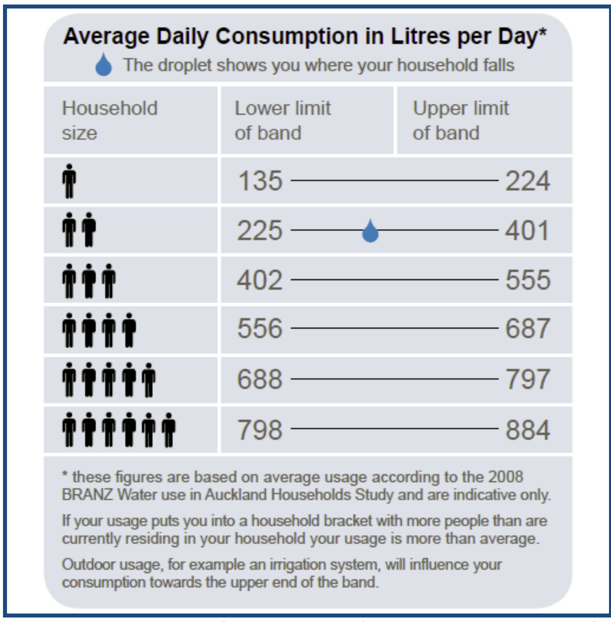

Figure 13.1: Image from an example Watercare Services Ltd Residential Water Invoice (Source: Watercare Services Ltd, 2011)

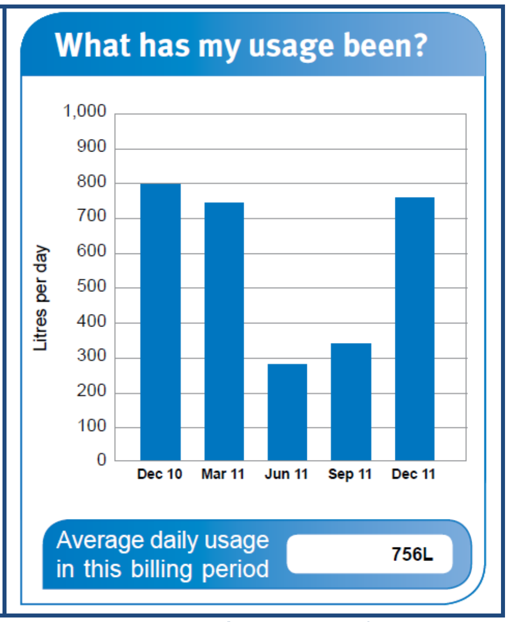

Figure 13.2: Image from an example Watercare Services Ltd Residential Water Invoice (Source: Watercare Services Ltd, 2011)

This also shows the previous invoiced amounts converted to litres per day for visual comparison. *Watercare Services Ltd* has enforced volumetric charging for water since the super-city merger in 2010 for all customers, with tariffs differing accordingly by customer (or connection) type.

13.1.6. TRANSITIONAL ISSUES & BARRIERS

A number of issues have so far been identified. These include a lack of supported educational or action information reaching the water consumers (end-users), as well as a lack of industry incentives for both understanding and reducing water consumption. This chapter considers other transitional barriers such as behaviour and managerial issues – which appear to be intertwined with education and awareness issues.

Quinn et al (2006) identifies that "behavioural aspects are often equally as important as the physical hardware that might be installed in office buildings to ensure that they are more water efficient." This means that technical measures, such as water efficient appliances, flow restrictors, etc, can only achieve so much. It is the "attitudes, behaviour, and competency of people using them" that determines their contribution to water conservation (Quinn et al, 2006).

Doron et al (2011) found their study participants pointing out important factors, such as the "hassle" concerned with making "big" changes, as well as the costs and investment associated with the upgrading of their current technologies – although their study had a residential focus.

The motivation for changing behaviour and technology is generally influenced by the knowledge of environmental information. Participants of Doron et al's (2011) study, felt they should be more regularly informed about their water use, by government, local authorities, or the water companies themselves. This shows that their participants were looking for educational information, and being more regularly informed of environmental issues and benefits, etc.

As a starting point, the *Report of the Land & Water Forum* (2010) proposes an investigation looking at the "possible benefits of rationalising the way these [urban] services are organised and that subsequently the issues of volumetric charging should be worked through collaboratively with stakeholders." If the key stakeholders are reluctant to adopt the tool, voluntary uptake will not occur and implementation will be slow. This is reflected in the attitude of the building industry, which has generally been slow to adopt change (Smith, 2008).

In summary, the biggest transitional barrier is educating the customers and the consumers through action-related information and communication techniques, although the educational, behavioural, and managerial (both at a community and individual level) barriers appear to overlap one another. The requirement for water efficiency in New Zealand needs to come first from the supply-side; this would then be filtered down through to consumer level. The lack of a national strategy and educational strategy is at present preventing demand-side potential from being realised.

Brown et al (2008) identify that for an effective change to occur in urban water management, there must be a "mutually reinforcing shift within each of the [three] pillars [cognitive, normative, and regulative] of institutional practice." They also go on to highlight that interventions are often focussed solely on either regulatory changes, or educational (cognitive) changes, failing to recognise the second and third "mutually reinforcing" shifts.

A number of different methods of potential implementation have been identified. These include national targets and building sustainability rating tools. In Smith's (2008) study, the participants indicated that *GSNZ* would not be the only tool, development, or initiative that would be required to assist the shift towards sustainable building in New Zealand, with the most desired piece of information being 'environmental and economic cost-benefit case studies.' A way of presenting this information has been identified through the use of the WERT.

13.2. WERT IMPLEMENTATION MODEL

Based on the results outlined herein, strategy has been formulated for the successful implementation of the WERT. Below is a summary of the proposed business plan.

13.2.1. WERT SUMMARY

The WERT is proposed to be implemented as an online software application, designed to rate, analyse, and facilitate the actioning of water efficiency in commercial office buildings. WERT offers evidence-based decision-making to identify water-saving solutions (savings have an estimated average of 28%) which leads to quantifiable triple bottom-line savings. Water end-uses can be estimated with high-usage (high-priority) areas visualised. Demonstration of the financial viability of implementing certain water efficiency measures enables the action of implementation. The benefit of this tool is realised when used in conjunction with on-site consultation to effect sound water efficiency decision-making and implementation.

13.2.2. THE CONCEPT

Wasted water is wasted money. Water and wastewater costs in the studied Auckland and Wellington office buildings ranged between NZD$6,630 and NZD$171,570 per year. Through the WERT and associated consultancy, commercial building managers can reduce their annual expenditure on water rates and tariffs. Through the industry workshops, it was identified that firstly, managers currently do not know if their buildings are water efficient or inefficient. Secondly, they do not know where to start to become more water efficient. And thirdly, they do not know what are the cost benefits of doing so are. In summary, there is a lack of education. Building managers have noted that their buildings become more marketable to potential tenants, the more sustainable systems are in place (Smith, 2008).

Water shortages during peak (summer) demand times are becoming a regular occurrence in some parts of New Zealand (Bates et al, 2008). By educating businesses and end-users on the effects of overusing water, and how to be water efficient or conservative, use of the WERT has the potential to delay the expenditure on implementation of new infrastructure.

Water suppliers can identify high users, and offer guidelines to their consumers on water efficiency measures, or subsidise the use of this calculator for them. The benefit to water providers is triple bottom-line, displaying social, environmental, and financial positives.

Currently buildings are not being rated in New Zealand for water performance, which means that building managers can only benchmark against their own portfolio of buildings year upon year. The target markets currently do not have access to the data to benchmark water use. This proposition provides these benchmarks relevant to regions specifically, and offers advice on moving forwards.

13.2.3. TARGET MARKET

The existing target market includes property managers and owners, water service providers and local authorities, and consultants. Through industry workshops with personnel from the target markets, the results show that there is a need for multi-factor decision aids to enable understanding and action towards water efficiency in New Zealand buildings such as the WERT, and tariff structure changes with neutral advice, which may require complex interactions between local authorities and water service providers.

As noted in Chapter 12.3, the WERT has been designed to provide appropriate information for a range of different users.

13.2.4. GO-TO-MARKET STRATEGY

The tool will be implemented on the internet as a secure log-in web-site, with a server back-up. Over the past three years, strong industry relationships have been established in the target market. The calculator together with the business model was demonstrated as part of the workshops. As a result, seven building managers, and two water agency and local authority personnel expressed their eagerness to participate in pilot trials, with one other building manager expressing their interest in further research and development work.

It is planned that through word-of-mouth and preferential auditing (e.g. from water service provider and local authority suggestions to their customers) that the initial go-to-market channels will be established. Passive advertising in sustainability focus groups and through meeting and pitching ideas to currently established partners will also be used to access the target markets.

Key partnerships with water service providers and local authorities would be ideal, with the intention of forming a quality mark type of certification scheme which entices customers to market their buildings as 'water efficient', if achieved. As well as being an independent rating forum, offering neutral advice and project management.

13.2.5. COMPETITION & COMPETITIVE POSITIONING

Real performance data from auditing 93 buildings differentiates this product from any competitors. The WERT will continuously gather data with each use, which keeps the performance benchmarks and results the most up-to-date. The full package includes the calculator, through to financial cost-benefit analysis, and an implementation service. The WERT acts as both a prediction (design) tool, and as a performance (analysis) tool, meaning it will describe both what a building should be using prior to construction, and how it is using water post-occupancy.

Branding will be a large part of the competitive positioning. Strategic relationships will be key to the promotion of the business, through national rating system/certification or subsidisation to consumers, etc.

The launching of the web-site and pilot trial of the finalised tool version will be critical to the WERTs success.

13.2.6. BUSINESS MODEL

It is envisaged that WERT will be paid for on a subscription basis. This could involve product tiers to match customer needs: from third-party advertising and minimal features through to an advertisement-free complete suite of functionality for "platinum users," as shown below in Table 13.3. There is also the possibility for subsidising by water service providers or local authorities for businesses.

Level	*Income Method*	*Notes*
Level 1: Water Use Index Calculator	Free Third Party Advertising	This level, together with generic web-links, forums, and information will be provided on the web-site free-of-charge with recommendation to further go through to next levels. Advertising from equipment suppliers is proposed as an income method.
Level 2: End-Use Estimators	Subscription	A subscription fee will be charged per user. An online library available on the web-page.
Level 3: Financial Cost-Benefit Advisor	Subscription	
Level 4: Value Added Consulting	Charge Out (Hourly)	Based on the project being undertaken, the charge will be time based.

Table 13.3: WERT Income Methods

Through strategic partnerships, it is expected that the marketable value of both the WERT and the implementation can be enhanced. Value will also be created through continuous activities in research and development, and being very up-to-date with the data presented to customers, which is self-generated through capturing customer data with each use of the calculator.

The foreseeable future growth of this project will be through expansion to the major commercial areas of New Zealand, expansion to include data for other building types, and through adapting to other industries and resources. In addition there is the potential to apply the tool overseas in the long run, especially in cities such as Perth, Dubai, Singapore, and Hong Kong where water is a highly valued commodity (both monetarily and non-monetarily).

To begin with, capturing the Auckland market through already established relationships and through other building management partners will be the initial aim. By discussing a quality mark package, this could then offer the WERT further afield in the targeted markets. Research and development is a key characteristic of this concept, and should be continuous, to keep education, innovation, and awareness as high as possible.

13.3. SUMMARY OF IMPLEMENTATION

The current market environment is majorly focussed on the supply-side management, as also outlined in Chapter 2. There is an encouraging shift, with the *Report of the Land & Water Forum*, towards a potential regulative change focussing on demand-side management opportunities. Through existing applications, it is proven that 'those councils that apply volumetric charging tend to have much lower water use than councils that do not'.

The most important pieces of information taken from the two industry workshops were 'benchmarking' and 'details in fact' for the Auckland group, and 'tariff differences' for the Wellington group. A common issue noted during these workshops and in the British study (Doron et al, 2011), was the lack of customer and consumer education, and the methods associated with increasing education. The fact that this diverse group of industry personnel were brought together into one situation was also not common, where a number of responses prompted further action or investigation on specific issues.

From a commercial tenant perspective, low staff awareness of resource consumption is common. However, as behavioural aspects are often equally as important is the physical hardware that might be installed in office buildings, it is education that is in much need of attention.

The lack of information being provided by the government, local authorities, and water suppliers could be improved. The biggest transitional barrier identified the lack of customer and consumer education through action-related information and effective communication techniques – such as that used by *Watercare Services Limited* in their residential water billing.

SECTION SIX: DISCUSSION

The discussion and key findings, which lead to future recommendations, are outlined within the sixth and final section. The aim of this section is to determine: if the research questions and aims have been met; provide a response to the hypothesis; and set the research in context by outlining its contribution to the literature.

Chapter 14. Discussion highlights key reflections of the main aims and research questions, and puts the research contribution in context. Chapter 15. Conclusions is where the principal results and the significance of these findings can be found, along with future research avenues which could be considered.

14. DISCUSSION

The overall aim of this research was to understand the water use performance of New Zealand's commercial office buildings, by testing the methodologies (refer Chapter 1.2.3.) as a means of setting suitable water performance benchmarks for commercial office buildings.

The specific aim of this chapter is to describe and discuss each of the previous sections, and how they contribute to the aims and research questions posed in Chapter 1.2.2:

- How is water used in New Zealand office buildings?
- What determines water use efficiency?
- How do New Zealand office buildings compare internationally?
- What is needed to provide the support for higher levels of water efficiency and conservation?

14.1. LITERATURE REVIEW

This section reviewed the existing literature. Its aim was to outline any issues relating to: water supply for New Zealand; water consumption; measurement and allocation of water; and water benchmarking and analysis tools.

Through analysing the existing literature on New Zealand's water supply, there is an industry perception that the water supply guidance for dealing with demand is largely non-existent (refer Chapter 2). The bulk of present publications are explicitly for the purpose of ensuring water supply is able to meet future demands. What the majority of the literature fails to recognise is that water and its availability are limited, and the focus must now be turned to finding ways to reduce water use demands.

The *Parliamentary Commissioner for the Environment (PCE)* has outlined through a number of reports, the effects that demand management and water efficiency strategies can play on the supply-side (Williams, 2001a). These need to be recognised as avenues where much progress could be focussed.

Given that commercial office buildings account for at least 27% of the non-residential building stock in New Zealand, little work has been put into understanding how water is consumed in these buildings. There does not appear to be a coherent method of reporting and/or evaluating performance within specific building types within New Zealand, other than for residential buildings (Heinrich, 2008, Heinrich, 2007), and for commercial building energy performance. In fact this thesis is the first research published on water performance in New Zealand commercial office buildings.

The primary water end-uses in comparable Australian buildings were in the Heating, Ventilation, Air-Conditioning (HVAC), primarily through the use of evaporative cooling, and the domestic amenities, with a similar proportion being lost through leakage (Quinn et al, 2006). To understand water use, the drivers of water demand first needed to be determined in the New Zealand context. This has been enabled through categorising the drivers into: building influenced; people influenced; and equipment influenced drivers.

With the use of effective water metering, water can be measured and charged for accordingly; thus, educating the customers (and/or consumers) through the quantity of water used, and helping to understand water use more accurately over time – as opposed to a static, annual, or periodic figure. The next step in understanding how demand management can help, is through monitoring and auditing water use, to help formulate an indicator which the users and managers of these buildings can easily implement into their existing operating strategies.

The 'increasing block rate' was identified as the most effective tariff structure for promoting water conservation, which increases in unit cost as the volume of water increases beyond specific limits. It was puzzling to find that some New Zealand regions which are facing water shortages in the near future may still be incentivising higher consumption levels through poorly structured tariffs and allocation strategies – such as the 'decreasing block rate', outlined in Chapter 4. However, there does not appear to be a single guide or legislation challenging these tariff structures in New Zealand.

Performance benchmarks, those that 'designate efficient levels of use', allow their respective building categories and regions to be assessed for water performance and water efficiency, as well at an individual building level. International studies, such as those from the UK (Kitchen et al, 2003; Waggett et al, 2006b), Australia (Bannister et al, 2005), and the USA (Dziegielewski et al, 2000), provided reference material on methods, results, and outcomes. All seven of the reference studies outlined in Chapter 5 demonstrated a significant relationship between water either Net Lettable Area (NLA) or Full Time Equivalent (FTE) occupants, or both.

At present, no formal water use benchmarking system exists in New Zealand for commercial buildings. This not only makes impossible any comparison between regions, but also the awarding of points for efficient levels of water consumption in any Built Sustainability Rating Tool (BSRT). It is this lack of any assessment system which inhibits the promotion of conserving water, and which presents the biggest opportunity for improvement, both at a research level and at an industry/commercial level. The only rating system in New Zealand currently is the *Green Star New Zealand (GSNZ)*, which has no performance baseline for water.

14.2. METHODOLOGY

The methodology chapters aimed to provide the principal methods for selecting the buildings to be studied, collecting the water performance data, and turning that data into useful benchmarking indices through analysis.

The building selection criteria meant that the study used a non-random sampling approach. However, as 93 buildings were studied overall, or approximately 0.7%, of buildings which could potentially meet the stated selection criteria. This is relatively close to the 1% aim proposed by Kitchen et al (2003), in their study in the UK. The selection criteria ensured each building had ≥80% of the NLA classified as office use, was multi-storey, had a metered water connection, and was physically located within the CBD boundaries outlined in Figures 6.1 and 6.2.

The use of the Building Warrant of Fitness (BWOF) in each building as a means to provide both relevant contact details for the building owner or manager, and to determine whether the building met the selection requirements, proved very time efficient. However, a large number of the BWOFs on display were either majorly incomplete or left blank.

Through the development of the empirical methodologies in Chapter 7, it was found that energy auditing methods and other international methods could be adapted. Firstly, permission and consent were gained from the building owners or managers, which achieved a 90% participation rate, giving the 93 building sample size. The Survey Level Water Audits (SLWA) utilised two forms, the Information Sheet completed by the building manager, and the Site Survey Sheet completed collaboratively during the site visit. This primary SLWA dataset then fed into the benchmarking analysis.

Finally, the Full Water Audits (FWA) included detailed monitoring on a smaller sub-set of the sample. This included installing monitoring equipment onto the main water meter in four (three completed) buildings from within the initial SLWA sample.

The data from the above processes were then analysed using methods which were adopted both from international studies, and from examining the current dataset to ensure the most appropriate model was being utilised, as outlined in Chapter 8. In simple terms, the data went through statistical and graphical analyses to form the Water Use Index (WUI) and benchmarking index model. The benchmarking index model builds on Bannister et al's (2005) set of benchmarking rules, and follows the market-based approach to allow implementation of the proposed model at a later stage.

14.3. FIELD STUDY ANALYSIS

The aim of the field study analysis was to provide a practical response to the first three research questions: how is water use in New Zealand office buildings; what determines water use efficiency; and how do New Zealand office buildings compare internationally?

From examining the 93 buildings in the collected sample, a number of observations were made. Ultimately, through the site visits, observing and recording each water end-use, location, approximate age, and physical condition, contributed to understanding where, why, and how water was being used in the existing office buildings within the sample.

As the location of the water meter(s) was largely unknown by a significant proportion of building managers, actually locating the water meter and talking through the meter characteristics was a valuable exercise for them. In the buildings studied, only a small portion had sub-meters installed in their buildings, and an even smaller proportion used these sub-meters to inform their cost-recovery methods with their tenants.

The percentage of buildings with domestic end-uses less than the *Water Efficiency Labelling Scheme (WELS)* certification was larger than expected. However, it was established that office buildings would generally be retrofitted every 10-15 years, while the *WELS* was published ~7 years ago, therefore the uptake of *WELS* rated appliances in these buildings is expected to increase in the coming years.

However, this slow implementation of the *WELS* rated appliances may also be linked to the tariff structures, or lack thereof. It was obvious through the analysis of tariff structures between Auckland and Wellington that well designed tariffs can incentivise water efficiency or water sensitive thinking on an individual level and on an institutional level. This in itself is an important finding which can contribute to both future research on optimum tariff structures, and practical guidelines for existing suppliers in New Zealand.

In terms of the FWAs undertaken, there have been real benefits, not only have time-of-use flow patterns and loads been able to be identified, but also the advantages of leak detection have been presented. In the sub-set of three completed FWA buildings, the base water loads were NOT determined by the presence or absence of people, but were driven by the building itself and/or its appliances. However, the daytime load was majorly determined by the occupants using the appliances, and thus was controlled by the presence of people. Therefore, the use of water was able to be split into the three categories proposed in Chapter 3: building; occupants; and appliance driven.

The FWA study demonstrated the importance of undertaking water monitoring at the more detailed level, both as a method of understanding how water is used, and how water efficiency can best be applied. However, as the sample size was small (n = 3), it should not be used as a representation for all New Zealand office buildings, rather as a guide based on the buildings described. The method however, provides opportunity for further research at this level to determine a more statistically representative outcome for New Zealand, and/or other regions.

The demand for water had little-to-no relationship with the ambient temperatures, unlike other international studies. The effects of statutory holidays were noticeable within the annualised water use data, for which the significant Christmas/New Year dip in the regional water demand is a response of. This was unable to be concluded from the SLWA historic billing data, justifying the necessity of the FWA study.

Upon assessing the dataset for the most appropriate normalisation measure, both the single and multiple regression analyses produced the same formula (Equation 11.1) for predicting water use. The benchmarking studies showed that NLA was the best driver for water use in this sample of office buildings. This is in line with existing international studies, where NLA was recognised as being one of the two most appropriate drivers of water use (the other being FTE occupants). This means that designers and building performance engineers can now predict a baseline water use (in Auckland and Wellington buildings) based on this equation.

The ANalysis of VAriance (ANOVA) tests showed that a separation of the benchmarks by geographic location was necessary for this dataset. The reasoning for this was explored, and hypothesised to be largely influenced by the tariff structure differences in the two locations (both at a commercial and residential level). However, if the efficiency-based approach was to be used, the median of the totalised dataset ($0.84m^3/m^2$/year) should be used. This in itself promotes an opportunity for further discussion and/or research.

Each participant was provided with an audit report on their individual building(s) at the conclusion of the data collection and analysis stages, showing their building's performance in contrast to the overall sample. The feedback from this reporting stage was very positive, and in some cases was being implemented during upcoming retrofits of the building's common areas.

Internationally the proposed benchmarks place both Auckland and Wellington between the UK and Australia in terms of benchmarking by NLA, which is about mid-range (refer Figure 11.14). These international studies had sample sizes of 5 in the USA (Dziegielewski et al, 2000), 132 in Australia (Bannister et al, 2005), 555 and 2,592 in the UK (Waggett et al, 2006b; Kitchen et al, 2003). The population of commercial buildings is expected to be much larger in these countries than in New Zealand, given the human population is 71 times larger in the USA[1], 14 times larger in the UK[2], and five times larger in Australia[3], than in New Zealand[4].

Using the data collected and developed in this thesis, it was calculated that a random sample size of 260 office buildings is needed to allow for complete statistical representation of New Zealand commercial office buildings, at 95% confidence probability.

14.4. TOOL DEVELOPMENT

With the aim to develop an interface to this thesis, and provide a practical medium which could provide understanding and/or education to the building and water industries, a Water Efficiency Rating Tool (WERT) was developed, validated, and implementation proposed.

This WERT was designed for building managers, consultants, and service providers specifically, and was built around a number of design criteria. These criteria were incorporated into the tool, through the WUI, End-Use Estimator, Financial Cost Benefit Advisor (FCBA), and then through implementation potential. Upon testing the tool on a study building it proved to be within ~3% of the prediction – thus, demonstrating its validity in an industry application.

[1] 2011 USA human population: 314,129,931 (United States Census Bureau, 2012).
[2] 2011 UK human population: 56,075,900 (Office for National Statistics, 2012).
[3] 2011 Australia human population: 22,696,013 (Australian Bureau of Statistics, 2012).
[4] 2011 New Zealand human population: 4,434,460 (Statistics New Zealand, 2012).

This WERT, together with the results from the field study and benchmarking analysis, was demonstrated in two industry workshops, several building managers, water service providers, and a local council expressed their interest to use this WERT for future analysis. Therefore, as this is seen as a potentially real application, its implementation and business model were also analysed, as well as other avenues of implementation. These form some of the next steps towards New Zealand becoming a water conscious country.

The current market environment was found to be majorly focussed on the supply-side management, as also outlined in the Section Two. However, there is an encouraging shift, with the *Report of the Land & Water Forum* (Land & Water Forum, 2010), in potential regulatory changes towards demand-side management. On an individual basis, it is all three pillars [cognitive, normative, and regulative], as identified by Brown et al (2008), that are falling behind in a "mutually reinforcing" way. A major transitional barrier is the lack of educational information being made available to customers and consumers, on the cost effects and benefits of implementing water efficient measures.

The implementation of water sensitive thinking, especially through the industry workshops, showed that there needs to be a movement towards water efficiency at a regulatory level. Through the development of the WERT and modelling its implementation, it found that the WERT provides a method for understanding how water use efficiency levels can be achieved on an individual building scale.

14.5. SUMMARY OF DISCUSSION

In relation to the research aim, the contribution of the research has been discussed in the context of its contribution to the body of knowledge.

The field study analysis and observations produced information on what kind of end-uses and facilities are provided in existing New Zealand office buildings, as well as details on influences of poorly designed tariff structures and legislation. The detailed monitoring provided time-of-use profiles which helped to determine how water is used, and what base loads are driven by. The obvious leak detection opportunities from monitoring were also demonstrated.

The benchmarking index model development demonstrated that NLA was the most appropriate driver to be used for normalisation, and created a prediction formula for water use based on this development. The two regions separation was hypothesised to be heavily influenced by the difference in tariff structures and supply-side demand management implementation.

Building managers, owners, and users can now put a baseline on their water performance. There is now an understanding of how, when, and where water is being used in commercial office buildings in New Zealand. New Zealand can now be compared internationally, and building managers can compare internally in an un-biased manner for commercial office building water use.

All of this information has been brought together to provide an interactive, educational, and informative tool (the WERT), which provides an interface to this research for industry and research use. This, through both the very high participation rate, and the very positive industry feedback (through workshops and reporting feedback) has demonstrated the practical research contribution of this applied research to the building and water industries as well as providing many future research and commercial opportunities.

15. CONCLUSIONS

As highlighted in Chapter 2, there is an increasing amount of literature outlining the issues underlying water shortages and restrictions to come in most regions throughout New Zealand, especially during the drier summer months. The problem is exacerbated through both a rising demand (via increasing population) and climate changes such as increasing temperatures, and reduced rainfall patterns for most of New Zealand.

However, no attempt has been made in New Zealand to assess how commercial buildings, via their users, are consuming potable water. There are no benchmarks for water performance in buildings, thus discouraging any attempts made in improving water efficiency in New Zealand. There are a few international examples of water consumption in these types of buildings, but these may not be appropriate for New Zealand buildings due to climatic, technical, and behavioural differences.

With the aim of understanding the water performance of New Zealand's commercial office buildings, 93 office buildings in Auckland and Wellington were analysed, testing the methodology as a means of establishing suitable performance benchmarks for these buildings. This empirical research approach was undertaken in an attempt to develop not only water performance guidelines, but also an implementable model of water demand which would sit well in the targeted industry market.

With regard to the initial hypothesis that *'a water performance benchmarking index system can be developed using performance based water consumption data obtained from water auditing a number of New Zealand commercial office buildings'*, the research found that the answer is – YES a benchmarking system can be developed. This research has demonstrated a method for the implementation through a Water Efficiency Rating Tool (WERT), making these benchmarks accessible to the building and water industries. The statistical analysis found strong evidence justifying the development of Water Use Indices (WUIs) based on the empirical methods used herein.

This research has provided the beginning of a database for developing and establishing water performance benchmarks, in which similar methods could be applied to other commercial building categories, for example retail and institutional buildings. This chapter further summarises key findings by thesis phase, any further recommendations, and then finishes with the significance of this research.

15.1. SIGNIFICANT FINDINGS

A number of key findings were established during each phase of the research, which have been further discussed below. These have been outlined by section of the thesis, starting at the literature review, then methodology, field study analysis, and tool development.

15.1.1. LITERATURE REVIEW

The literature review found a small number of existing guidelines on water use in commercial buildings in Australia, the UK, and the USA. These publications are very specific to certain fields, for example Heating, Ventilating, Air-Conditioning (HVAC), appliances, water meters, or benchmarking, and ranged in sample sizes (from 5 to 2,592 buildings). However, when considering total building water use the most comprehensive publication found was the *'Handbook of Water Use and Conservation'* (Vickers, 2001) and the *SWC* studies (SWC, 2007), which provide information on how often people use certain water end-uses in an office environment, and guidelines on how water is used in an office building, respectively.

It was concluded, both in this study and by the *IPCC*, that "ongoing water security problems are very likely to increase" (Bates et al, 2008) in high demand areas in the near future. In New Zealand such areas are Auckland, Hamilton, Wellington, and Christchurch – with Auckland potentially reaching water supply capacity by 2039.

This is influenced by both the changing climate, and the ever growing population – thus reducing the individual water share.

As identified in Chapter 3, approximately one quarter of urban water demand is attributed to industrial and commercial buildings. However, it is only for a small percentage of regions that this data is available, and the percentage figure can thus far not be disaggregated any further. As a result, no water use breakdown is available nationally.

A number of methodological reports from Australia identified the proportion of water consumed by particular areas in an office building. It was found in Sydney that approximately 37% goes to domestic amenities, 31% to HVAC cooling, 6% going to other uses (such as cleaning, irrigation, and ground floor uses), while the remaining 26% is consumed through leakage/baseflow (Quinn et al, 2006).

There are a varying number of tariff types and structures currently used around the world. The decreasing block rate effectively incentivises people to use more water in order to pay less, and is still very much present in some New Zealand regions and internationally. The reverse of this, the increasing block rate, could well be more effective at promoting water conservation. However, this can only be implemented if water metering exists.

Current legislation for demand-side management of water is very much lacking in New Zealand, other than a small statement in Part 1 Section 4(o) principles of the *Building Act 2004*, and the *Report of the Land & Water Forum* (2010).

Two methods of auditing buildings were identified: Survey Level Water Audit (SLWA); and Full Water Audit (FWA). For the FWA, there are a number of items of monitoring equipment available in New Zealand, however these must be appropriately matched with their compatible water meters.

At present no formal benchmarking system exists in New Zealand, limiting any attempts for comparison and target setting. The two types of benchmarks, consumption and performance, were considered, which can also be broken into market-based and efficiency-based. It was decided that, for the purposes of this research, the performance market-based benchmarks would be most appropriate. This was mainly due to the percentage of population exclusion, and added complexity and understandability – which could potentially create a less than ideal market uptake.

The development of benchmarks from the international studies identified showed Net Lettable Area (NLA) and Full Time Equivalent (FTE) occupants to be the most suited water consumption drivers. A climate normalisation calculation established in an Australian study was used to consider international placement without the effects of climate related evaporative losses. A number of existing international self-assessment water rating tools were also identified. However, none that offered a complete package of detail through to promotion of action or implementation was identified. The *Watermark* project (UK) has been identified as the 'the most comprehensive study on commercial building water use', collecting data from 555 buildings (Quinn et al, 2006).

15.1.2. METHODOLOGY

The buildings were selected non-randomly, using Auckland and Wellington as the main focal areas. Ideally a total of thirty buildings from each area were desired, for acceptable statistical significance. The Building Warrant of Fitness (BWOF) was found to be the most effective method of gaining building manager contact details, and basic building characteristics; although most were found to be very much incomplete.

A 90% response rate was received at SLWA level, with 93 buildings (37 in Auckland and 56 in Wellington) being audited at this level. The water auditing methods included permission and consent (both participation and access to historic billing data consents), information sheets, and site visits.

The four (three successful) FWA buildings (all in Wellington) were selected on the basis of the installed meter compatibility with the available pulse sensors. The time-of-use monitored data showed that the most appropraite recording interval was 10-minutes, which still provided enough sensitivity to analyse the data in-depth, but kept the data at a manageable size.

It was also found during this phase that the disaggregation of end-uses was virtually impossible without the implementation of extensive sub-metering throughout the buildings – as a result the available software *TRACEWIZARD* is not appropriate for commercial scale projects. However, when undertaking the fingerprint analysis in building W39, the following detail demonstrated significant variance in flow rates throughout the building, which could be influenced by the staged tank system – having higher flow rates on the lower floors (due to increased force of gravity) than on the floors immediately below the relevant tank.

Appliance	Minimum Flow Rate or Duration	Mean Flow Rate or Duration	Maximum Flow Rate or Duration
Toilet	3.40 seconds/flush	12.74 seconds/flush	27.80 seconds/flush
Urinal	2.40 seconds/flush	7.94 seconds/flush	19.40 seconds/flush
Wash Hand Basin – HOT	5.55 L/minute	16.13 L/minute	34.41 L/minute
Wash Hand Basin – COLD	6.19 L/minute	18.62 L/minute	56.96 L/minute
Wash Hand Basin – MIXER	4.19 L/minute	5.33 L/minute	6.68 L/minute
Shower	14.08 L/minute	20.30 L/minute	24.49 L/minute

Table 15.1: Fingerprint Measured Flow Rates

Statistical techniques for analysing the dataset included outlier identification, a simple linear regression, multiple regression, and ANalysis Of VAriance (ANOVA) to determine the most appropriate driver for water use, and for the benchmark development.

15.1.3. FIELD STUDY ANALYSIS

The vast majority of businesses (by count) were identified as "financial and insurance services" or "professional, scientific, and technical services", which meant the selection criteria was appropriately used. The occupant density was skewed based on whether government agencies occupied the building, with smaller per occupant areas than if private offices were tenanting the buildings.

In a number of cases multiple buildings shared their sole water meter with another building. This meant the building data had to be combined to match the water data. It was also understood that the general range of water meters utilised around the world have a relatively short life span (~10 years). The predominant water meters in Auckland were the *Elster-Kent C4000* (combination) meter, while in Wellington the older *Elster-Kent H4000* (Helix) meters were more prevalent. There are maintenance regimes in place in both Auckland and Wellington, to progressively replace all water meters five or ten years old, respectively.

Only 26% of the studied buildings employed sub-meters, however only 30% of these sub-metered buildings' managers were aware of the presence of the sub-meters and/or their locations. Only three buildings used the sub-meters to determine charge-recovery of the water bill from tenants. The sub-meters were predominantly installed on cooling towers in Auckland.

Most (56%) of the buildings employed water-cooled heat-rejection systems (cooling towers), however the sample of buildings were all in the upper quintile of building size, by NLA, as per the *Building Energy End-use*

Study (BEES) stratification method. The field study found these heat-rejection systems were often newer in Auckland than Wellington, as were the installed domestic appliances.

A higher level of *Water Efficiency Labelling Scheme (WELS)* rated appliances were found in Auckland also. However as the *WELS* standard is still relatively new in regard to the frequency of building upgrades, the uptake is still rather low in these office buildings studied. Over the complete dataset flush valve and single flush toilets (i.e. the least efficient flushing systems), comprised 89% of all toilets identified and recorded. Likewise, a similar proportion was found for urinals, with 52% using cyclic (timed) flushing mechanisms.

It was also identified that, due to the tariff differences in Auckland and Wellington, the cost benefits, or rather the payback period for replacing the urinal flushing mechanisms in one building, was more than twice in Wellington (1.17 years) than in Auckland (0.46 years)

The tariff structure for both cities was considered, using a hypothetical building scenario: NZD$59,000,000 capital value, using 28,000m^3/year of water. Using the 2011 rates, the Table 9.9 outlines this scenario. A lack of understanding and/or regulatory change is apparent, which could severely influence the demand management in those regions.

This showed that primarily because the Wellington wastewater tariff is hidden within the annual council rates, and does not appear on the water invoice, building managers believed they paid three or four times as much for water in Auckland than in Wellington. Wellington in fact pay only ~3% more than Auckland for a similar building. It was also found that Auckland buildings harvesting rainwater were able to avoid a similar proportion (to harvested rainwater) of wastewater charges due to the wastewater tariff being charged at 75% of the ingoing potable water amount.

The detailed water analysis considered regional demand data, billing data, and monitored data. When the billed data was plotted against the respective region's water demand line, the visual correlation was minimal due to the difference in recording frequencies. The point of interest was the summer holiday (Christmas/New Year) period when the buildings are expected to be closed or operating with reduced staff numbers for up to three weeks. The demand line drops significantly over this period, while there appears to be only a moderate dip in the building data.

The monitored data showed obvious day/night and weekday/weekend patterns. All monitored buildings rarely reduced completely to zero usage. Time-of-use flow patterns and loads were able to be identified; however the benefits of leak detection were encountered along the way. When estimating the appliance end-uses, it was found that the biggest water uses were from the restrooms (wash hand basins, toilets, and urinals).

Annual charts aided in the visualisation of the consumption, especially over the summer holiday period. This shows that the building demands do in fact reduce significantly over this period. The peak for each building occurred around February (anomalies aside) and the trough was obviously around January, probably due to the Christmas/New Year holiday shut-down period.

It was interesting to find no correlation in the relationships between ambient temperatures, water demand, or water consumption. On first thought, it was assumed that there would be a much stronger correlation, caused by the climate influenced evaporative losses. Although the three buildings did not employ water cooled HVAC, it would be ideal to undertake this FWA monitoring on a building with cooling towers.

It is concluded that NLA is the most statistically and pragmatically appropriate normalisation factor to be used for water performance benchmarking in New Zealand. When using both simple and multiple regression analysis, the same formula (as shown in Equation 11.1) was concluded for the prediction of water use based on NLA, whereby the prediction is that with every increase in NLA of 1m^2, the water consumption will increase by 0.79 m^3/year, with a base use of 1,834 m^3/year.

A number of statistical tests were performed on the collected dataset, with the results concluding that Auckland and Wellington benchmarks should stand independent from one another when employing the market-based approach to benchmarking. These benchmarks are outlined in Table 15.2 below.

Auckland	PERCENT OF SAMPLE AT THIS LEVEL OR BETTER	Wellington
0.57 m^3/m^2/year	25% (Best Case)	0.73 m^3/m^2/year
0.76 m^3/m^2/year	50% (Typical)	1.03 m^3/m^2/year
0.97 m^3/m^2/year	75% (Excessive Use)	1.33 m^3/m^2/year

Table 15.2: Proposed Benchmarks for Commercial Office Buildings

It was found that the Wellington 'Best-Case' benchmarks are not that dissimilar from the Auckland 'Typical' benchmarks. However, if an efficiency-based system were to be implemented, the median of the entire dataset would be more appropriate (0.84m^3/m^2/year).

The reason for the difference between Auckland and Wellington's market-based benchmarks was investigated. This led to the hypothesis that the reason for the difference in benchmarks between Auckland and Wellington was primarily due to tariff structures, but may also be influenced by the use of residential metering in Auckland, therefore promoting awareness and understanding of individual consumption in the commercial sector as well. Together with the experience of water shortages first-hand, and higher tariff incentives in Auckland, it has prompted a higher awareness of water related issues than in Wellington, and thus the reason for the benchmark separation.

Internationally, these benchmarks are on par with similar Australian building (*NABERS*), and suggest the New Zealand buildings are performing far better than the American studied buildings (*CIEUWS*). However UK buildings appear to use much less water (*CIRIA*, *Watermark*).

These benchmarks were climate normalised by Cooling Degree Days (CDD) to 15 °C wet-bulb, to test the benchmarks without the effect of climate induced evaporative losses, as per Bannister et al's (2005) study results. This caused the Wellington benchmark to be much higher, only exceeded by the *CIEUWS* (USA) study. The Auckland benchmark stays much the same in terms of international placement, although there was only a very weak correlation between water use and the ambient temperatures for these two regions (Auckland and Wellington).

15.1.4. TOOL DEVELOPMENT

A Water Efficiency Rating Tool (WERT) has been developed using the performance based data collected in the field study phase, using *MS Excel*, and is proposed to be implemented as a web-based software application, designed to rate, analyse, and facilitate the actioning of water efficiency in commercial office buildings.

The WERT was developed using criteria such as accuracy, relevance, practicality, promotion of understanding and action, and most of all, effective communication. The WERT offers evidence-based decision-support to identify water-savings solutions, which lead to quantifiable triple bottom-line savings. Each of the 93 buildings were tested using the tool, using both the performance and prediction methods.

When using the Financial Cost Benefit Advisor (FCBA) level of the WERT at 'low' budget with a 5% interest rate, it was found that a calculated average of 28% water savings could be made across the sample, with the financial benefit on average four times greater in Auckland than Wellington (see Table 15.3), due to the difference in tariff structures.

	New WUI	Payback Period	NPV	IRR	Investment	Savings	Savings
	m^3/m^2/year	Years	NZD$	%	NZD$	NZD $	% of m^3
Auckland	0.52	10.61	59,799.18	13	81,878.89	11,497.09	26
Wellington	0.68	27.25	-13,621.71	2	63,511.44	4,002.42	29

Table 15.3: Average FCBA Results

The study identified an issue with building W18, which had an extremely low WUI of 0.20m^3/m^2/year, and equipment (pulse sensor & data logger) failure. Using the WERT, it was predicted that the WUI should be 1.04m^3/m^2/year. Once the meter was calibrated by *Capacity Ltd*, the WUI increased to 1.01m^3/m^2/year, within ~3% of the prediction method estimate – demonstrating WERT's strengths in accuracy, relevance, and practicality.

The market environment was tested through industry workshops, with invited participants from a range of the targeted end-users in attendance. The results from both table discussions and individual questionnaire feedback showed that there is currently a lack of industry data. This was also demonstrated through the participants showing a keen interest in the benchmarking results. There is a relatively large demand for education around water use and water efficiency in these areas.

The current industry situation was also considered, to determine what issues and/or barriers may be present in this market environment. It was identified that there is largely a lack of commitment to demand-side management throughout New Zealand; primarily due to the minimal level of educational information available to both customers and consumers, or that being provided by water service providers and local authorities. And as Brown et al (2008) highlight, there needs to be a mutual shift: cognitively, normatively, and regulatively.

A recent *OECD* report summarised the need to improve this situation. "With greater water conservation efforts by both industrial and municipal users, the need for expensive and environmentally intrusive supply-side solutions such as dams and reservoirs could be avoided or postponed" (OECD, 2006).

Through further comparison of the industry situation to recent studies from Smith (2008) and Doron et al (2011), it was found there is a general lack of educational information available to both customers and consumers. However, this is not just a New Zealand specific issue, with Doron et al's (2011) study based in London. In Smith's (2008) study, the most sought after piece of information from customers was "environmental and economic cost-benefit case studies."

The *Parliamentary Commissioner for the Environment (PCE)* has outlined through a number of reports, the effects demand management and water efficiency strategies can play on the supply-side. "Solutions are needed to support more efficient water use and to recognise the important linkages between the different water services components of water supply, treatment, use, and disposal of wastewater, and storm water. Progress could also be made in the area of demand management and least cost planning. In practice this will involve a package of measures including regulation, economic instruments, information, and education, along with measures which directly address production as well as consumption patterns" (Williams, 2001a).

The WERT is proposed to be implemented as a business start-up in the coming year; however this is not the solution to the water crises that have presented themselves both in New Zealand and around the world recently.

Participants from Doron et al's (2011) study in London stated they understood that water conservation was a problem which everyone is responsible for, but did not know how to act. Glennon (2012) identified that, from a customer point of view, if the savings opportunities are not there (through tariff structure setting), then why bother implementing water efficiency measures? This identifies that it is not solely the technological advances that create water efficiency, but it is also the effects from individual behaviours, attitudes, and management towards this resource. This is a common concern that needs to be addressed by the supply-side, and/or other regulatory bodies – offering educational guidelines and information which promote action.

15.2. FURTHER RECOMMENDATIONS

Based on the resultant outcomes from this study, a number of recommendations have been formulated both in terms of steps of action and in terms of future research work. The major suggestions can be broken down into demand-side management, legislation, water pricing issues, water metering issues, and future study expansion.

15.2.1. DEMAND-SIDE MANAGEMENT

As Memon et al (2003) highlight, "instead of developing new water resources, which arguably is less attractive option both financially and environmentally," considerable effort should be placed on the implementation of demand management options. Much effort is already being put into supply-side efficiency and management, however, if demand side options were considered, this could possibly postpone the need for expensive infrastructure, while educating individual's at the same time.

This subsequently can be discussed through further avenues, such as those discussed in the following areas: legislation, water tariffs, water meters, and future research.

15.2.2. LEGISLATION

The *Report of the Land & Water Forum* (2010) is the first step towards a national legislative document, however, it still fails to concern urban water issues and demand management in much depth; while mainly focussing on supply and rural demands and irrigation. By providing a national target for conservation of potable water it will demonstrate to users the seriousness of the coming shortages predicted with the changing weather patterns, as well as projected population trends.

On the demand-side, the introduction of a New Zealand water use standard similar in content to the *AS/NZS 4220: 1982 Code of Practice for Energy Conservation in Non-Residential Buildings* would be highly beneficial, in both increasing the awareness and education of water conservation methods. To make this possible, further end-use studies would be required for a range of building uses.

Another method could be a collaboration between water service providers, local authorities, and building managers, to form a quality mark subsidisation scheme, utilising WERT, or similar, to educate and promote action.

15.2.3. WATER TARIFFS

A number of sources stated that the current price of water does not match the true costs to source, treat, pump, store, and deliver water to its customers. As outlined in Chapter 11.2, the Wellington tariffs are not at all incentivising building owners and managers to implement water efficiency measures (either through technological or behavioural methods). This is extremely frustrating to a number of the owners of the studied buildings.

"Price based or economic instruments can incentivise desired behaviours or create disincentives through price and market mechanisms" (Land & Water Forum, 2010). The Auckland tariff structure for wastewater is based on a percentage of ingoing potable water (with the reduced percentage attributed to evaporative losses). In Wellington, as the “three waters” (wastewater, storm water, and portable water) are not managed under one control, neither are their charging mechanisms. The ingoing potable water is based on volumetric charging, while the wastewater portion is calculated based on the capital value of the building and charged for through the annual council rates – not on the bi-monthly water invoice.

When using the hypothetical building scenario in Table 14.4, the financial savings from implementing water efficiency measures are much higher in Auckland – yet the volumes of water saved are much higher in Wellington. Very little incentive is offered to introduce water efficiency measures in Wellington, the higher water user.

Through the industry workshops, the building managers and consultants emphasised their desire for a Wellington tariff re-structure to match Auckland. This offers a win-win situation, charging users for their actual consumption (or waste) has the potential to reduce the costs for the customers (though self-implementation of water efficiency measures), and also reduce the demands on the supply network and postpone infrastructure investment.

The positive effect of implementing residential volumetric charging has been demonstrated in a number of cases, both in New Zealand and internationally. As Williams (2001b) highlights, “metering and charging for water is likely to be an important tool for improving the efficiency of water use.”

15.2.4. WATER METERS

It was identified that there is a rather short lifespan for water meters, with 32% of all water meters having been replaced over the last 5 years (due to both scheduled replacements and/or failure). Given that water is consistently moving through these devices, and the corrosive nature of some particles found in water, it is understandable that some wear on the internal mechanisms is likely. However, further research is recommended into their durability.

Outpost Central, based in Auckland, offer a live monitoring system (via SIM communications), connected to a web-based “dashboard” for monitoring water use, and enabling leak detection. This is something that is largely lacking in New Zealand, along with sufficient sub-metering and cost-recovery mechanisms. A recommendation for ongoing water monitoring has been forwarded to those participants of the study who requested building audit reports.

Through the industry workshops, the building managers expressed their concern about the associated costs of implementing such monitoring systems. This suggests that, if the benefits are great, then the water service providers and/or local authorities should work together with *Facilities Management Association of New Zealand (FMANZ)* to provide incentives for promoting such a system. Again, this has come back to the lack of action-related information available.

15.2.5. FUTURE RESEARCH

Further investigation is suggested at a scale that is more statistically representative of a wider region of New Zealand. This could include expanding to reach the minimum ideal sample size (>260 office buildings) through studying commercial office buildings in further regions of New Zealand. Also, other building types should be analysed and included for analysis using the same empirical research methods proved in this study on understanding water consumption in commercial office buildings in New Zealand. This would lead to a resource which could form the base for a water use efficiency standard.

The WERT proved to be an accurate (±8.5%), practical, and realistic tool which promotes action by implementation; for analysing and predicting water performance in office buildings. Future work is planned to implement this model, and continue building on the water efficiency and conservation knowledge database for New Zealand, and the world. However, the breaking limits of the WERT (i.e point at which it will fail) have not yet been established, and it is therefore currently restricted only to the scale of buildings falling within the range of the 93 buildings studied herein.

15.3. RESEARCH SIGNIFICANCE

This research has provided an understanding of both the water supply and the water demand issues in the New Zealand context. The detailed monitoring allows an understanding of how and when water is being used, and highlights the obvious benefits of leak detection.

The benchmark index system provides commercial office buildings in New Zealand with a baseline for water performance and rated levels of water efficiency. It will support the setting of both policy and individual use targets for commercial users, as well as building performance rating tools.

The development and demonstration of WERT to the targeted industries proved successful, in that a number of the attendees (and their colleagues) expressed their interest to be part of the trialling and any further research and development work. This has demonstrated two things: the severe lack of water demand related information available in the industry; and the industry need for an informative multi-factor decision aid – such as the WERT.

The aim of this research was 'to understand the water performance of New Zealand's commercial office buildings, by testing the methodology as a means of establishing suitable performance benchmarks for commercial office buildings'. It is concluded that it is the price of water that drives education, awareness, and the individual's justification for efficiency and conservation measures. Until this is realised, water consumption levels will stay the same, if not increase.

Volumetric charging should be considered for implementation at a residential scale to promote awareness and education in order for it to have any behavioural effects in other sectors. And the commercial tariffs should incentivise water efficiency and conservation through volumetric charging of both water and wastewater, through increasing block rates.

"Starting now, we need to put in place a water management system that works significantly better, that is durable, and that is capable of driving changes for the future" (Land & Water Forum, 2010). It is hoped that the WERTs implementation will aid in driving some of these changes, however, as Glennon (2012) states "all we need now is the courage and the political will to act."

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LIST OF APPENDICES

APPENDIX A: TERMS & ABBREVIATIONS

°C – is the ambient temperature measured in degrees Celsius.

ΔT – temperature differential.

μ – sample mean, a statistical value.

ABGR – Australian Building Greenhouse Rating tool, now officially called NABERS.

AC – Auckland Council.

ADSM – Advanced Demand Side Management. A UK based firm.

AHU – Air Handling Unit.

AIDA – attention, interest, desire, action. A business process.

ANOVA – ANalysis Of VAriance. A statistical technique for the testing of two means.

ANZSIC – Australia and New Zealand Standard Industrial Classification.

ASHRAE – The American Society of Heating, Refrigerating, and Air-conditioning Engineers, Inc.

AUD – Australian Dollar.

AWUS – Auckland Water Use Study. A study undertaken by BRANZ.

AWWA – American Water Works Association.

B – bleed in a cooling tower.

BASIX – An Australian residential building rating tool.

BEES – Building Energy End-use Study, which is administered by BRANZ. It is a six year long study investigating the end-uses of both energy and water in commercial buildings around New Zealand.

BIA – Building Industry Authority.

BMS – Building Management System.

BOMA – Building Owners and Managers Association.

BQI – Building Quality Indicator.

BRANZ – Building Research Association of New Zealand.

BREEAM – British Research Establishment Environmental Assessment Method.

BSRT – Building Sustainability Rating Tool.

BWOF – Building Warrant of Fitness.

c – specific heat capacity.

CBD – central business district.

CBPR – Centre for Building Performance Research.

CCC - Christchurch City Council.

CCINZ – Climate Change Information New Zealand.

CDD – cooling degree days. Is the measure of the amount of heat, which is related to the temperature of the ambient air during the warmer seasons. For every 1ºC over a base temperature (usually 15ºC in this case), can be said to be one cooling degree day.

CIEUWS – Commercial & Institutional End Uses of Water Study, is the title of the report published by Dziegielewski et al, 2000. This study investigated water consumption in a number of commercial and institutional buildings across the United States of America.

CIRIA – Construction Industry Research and Information Association. A UK based association.

CLT – Central Limit Theorem.

CR – Concentration Ratio.

D – drift in a cooling tower.

DBH – Department of Building and Housing, a New Zealand Government Department responsible for administering the New Zealand Building Code.

DECC – Australian Government, Department of Energy and Climate Change. Now known as DEH.

DEH – Australian Government, Department of Environment and Heritage.

DIY – Do It Yourself.

dT – change in temperature.

E – evaporation losses in a cooling tower.

E_{2011} – estimated water use in 2011.

E_{2031} – estimated water use in 2031.

ESD – environmentally sustainable design.

EUI – Energy Use Index or Indices.

FCBA – Financial Cost Benefit Advisor, step four of the WERT.

FMANZ – Facilities Management Association of New Zealand.

FTE – Full Time Equivalent (occupants). Is the measure of the number of occupants which are on-site for the equivalent of a full working week. This measure takes into account part-time occupants as a fraction of the time on-site.

FWA – full water audit. Refer to Chapter 7.3.

G – regional population growth, as a percentage.

GFA – Gross Floor Area, the total building floor area.

GHG – Green House Gases.

GSNZ – GreenStar New Zealand – a BSRT.

GWRC – Greater Wellington Regional Council, is responsible for the supply and treatment of bulk water to city reservoirs for Wellington City Council, Hutt City Council, Upper Hutt District Council, and the Kapiti Coast District Council.

H_A – Alternate Hypothesis.

H_O – Null Hypothesis.

HHC – Housing Health Checklist, developed by Hasselaar, 2004.

HK – Hong Kong Dollar.

hPa - hecto Pascals.

HVAC – Heating, Ventilation, and Air-Conditioning. Is the abbreviated term used for mechanical heating/cooling within a building.

IEQ – Indoor Environmental Quality.

IPCC – Intergovernmental Panel on Climate Change.

IQR – Interquartile Range, or the range between the UQ and the LQ.

IRR – Internal Rate of Return.

ISA – International Sustainability Alliance.

ISO – International Organisation for Standardisation.

kJ – kilo Joule.

kL – kilolitre. 1,000 L = 1kL = 1m^3.

kPa – kilo Pascal.

KPI – key performance indicator, is the measure of performance associated with an activity or process. The information provided by a KPI can be used to determine how an organisation compares with others of similar type, and will directly influence a move towards good practice.

kWh – kilowatt hours.

L – litre, is the metric unit to measure the volume of fluid (in this case – water).

LEED – Leadership in Energy and Environmental Design, is the building sustainability rating tool for Canada.

LQ – Lower Quartile, the 25^{th} percentile.

m – Mass.

M – Cooling tower make-up supply required.

m^2 - square metres, a unit of floor area.

m^3 – cubic metres. 1,000 L = 1m^3 = 1 kL.

mm – millimetres.

MED – Ministry of Economic Development.

MfE – Ministry for the Environment.

ML – megalitre. 1,000,000 L = 1ML = 1,000 kL = 1,000m^3.

MS – Microsoft. Using Access or Excel in this case, and Excel add-ins such as 'Statplus' and 'Data Analysis Toolpak.'

n – sample size.

n_o – the first approximation of the sample size.

N – Normalised water consumption intensity.

N - Population size.

NABERS – The National Australian Built Environment Rating System. Formally known as the ABGR.

NCC – Nelson City Council.

NIWA – National Institute of Water and Atmospheric research.

NLA – Net Lettable Area is the measure of rentable area within a building, as square metres (m^2). Non-rentable areas include stairwells, electrical cupboards, telephone riser enclosures, lift shafts, escalators, vertical ducts, columns, areas set aside as public space or thoroughfares (ground floor entrance lobby), areas set aside as plant and lift motor rooms or for the provision of facilities or services to the building, areas set aside for the use by service vehicles and for the delivery of goods and accessways thereto, and areas set aside for carparking and accessways thereto (BOMA, 2006).

NPV – Net Present Value.

NZ ALI – New Zealand Apartment Liveability Index, developed by Bennett, 2010.

NZBC – New Zealand Building Code.

NZD – New Zealand Dollar.

NZGBC – New Zealand Green Building Council, is responsible for the development, administration and assessment of all Green Star New Zealand rating tools and rated buildings.

OECD – Organisation for Economic Cooperation and Development.

p-value – probability value of significance used in statistics.

PCE – Parliamentary Commissioner for the Environment (Williams, 2001).

PGSA - Post Graduate Students Association, at Victoria University of Wellington.

pH – potential of Hydrogen, indicates the acidity or alkalinity of a substance.

PPL - Pulses Per Litre.

Q – Energy required.

Q_a - Start-up flowrate.

Q_{min} – Minimum flowrate.

Q_p – Permanent flowrate.

Q_s – Overload flowrate.

Q_t – Transitional flowrate.

r – Pearson's correlation coefficient.

r - relative error.

r^2 – R-squared value, also known as the correlation coefficient. It is an indicator that ranges in value from 0 to 1 and reveals how closely the estimated values for the trend line correspond to actual data. A trend line is most reliable when its r^2 value is at or near 1.

RBNZ – Reserve Bank of New Zealand.

RMA – Resource Management Act.

RR – Reticulation Rate form water circulating pumps.

s – population standard deviation.

SIM – Subscriber Identity Module.

SLWA – survey level water audit.

SWC – Sydney Water Corporation.

t – confidence probability.

t-tests – see ANOVA.

UQ – Upper Quartile, or 75th percentile.

W – water consumption intensity.

W – Cooling tower wastage.

W_{corr} – climate normalisation.

WCC – Wellington City Council, is the territorial authority for the Wellington region. They are also responsible for the billing of water to its customers – referred to as the local billing utility herein.

WEEP – Water Efficiency and End-Use Project, was a study undertaken by BRANZ, at the BRANZ offices in Judgeford, Lower Hutt. This study monitored the water use within the buildings on-site.

WELS – Water Efficiency Labelling and Standards as outlined by the New Zealand/Australian Standard AS/NZS 6400:2005 Water Efficiency Products – Rating and Labelling.

WERT – Water Efficiency Rating Tool.

WRC – Wellington Regional Council, now known as the Greater Wellington Regional Council (GWRC).

WUI – Water Use Index or Indices.

$\bar{Y}$ – population mean value.

APPENDIX B: SUPPORTING INFORMATION

B1: NEW ZEALAND DOCUMENTS FOR THE SUPPLY OF WATER

PRIMARY LEGISLATION
Building Act 2004
Health (Amendment) Act 2007
Local Government Act 2002
Resource Management Act 1991
Water Supplies Protection Regulations 1991

WATER SUPPLY STANDARDS	
AS/NZS 2845.1:1998	Water Supply – Backflow Prevention
AS/NZS 3499:2006	Water Supply – Flexible Hose Assemblies
AS/NZS 3718:2005	Water Supply – Tap-ware
NZS 9201.7:2007	Model General Bylaws – Water Supply

WATER RELATED STANDARDS	
AS/NZS 1547:2000	Recycled Water
AS/NZS 3497:1998	Drinking Water Treatment Units
AS/NZS 3500.1:2003	Design, Installation & Commissioning of Cold Water Services, and Non-Drinking Water
AS/NZS 3500.2:2003	Design & Installation of Sanitary Plumbing & Drainage from Fixture to Sewer
AS/NZS 3500.3:2003	Materials, Design, Installation & Testing of Roof Drainage Systems, Surface Drainage Systems, and Subsoil Drainage Systems
AS/NZS 3500.4:2003	Installation of Heated Water Services Using Drinking Water
AS/NZS 3500.5:2003	Installation of Hot & Cold Water Supply, Sanitary Plumbing & Drainage, ans Storm Water Drainage for Domestic Plumbing Work
AS/NZS 3501:1976	Specification for Copper Tubes for Water
AS/NZS 3666.1:2002	Air-Handling and Water Systems of Buildings
AS/NZS 3666.2:2002	Air-Handling and Water Systems of Buildings
AS/NZS 3666.3:2000	Air-Handling and Water Systems of Buildings
AS/NZS 3896:2008	Water – Examination of Legionella spp.
AS/NZS 4020:2005	Testing of Products for use in Contact with Water
AS/NZS 4276.1:2007	Water Microbiology
NZS 4302.1:1987	Code of Practice for the Control of Hygiene
AS/NZS 4348:1995	Domestic Type Water Treatment Appliances
AS/NZS 5607:1998	Water Quality - Sampling
AS/NZS 6400:2005	Water Efficient Products – Rating & Labelling
SAA/SNZ HB32:1995	Control of Microbial Growth in Air-Handling
SNZ PAS 4509:2008	New Zealand Service Firefighting Water Supplies Code

OTHER DOCUMENTATION	
Ministry of Health (2005)	Drinking Water Standards for New Zealand
NZWWA (2006)	Backflow Prevention Code of Practice
NZWWA (2003)	Water Meter Code of Practice

INTERNATIONAL STANDARDS & DOCUMENTATION	
OIMC R 49-1/2/3:2006	Water Meters for the Metering of Cold Potable and Hot Water
BS EN 14154-3:2005	Water Meters, Test Methods & Equipment

B2: WATER SUPPLIERS (& THEIR COMMERCIAL TARIFFS) IN NEW ZEALAND

Water Utility Business	Region	Type	Rate Type	Rate
Christchurch City Council	Christchurch	Water, Wastewater	Fixed + Uniform	\$102/year + \$0.56/m³
Dunedin City Water Services	Dunedin	Water	Fixed + Uniform	\$171/year + \$1.33/m³
Far North District Council	Northland	Water Wastewater	Uniform	\$2.32/m³
Gisborne District Council	Gisborne	Water Wastewater	Uniform	\$1.15/m³
Greater Wellington Regional Council	Wellington, Hutt City, Upper Hutt, Porirua	Water	Uniform Supply to City Councils	
Hastings District Council	Hastings	Water Wastewater	Fixed + Uniform	\$205/year + \$0.40/m³
Huruni District Council			Fixed + 'Unit' Block	Ranging \$80 - \$184
Hutt City Council	Hutt City	Water Wastewater	Fixed + Declining Block	\$63/year + <100,000m³ = \$1.61/m³ >100,000m³ = \$1.15/m³
Kaikoura District Council	Kaikoura	Water	Fixed + Uniform	\$33/year + \$1.00/m³
Nelson City Council	Nelson	Water	Fixed + Declining Block	\$187.17/year + <10ML: \$1.75m³ 10-100ML: \$1.62/m³ >100ML: \$1.28/m³
Palmerston North	Palmerston North	Water Wastewater		
Tasman District Council	Tasman	Water Wastewater	Fixed + Uniform	\$189.40/year + \$1.50/m³
Tauranga City Council	Tauranga & Surround	Water Wastewater	Fixed + Uniform	\$1.58/m³
Thames Coromandel District Council	Papakura, Ruapehu, Thames-Coromandel, Wellington	Water Wastewater	Fixed + Declining Block	<50,000m³ = \$1.23/m³ >50,000m³ = \$0.85/m³
Wanganui District Council	Wanganui		Fixed	\$609/year
Watercare Services Ltd	Greater Auckland	Water Wastewater	Fixed + Uniform	\$43/year + \$1.30/m³ Ww = \$4.056/m³ @ 75% of water
Wellington City Council Capacity Ltd	Wellington	Water, Stormwater, Wastewater	Fixed + Uniform	\$100/year 0.00130171% /Cap Val
Western Bay of Plenty District Council	Western Bay of Plenty	Water Wastewater		
Whakatane District Council	Whakatane & Surrounds	Water Wastewater	Fixed + Variable Uniform	Mar-Nov = \$1.02/m³ Dec-Feb = \$2.04/m³
Whangarei District Council	Whangarei Region	Water Wastewater	Fixed + Uniform	

B3: CHEMICALS & PROPERTIES FOUND IN AND USED FOR THE TREATMENT OF WATER

Property/Chemical	Found in freshwater	Used for treatment of freshwater
Acidity (<pH 7.0)	The most usual causes are free carbon dioxide in water, and organic acids	
Alkalinity	The cause of alkalinity is the presence of bio-carbonates, carbonates and hydroxides of calcium, magnesium, potassium and sodium	
Aluminium	Found in some natural waters in a detectable amount	
Ammonia Compounds		
Arsenic	A well known toxic element	
Biochemical Oxygen Demand	Degree of pollution of rivers and streams	
Calcium	As a bio-carbonate	
Carbon Dioxide (CO_2)	See Above	
Carbonate	See Above	
Chlorides	Present in all water supplies (for rivers a usual range is 20 to 80mg/l	
Chlorine		A sterilising gas added to water
Colour		
Corrosive Quality	A low pH value, high free CO^2 content, alkalinity	
Copper	Toxic to fish	Traces obtained from copper pipes are rarely sufficient to affect human beings
Cyanide	Most indicative by fish	
Detergents		Used in contaminated water
Fluoride		1mg/l is safe and effective in substantially reducing dental decay
Hardness	Measured in mg/l as $CaCO_3$	
Iodine		A small amount is a necessary dietary ingredient
Iron	Frequently found in raw waters	
Lead	Well known cumulative poison, rarely detectable in natural waters	
Magnesium	Causes water 'hardness'	
Manganese	Troublesome element in water even in the smallest quantities	
Mineral Constituents	Cations, calcium, magnesium, sodium and potassium and anions bio-carbonates, sulphate, chloride, nitrate, and silica	
Nitrate and Nitrite	Final stage in the oxidation of ammonia and of nitrogen form organic matter	
Odour		
Organic Content	Comes from plant and animal life and sewage and industrial effluents	
pH	Measure of acidity or alkalinity	Measure of acidity or alkalinity

Property/Chemical	Found in freshwater	Used for treatment of freshwater
Pesticides	Organo-chlorine pesticides, aldrin, BHC, dieldrin, DDT have had world wide publicity regarding persistence	
Phenols	Substances in water which originate from trade wastes, washing from tarmac roads, gas liquors and creosoted surfaces	
Phosphates	Originate principally from sewage effluents including detergents	
Polynuclear Aromatic Hydrocarbons	Can be carcinogenic	
Potassium	Low in most waters	
Radioactive Substances		
Silica	Exists in most water – up to 40mg/l in hard water	
Sodium	Evidence of pollution by sea water or sewage	
Sulphates	Calcium sulphates is often dissolved from clays	
Suspended Solids		
Taste		
Total Solids in Solution		
Turbidity	Caused by suspended solids in water	
Zinc	Very rarely present in water, but when at consumers taps, is because of the use of galvanised iron piping and tanks	

(Source: Twort et al, 1974)

B4: DISEASES TRANSMITTED FROM CONSUMING WATER

If the testing of water and use of treatments are inadequate, the following diseases can be caught from consuming water:

Disease Type	Disease	Effects
Bacterial Disease	Cholera	Small intestine infection. Profuse, watery diarrhoea, vomiting, dehydration, reduced electrolytes, and in some cases, death.
	Typhoid Fever	Bacteria perforate through intestinal wall. A slowly progressive fever, profuse sweating, and gastroenteritis. Less commonly a rash of flat rose coloured spots. Can last up to four weeks, headache, cough, bleeding nose, abdominal pain, decreased number of white blood cells, and dehydration.
	Paratyphoid Fever	Bears similarities with Typhoid Fever, but it is more abrupt, with milder symptoms, and has a shorter course.
	Bacillary Dysentery	A type of dysentery and a severe form of shigellosis. Transmission is faecal-oral. Blood in stool, caused by bacteria escaping the epithelial cell phagolysome, multiplying within the cytoplasm, and destroying host cells.
	Traveller's Diarrhoea	Defined as three or more unformed stools in 24 hours passed by a traveller, commonly accompanied by abdominal cramps, nausea, and bloating.
	Leptospirosis	Water that has been contaminated by animal urine. Two phases: influenza symptoms (fever, chills, myalgias, headache); and severe symptoms (meningitis, jaundice, renal failure, red eyes, abdominal and other muscle pain, diarrhoea, and rash).
Protozoal Disease	Amoebisis Amoebic Dysentery	Faecal-oral contamination. Ingestion of the cyst form of the parasite, a semi-dormant and hardy structure found in faeces. Mild diarrhoea, dysentery with blood and mucous. Blood comes from amoebae invading the lining of the intestine. Commonly affects other internal organs, e.g. liver.
Virus Disease	Poliomyelitis	An acute, viral, infectious disease spread from person to person via faecal-oral route. 90% of time, no symptoms and virus enters bloodstream. 1% of time the virus enters the central nervous system, infecting and destroying motor neurons, leading to muscle weakness and acute flaccid paralysis (spinal, bulbar, or bulbospinal).
	Infectious Hepatitis	Hep A. An acute infectious disease of the liver. Usually spread faecal-oral route. Influenza symptoms, after 2-6 weeks of initial infection. Fatigue, fever, abdominal pains, nausea, loss of appetite, jaundice, etc.
Helminthic (worm) Disease	Schistosomiasis	A chronic illness that can damage internal organs, impair growth and cognitive development. Contact or ingest contaminated water with parasitic larvae. Abdominal pains, cough, diarrhoea, extremely high white blood cell count, fever, fatigue, enlarged liver and spleen, genital sores.

(Source: Twort et al, 1974).

B5: RESOURCE MANAGEMENT ACT 1991 – Schedule 3: Water quality classes

Water Quality Class	Purpose	Comments
AE Water	Being water managed for aquatic ecosystem purposes	1- The natural temperature of the water shall not be changed by more than 3°C. 2- The following shall not be allowed if they have an adverse effect on aquatic life: a – any pH change, b – any increase in the deposition of matter on the bed of the water body or coastal water, c – any discharge of a contaminant into the water. 3 – The concentration of dissolved oxygen shall exceed 80% of saturation concentration. 4 – There shall be no undesirable biological growths as a result of any discharge of a contaminant into the water.
F Water	Being water managed for fishery purposes	1 – The natural temperature of the water: a – shall not be changed by more than 3°C, b – shall not exceed 25°C. 2 – The concentration of dissolved oxygen shall exceed 80% of saturation concentration. 3 – Fish shall not be rendered unsuitable for human consumption by the presence of contaminants.
FS Water	Being water managed for fish spawning purposes	1 – The natural temperature of the water shall not be changed by more than 3°C. The temperature of the water shall not adversely affect the spawning of the specified fish species during the spawning season. 2 – The concentration of dissolved oxygen shall not exceed 80% of saturation concentration. 3 – There shall be no undesirable biological growths as a result of any discharge of a contaminant into the water.
SG Water	Being water managed for the gathering or cultivating of shellfish for human consumption	1 – The natural temperature of the water shall not be changed by more than 3°C. 2 – The concentration of dissolved oxygen shall not exceed 80% of saturation concentration. 3 – Aquatic organisms shall not be rendered unsuitable for human consumption by the presence of contaminants.
CR Water	Being water managed for contact recreation purposes	1 – The visual clarity of the water shall not be so low as to be unsuitable for bathing. 2 – The water shall not be rendered unsuitable for bathing by the presence of contaminants. 3 – There shall be no undesirable growths as a result of any discharge of a contaminant into the water.
WS Water	Being water managed for water supply purposes	1 – The pH of surface waters shall be within the range 6.0-9.0 units. 2 – The concentration of dissolved oxygen in surface waters shall exceed 5 grams per cubic metre. 3 – The water shall not be rendered unsuitable for treatment (equivalent to coagulation, filtration, and disinfection) for human consumption by the presence of contaminants. 4 – The water shall not be tainted or contaminated so as to make it unpalatable or unsuitable for consumption by humans after treatment (equivalent to coagulation, filtration, and disinfection), or unsuitable for irrigation.

Water Quality Class	Purpose	Comments
I Water	Being water managed for irrigation purposes	1 – The water shall not be tainted or contaminated so as to make it unsuitable for the irrigation of crops growing or likely to be grown in the area to be irrigated. 2 – There shall be no undesirable biological growths as a result of any discharge of a contaminant into the water.
IA Water	Being water managed for industrial abstraction	1 – The quality of the water shall not be altered in those characteristics which have a direct bearing upon its suitability for the specified industrial abstraction. 2 – There shall be no undesirable biological growth as a result of any discharge of a contaminant into the water.
NS Water	Being water managed in its natural state	1 – The natural quality of the water shall not be altered.
A Water	Being water managed for aesthetic purposes	1 – The quality of the water shall not be altered in those characteristics which have a direct bearing upon the specified aesthetic values.
C Water	Being water managed for cultural purposes	1 – The quality of the water shall not be altered in those characteristics which have a direct bearing upon the specified cultural or spiritual values.

(Source: Resource Management Act, 1991)

B6: ANZSIC CLASSIFICATIONS & CODES

DIVISION CODE	DIVISION	DETAILED CLASSIFICATION CODE	DETAILED CLASSIFICATION
A	Agriculture, Forestry and Fishing	011	Horticulture and Fruit Growing
		012	Grain, Sheep and Beef Cattle Farming
		013	Dairy Cattle Farming
		014	Poultry Farming
		015	Other Livestock Farming
		016	Other Crop Growing
		021	Services to Agriculture
		022	Hunting and Trapping
		030	Forestry and Logging
		041	Marine Fishing
		042	Aquaculture
B	Mining	110	Coal Mining
		120	Oil and Gas Extraction
		131	Metal Ore Mining
		141	Construction Material Mining
		142	Mining n.e.c.
		151	Exploration
		152	Other Mining Services
C	Manufacturing	211	Meat and Meat Product Manufacturing
		212	Dairy Product Manufacturing
		213	Fruit and Vegetable Processing
		214	Oil and Fat Manufacturing
		215	Flour Mill and Cereal Food Manufacturing
		216	Bakery Product Manufacturing
		217	Other Food Manufacturing
		218	Beverage and Malt Manufacturing
		219	Tobacco Product Manufacturing
		221	Textile Fibre, Yarn and Woven Fabric Manufacturing
		222	Textile Product Manufacturing
		223	Knitting Mills
		224	Clothing Manufacturing
		225	Footwear Manufacturing
		226	Leather and Leather Product Manufacturing
		231	Log Sawmilling and Timber Dressing
		232	Other Wood Product Manufacturing
		233	Paper and Paper Product Manufacturing
		241	Printing and Services to Printing
		242	Publishing
		243	Recorded Media Manufacturing and Publishing
		251	Petroleum Refining
		252	Petroleum and Coal Product Manufacturing n.e.c.
		253	Basic Chemical Manufacturing
		254	Other Chemical Product Manufacturing
		255	Rubber Product Manufacturing
		256	Plastic Product Manufacturing

DIVISION CODE	DIVISION	DETAILED CLASSIFICATION CODE	DETAILED CLASSIFICATION
		261	Glass and Glass Product Manufacturing
		262	Ceramic Manufacturing
		263	Cement, Lime, Plaster and Concrete Product Manufacturing
		264	Non-Metallic Mineral Product Manufacturing n.e.c.
		271	Iron and Steel Manufacturing
		272	Basic Non-Ferrous Metal Manufacturing
		273	Non-Ferrous Basic Metal Product Manufacturing
		274	Structural Metal Product Manufacturing
		275	Sheet Metal Product Manufacturing
		276	Fabricated Metal Product Manufacturing
		281	Motor Vehicle and Part Manufacturing
		282	Other Transport Equipment Manufacturing
		283	Photographic and Scientific Equipment Manufacturing
		284	Electronic Equipment Manufacturing
		285	Electrical Equipment and Appliance Manufacturing
		286	Industrial Machinery and Equipment Manufacturing
		291	Prefabricated Building Manufacturing
		292	Furniture Manufacturing
		294	Other Manufacturing
D	Electricity, Gas and Water Supply	361	Electricity Supply
		362	Gas Supply
		371	Water Supply, Sewerage and Drainage Services
E	Construction	411	Building Construction
		412	Non-Building Construction
		421	Site Preparation Services
		422	Building Structure Services
		423	Installation Trade Services
		424	Building Completion Services
		425	Other Construction Services
F	Wholesale Trade	451	Farm Produce Wholesaling
		452	Mineral, Metal and Chemical Wholesaling
		453	Builders Supplies Wholesaling
		461	Machinery and Equipment Wholesaling
		462	Motor Vehicle Wholesaling
		471	Food, Drink and Tobacco Wholesaling
		472	Textile, Clothing and Footwear Wholesaling
		473	Household Good Wholesaling
		479	Other Wholesaling
G	Retail Trade	511	Supermarket and Grocery Stores
		512	Specialised Food Retailing
		521	Department Stores
		522	Clothing and Soft Good Retailing
		523	Furniture, Houseware and Appliance Retailing

CODE	DIVISION	DETAILED CLASSIFICATION CODE	DETAILED CLASSIFICATION
		524	Recreational Good Retailing
		525	Other Personal and Household Good Retailing
		526	Household Equipment Repair Services
		531	Motor Vehicle Retailing
		532	Motor Vehicle Services
H	Accommodation, Cafes and Restaurants	571	Accommodation
		572	Pubs, Taverns and Bars
		573	Cafes and Restaurants
		574	Clubs (Hospitality)
I	Transport and Storage	611	Road Freight Transport
		612	Road Passenger Transport
		620	Rail Transport
		630	Water Transport
		640	Air and Space Transport
		650	Other Transport
		661	Services to Road Transport
		662	Services to Water Transport
		663	Services to Air Transport
		664	Other Services to Transport
		670	Storage
J	Communication Services	711	Postal and Courier Services
		712	Telecommunication Services
K	Finance and Insurance	731	Central Bank
		732	Deposit Taking Financiers
		733	Other Financiers
		734	Financial Asset Investors
		741	Life Insurance and Superannuation Funds
		742	Other Insurance
		751	Services to Finance and Investment
		752	Services to Insurance
L	Property and Business Services	771	Property Operators and Developers
		772	Real Estate Agents
		773	Non-Financial Asset Investors
		774	Machinery and Equipment Hiring and Leasing
		781	Scientific Research
		782	Technical Services
		783	Computer Services
		784	Legal and Accounting Services
		785	Marketing and Business Management Services
		786	Other Business Services
M	Government Administration and Defence	811	Government Administration
		812	Justice
		813	Foreign Government Representation
		820	Defence
N	Education	841	Preschool Education
		842	School Education
		843	Post School Education

DIVISION CODE	DIVISION	DETAILED CLASSIFICATION CODE	DETAILED CLASSIFICATION
		844	Other Education
O	Health and Community Services	861	Hospitals and Nursing Homes
		862	Medical and Dental Services
		863	Other Health Services
		864	Veterinary Services
		871	Child Care Services
		872	Community Care Services
P	Cultural and Recreational Services	911	Film and Video Services
		912	Radio and Television Services
		921	Libraries
		922	Museums
		923	Parks and Gardens
		924	Arts
		925	Services to the Arts
		931	Sport
		932	Gambling Services
		933	Other Recreation Services
Q	Personal and Other Services	951	Personal and Household Goods Hiring
		952	Other Personal Services
		961	Religious Organisations
		962	Interest Groups
		963	Public Order and Safety Services
		970	Private Households Employing Staff

(Source: Trewin et al, 2006)

B7: CHARACTERISTICS OF METROLOGICAL CLASSES (WATER METERS)

Q_p (m^3/hr)	Class A		Class B		Class C		Class D		Q_s (L/hr)
	Q_{min} (L/hr)	Q_t (L/hr)	Q_{min} (L/hr)	Q_t (L/hr)	Q_{min} (L/hr)	Q_t (L/hr)	Q_{min} (L/hr)	Q_t (L/hr)	
0.6	24	60	12	48	6	9	4.5	6.9	1.2
1	40	100	20	80	10	15	7.5	11.5	2
1.5	60	150	30	120	15	22.5	11.25	17.25	3
2.5	100	250	50	200	25	37.5	18.75	28.75	5
3.5	140	350	70	280	35	52.5	26.25	40.25	7
6	240	600	120	480	60	90	45	69	12
10	400	1000	200	800	100	150	75	115	20
15	1200	4500	450	3000	90	225	-	-	30
20	1600	6000	600	4000	120	300	-	-	40
25	2000	7500	750	5000	150	375	-	-	50
30	2400	9000	900	6000	180	450	-	-	60
40	3200	12000	1200	8000	240	600	-	-	80
50	4000	15000	1500	10000	300	750	-	-	100
60	4800	18000	1800	12000	360	900	-	-	120
100	8000	30000	3000	20000	600	1500	-	-	200
150	12000	45000	4500	30000	900	2250	-	-	300
250	20000	75000	7500	50000	1500	3750	-	-	500
400	32000	120000	12000	80000	2400	6000	-	-	800
600	48000	180000	18000	120000	3600	9000	-	-	1200
1000	80000	300000	30000	200000	6000	15000	-	-	2000
1500	120000	450000	45000	300000	9000	22500	-	-	3000
2500	200000	750000	75000	500000	15000	37500	-	-	5000
4000	320000	1200000	120000	800000	24000	60000	-	-	8000

(Source: Arregui et al, 2006)

APPENDIX C: RESEARCH DOCUMENTATION

C1: VUW HUMAN ETHICS COMMITTEE MEMORANDUM

TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI
VICTORIA
UNIVERSITY OF WELLINGTON

MEMORANDUM

Phone 0-4-463 5676
Fax 0-4-463 5209
Email Allison.kirkman@vuw.ac.nz

TO	Lee Bint
COPY TO	Robert Vale Nigel Isaacs
FROM	Dr Allison Kirkman, Convener, Human Ethics Committee
DATE	20 June 2011
PAGES	1
SUBJECT	**Ethics Approval: 18557 - Water performance benchmarks for New Zealand: Understanding water consumption in commercial office buildings**

Thank you for your application for ethical approval, which has now been considered by the Standing Committee of the Human Ethics Committee.

Your application has been approved from the above date and this approval continues until 15 March 2012. If your data collection is not completed by this date you should apply to the Human Ethics Committee for an extension to this approval.

Best wishes with the research.

Allison Kirkman
Human Ethics Committee

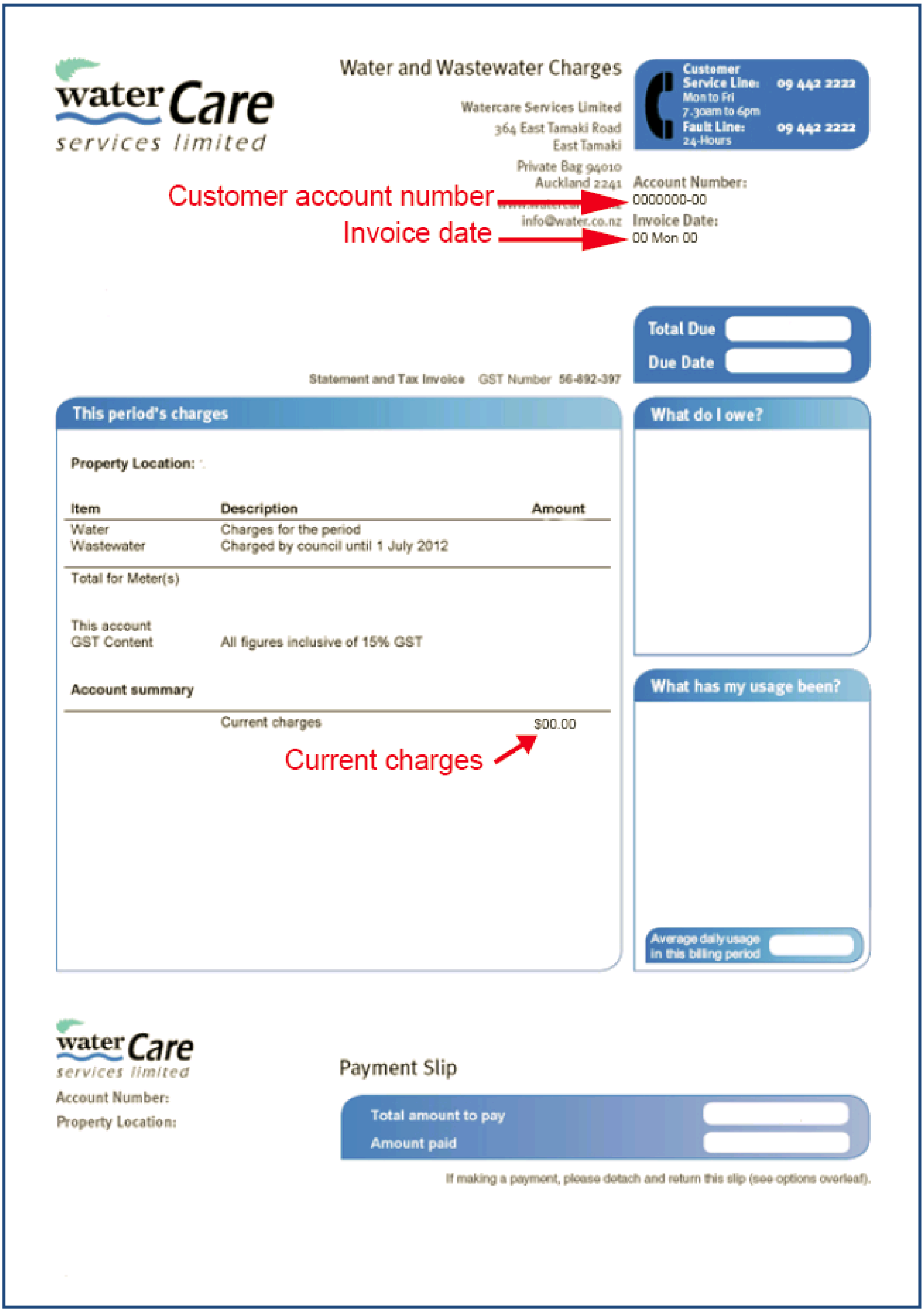
C2: EXAMPLE BWOF

ACME INSPECTION & MAINTENANCE SERVICES LTD

FORM 12, SECTION 108, BUILDING ACT 2004	
BUILDING WARRANT OF FITNESS	
THE BUILDING	
Compliance schedule no: CS499	Annual BWOF expiry date: 14 December 2007
Name: M & H Building Address: 1015-1021 Main Road North, Stoneville Level/unit number: 1 level with mezzanine Legal description: Lot 707, DP 4846 Location of building within site/block number: On street frontage	Current lawfully established use: Commercial (bulk retail store with associated mezzanine offices and staff facilities) Intended life of the building (if 50 years or less): Indefinite Highest fire hazard category for building use: 3 Year first constructed: 2005
THE OWNER	
Name of owner: M & H Limited Contact person: Harry Ford Street address/registered office: 99 South Rd, Stoneville Mailing address: PO Box 13, Stoneville	Telephone (daytime): (02) 212938 Telephone (after-hours): (02) 212938 Mobile: 022 212938 Facsimile: (02) 212939 E-mail: mandh@uhug.co Web-site: www.mandh.limited.nz
THE AGENT	
Name of agent: Acme Inspection & Maintenance Services Ltd Contact person: John Richard Smith Street address/registered office: 9 Station St, Stoneville Mailing address: PO Box 111, Stoneville Relationship to owner: Independent qualified person (see owner's letter with the Form 11)	Telephone (daytime): (02) 437698 Telephone (after-hours): 022 214389 Mobile: 022 214389 Facsimile: (02) 437699 E-mail: acmeinspect@uhug.co Web-site: www.acmeinspect.co
LIST THE SPECIFIED SYSTEMS (inspected and maintained in accordance with the compliance schedule)	
SS2 – Emergency warning systems SS3/2 – Access-controlled doors SS4 – Emergency lighting systems SS9 – Mechanical ventilation or air conditioning systems SS14/2 – Signs for SS1-13 SS15/2 – Final exits SS15/3 – Fire separations SS15/4 – Signs for facilitating evacuation	
WARRANT	
The maximum number of occupants that can safely use this building is: Ground 100, Mezzanine 10 The inspection, maintenance, and reporting procedures of the compliance schedule for the above building have been fully complied with during the 12 month prior to the date stated below.	
The compliance schedule is kept at: 1015-1021 Main Road North, Stoneville (Store Manager's office on mezzanine)	
ATTACHMENTS	
✓ Certificates relating to inspections, maintenance and reporting (Form 12A) x1 (HVAC), x1 (rest) ✓ Recommendations for amendments to the compliance schedule, if any.	
J R Smith .... Signature of ~~owner~~/agent on behalf of owner	
Date: 14 December 2006	

(Source: Department of Building and Housing, n.d.)

C3: EXAMPLE WATER TAX INVOICE



water Care services limited

Water and Wastewater Charges

Watercare Services Limited
364 East Tamaki Road
East Tamaki
Private Bag 94010
Auckland 2241
info@water.co.nz

Customer Service Line: 09 442 2222
Mon to Fri 7.30am to 6pm
Fault Line: 09 442 2222
24-Hours

Account Number: 0000000-00

Invoice Date: 00 Mon 00

Total Due

Due Date

Statement and Tax Invoice GST Number 56-892-397

This period's charges

Property Location:

Item	Description	Amount
Water	Charges for the period	
Wastewater	Charged by council until 1 July 2012	
Total for Meter(s)		
This account		
GST Content	All figures inclusive of 15% GST	

Account summary

	Current charges	$00.00

What do I owe?

What has my usage been?

Average daily usage in this billing period

water Care services limited

Account Number:

Property Location:

Payment Slip

Total amount to pay

Amount paid

If making a payment, please detach and return this slip (see options overleaf).

C4: COVER LETTER TEMPLATE

TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI
VICTORIA
UNIVERSITY OF WELLINGTON

DD-MMMM-YYYY

Dear Building Managers,

RE: 'WATER & OFFICE BUILDINGS'

At present there is no formal information on water use in New Zealand commercial buildings, or how much water a building might be expected to use for a given purpose. As part of a PhD in Building Science through Victoria University of Wellington, I am investigating water use in a selection of existing Wellington and Auckland CBD office buildings. There are currently two levels of water audits which are freely available to you through this study; that of a *Survey Level Water Audit (SLWA)*, and a *Full Water Audit (FWA)*.

Both levels of water auditing involve the completion of a basic information sheet identifying building characteristics and water consumption data (see attached). Once you return the information sheet, I would like to arrange a site visit to your building. This site visit will involve access into the building to assess water fixtures and fittings and, if necessary, to the plant room to observe water consuming plant equipment.

In addition to this, the FWA involves undertaking detailed monitoring and logging via the installation of temporary equipment, mainly concerning the existing water meter(s) and possibly some end-uses within the building. This will allow daily water usage (e.g. weekday vs. weekend) and time-of- use patterns (e.g. overnight vs. workday) to be determined. This will also help identify the main breakdown of water using activities (e.g. are urinals more or less important than toilets?). This may also involve some minor surveying of the tenants to get an idea of how water is actually being used within each building.

The results of this work will discuss 90+ SLWA and 3+ FWA office buildings surveyed within both Auckland and Wellington CBDs, and will be of benefit to all stakeholders/participants within building and water related industry. The results will enable analysis of water performance in office buildings, whether it is to resolve un-noticed water meter failures or leaks; to promote and implement water efficiency; to replicate methods for similar types of buildings; or simply to manage individual building water consumption through target setting.

This research will respect your confidentiality should you wish your building not be identifiable in any way. At project completion, feedback will be available to you upon request; in the form of your individual building and water results, and the final thesis will be available at the Victoria University of Wellington library from mid 2012 onwards.

This work is under the co-supervision of the following persons:

Dr. Robert Vale
Professorial Research Fellow
Victoria University of Wellington
Phone: (04) 463 6275
Email: Robert.Vale@vuw.ac.nz

Mr. Nigel Isaacs
Teaching and Research Fellow
Victoria University of Wellington
Phone: (04) 463 9745
Email: Nigel.Isaacs@vuw.ac.nz

I would like to propose a meeting to discuss, in more depth, what is involved, and if there is anything you would particularly like to investigate within your building. Please inform me at the earliest convenience by returning the attached consent forms to bintlee@myvuw.ac.nz, of your consent decisions.

Kind Regards
Lee Bint
PhD Candidate
School of Architecture
Victoria University of Wellington

SCHOOL OF ARCHITECTURE Te Kura Waihanga
139 Vivian Street, PO Box 600, Wellington, New Zealand
Phone +64-4-463 6253 Mob +64-21-322 139 Email bintlee@myvuw.ac.nz Website www.vuw.ac.nz

C4: PARTICIPATION CONSENT FORM TEMPLATE

TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI
VICTORIA UNIVERSITY OF WELLINGTON

RE: WATER AUDIT PARTICIPATION CONSENT

Please only complete the relevant sections below to which you wish to consent.

(a) ☐ I, ______________________________, on behalf of/representing ______________________________, consent to participating in this research project, by allowing the following buildings to be audited at the specified level.

BUILDING NAME	BUILDING ADDRESS	AUDIT LEVEL*
		SLWA / FWA
		SLWA / FWA
		SLWA / FWA
		SLWA / FWA
		SLWA / FWA
		SLWA / FWA
		SLWA / FWA
		SLWA / FWA
		SLWA / FWA

*SLWA: Survey Level Water Audit; FWA: Full Water Audit

(b) I do/do not consent to the above building(s) being identifiable within any published data.

(c) ☐ I wish to request an analysis report for each building audited.

(d) ☐ I understand that at the completion of this research (or if I withdraw from the project), any data obtained will be returned to me, or destroyed.

Please provide preferred contact details below, and sign and date to validate this consent form. Forms can be returned via email to bintlee@myvuw.ac.nz. Alternatively postage details can be found in the footer of this letter.

Preferred method of contact: ______________________________

Phone: ____________________ Best Contact Time: ____________________

Email: ______________________________

Signed: ____________________ Date: ____________________

SCHOOL OF ARCHITECTURE Te Kura Waihanga
139 Vivian Street, PO Box 600, Wellington, New Zealand
Phone +64-4-463 6253 Mob +64-21-322 139 Email bintlee@myvuw.ac.nz Website www.vuw.ac.nz

C4: WATER CONSENT FORM TEMPLATE

TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI
VICTORIA
UNIVERSITY OF WELLINGTON

RE: WATER ACCOUNT PERMISSION

(c) ☐ I, ____, on behalf of/representing____,
agree to allow Lee Bint, a PhD Candidate at Victoria University of Wellington, access to my water billing records and related water use data for the purpose of conducting her study. I confirm that I have the authority to give such consent in respect of the utility accounts specified below, and I acknowledge that Lee Bint intends to provide a copy of this consent to the utility supplier(s) listed below, and that each of those suppliers will act in reliance on this consent form in disclosing my billing records and related water used data for this study.

BUILDING NAME	BUILDING ADDRESS	WATER SUPPLIER*	ACCOUNT NUMBER

*Metrowater, Auckland City Council, or Wellington City Council

Please provide preferred contact details below, and sign and date to validate this consent form. Forms can be returned via email to bintlee@myvuw.ac.nz. Alternatively postage details can be found in the footer of this letter.

Signed: ______________________________ Date: ______________

This consent is valid until the submission of Lee Bint's Victoria University of Wellington PhD thesis, or 15 March 2012, whichever is first. It will only be used to obtain the listed data from the named suppliers.

SCHOOL OF ARCHITECTURE Te Kura Waihanga
139 Vivian Street, PO Box 600, Wellington, New Zealand
Phone +64-4-463 6253 Mob +64-21-322 139 Email bintlee@myvuw.ac.nz Website www.vuw.ac.nz

C5: INFORMATION SHEET TEMPLATE

INFORMATION SHEET

BUILDING IDENTIFICATION:			
Building Name:			
Building Address:			
		Postcode:	

BUILDING MANAGEMENT:			
Name :		Position:	
Phone:		Email:	

HISTORY OF BUILDING:			
Year Constructed:		Year Refurbished:	
Net Lettable Area (NLA):		HVAC type:	
Gross Floor Area (GFA):		Number of Storeys:	

DESCRIPTION OF SPACES:						
	Space ID & Brief Description of Space: (i.e. Level 1; tenant use (i.e. government office); etc)	Number of FTE* Occupants:	NLA:	Hours/ Week used:	Sub-metered?	Air-Conditioned?
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
Total						

Please attach a copy of the latest water invoice for this building, a typical floor plan, and any additional information regarding water supply to the building (if any).

*FTE = Full Time Equivalent occupants

Lee Bint
PhD in Building Science
Victoria University of Wellington

'Water & Office Buildings' Survey

C6: SITE SURVEY SHEET TEMPLATE – page 1

WELLINGTON

WATER-USE FEATURES ON-SITE:						
DESCRIPTION			TYPE	NUMBER	TYPE	NUMBER
SANITATION	Waterless Urinals		WP		TR	
	Manual Flush Urinals		WP		TR	
	Sensor Flush Urinals		WP		TR	
	Cyclic Flush Urinals		WP		TR	
	Single Flush Toilets					
	Dual Flush Toilets					
	Flush Valve Toilets					
	Wash Hand Basins		MT		IF	
AMENITIES	Kitchen Sinks		MT		IF	
	Dishwasher		DOM		COM	
	Washing Machine		DOM		COM	
	Shower		NORM		EFF	
	Drink Fountain		PLMB		OTH	
	Cleaners Tub					
SUPPLY	Rainwater Harvesting					
	Greywater Recycling					
	Other					
EXTRA	Water Feature	Location:	INT		EXT	
	Irrigation System	Location:				
	Other	Explain:				
OTHER						
	Hair-Dresser Basins					
	Ice Machine					
	Coffee Machine – Plumbed		DOM		COM	
	Fire Hose Reel					
Total Number WATER-USE FEATURES on-site:						

ADDITIONAL WATER INFORMATION:				
Is your water currently metered?	YES	NO	Location:	
Do you have access to this meter?	YES	NO		
Do you have sub-meters installed?	YES	NO	Number(s):	
Do you have access to these?	YES	NO		
SUB-METER Locations:				
How are each of the different tenancies charged for their water usage?	GROSS LEASE	NET LEASE		
Do you monitor annual water consumption and set targets?	YES	NO		
Do you have any water management strategies in place?	YES	NO		

LIST OF PLANT EQUIPMENT:	
Boiler:	
Chiller:	
Air Handling Unit:	
Cooling Tower:	
BMS:	
Other:	

Lee Bint
PhD Candidate
Victoria University of Wellington

1

'Water & Office Buildings' Survey
SITE SURVEY SHEET

C6: SITE SURVEY SHEET TEMPLATE – page 2

WELLINGTON

WATER METER INFORMATION:			
Meter 1 Location & Number:			
Reading:		Time:	
Meter 2 Location & Number:			
Reading:		Time:	
Meter 3 Location & Number:			
Reading:		Time:	
Other Meters/Observations:			

OTHER INFORMATION:

Lee Bint
PhD Candidate
Victoria University of Wellington

2

'Water & Office Buildings' Survey
SITE SURVEY SHEET

C7: REPORT TEMPLATE – page 1

Preliminary Results (as at DD-MMMM-YYYY) of the

'WATER & OFFICE BUILDINGS' study

By Lee Bint
PhD Candidate
School of Architecture, Victoria University of Wellington
P: +64-4-463-6253, M: +64-21-322-139, E: bintlee@myvuw.ac.nz

Confidential to:
COMPANY NAME
Auckland Portfolio

Based on the building data provided by Company Name on DD-MMMM-YYYY, the water data provided by Watercare Services Limited on DD-MMMM-YYYY, and the data collected from thirty-three (thirty-seven total) similar Auckland office buildings, the following information is provided.

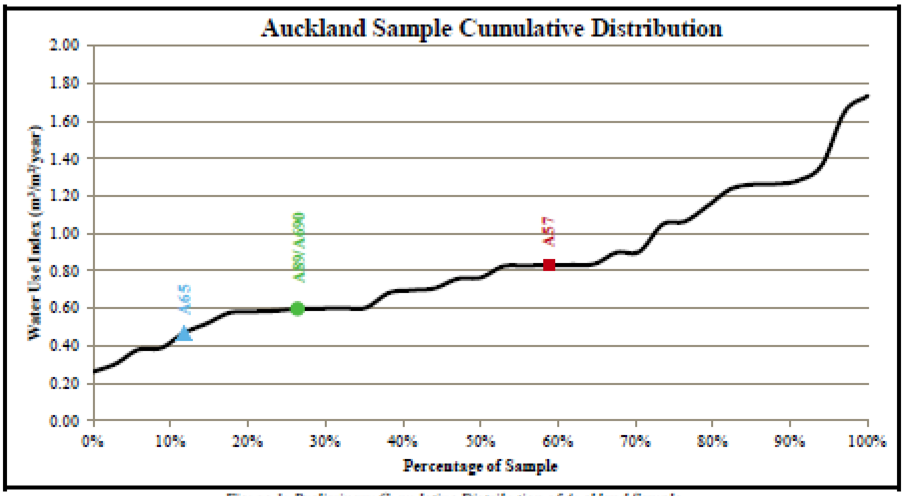


Figure 1: Preliminary Cumulative Distribution of Auckland Sample.

Figure 1 shows the four Company Name Auckland office buildings (three metered accounts) in relation to the other thirty-five Auckland office buildings studied. An overview of the building data provided is outlined below.

Building	Water (m^3)	NLA (m^2)	WUI (m^3/m^2/year)	Auckland Percentile
A57	8,059	17,229	0.47	14
A89/A90	15,598	26,141	0.60	29
A65	32,671	39,490	0.83	57

Table 1: Relative to Figure 1 above.

The Company Name Auckland buildings are all performing relatively well (with all three buildings below the 60th percentile). However, there is still opportunity for their water performance to be improved.

The following report outlines the building audit reports for Building Name, Building Name(s), and Building Name, which include remedial suggestions. This is then followed by an explanatory and methodological summary of the surrounding research study.

Auckland (m^3/m^2/year)	Benchmark	Wellington (m^3/m^2/year)
0.57	Best Case	0.73
0.76	Typical	1.03
0.97	Excessive Use	1.33

Table 2: Regional Benchmarks

One of the most important changes to make includes standardising sub-metering in your water management plan, and implementing a cost-recovery mechanism which then promotes water efficiency to the end-users (i.e. building tenants).

The Water Efficiency Rating Tool (WERT) will soon be available to determine a suitable water efficient appliance package. For any further information, or to discuss implementation strategies, please make contact using the header details.

C7: REPORT TEMPLATE – page 2

BUILDING A57:

Street Address, Auckland Central

The Building Name at Street Address was audited on DD-MMMM-YYYY as part of the 'Water & Office Buildings' study, a PhD project at Victoria University of Wellington. The following page outlines the findings specific to the Building Name.

Water	NLA	Water Use Index	Occupancy	Year Built	Percentile	Lease
32,671m³	39,490m²	0.83	2,820	2000	57	Gross

Table 3: Building Name Data.

Billing history (from 2007-2010) shows that the water consumption peaks over January & February on a common basis, with a notable jump in data from December, and again in April. This is assumed to be due to increased need for irrigating garden areas, and evaporative heat rejection systems, such as cooling towers.

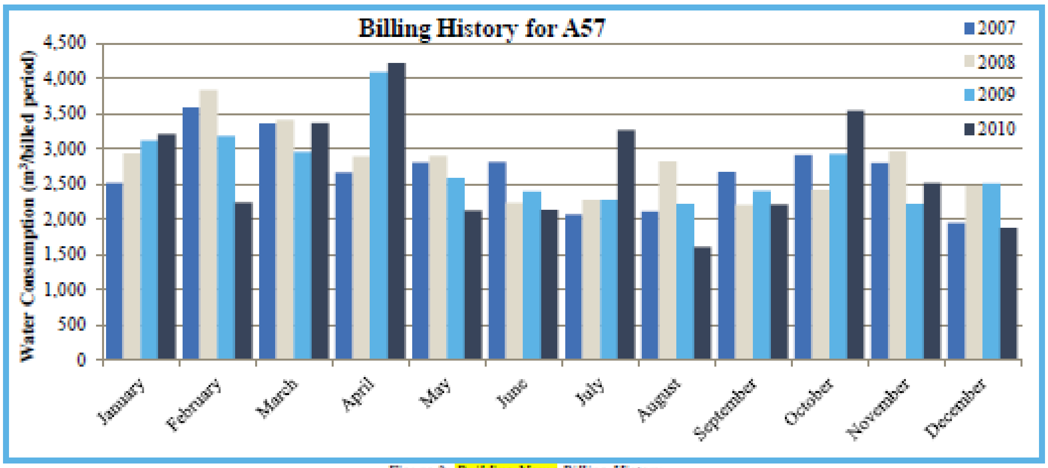


Figure 2: Building Name Billing History.

The present Auckland tariff structure is made up of ingoing potable water + outgoing wastewater as a percentage (75%) of ingoing potable water, and an annual service charge. This structure presents increased opportunities for financial savings through water efficiency means. Saving just 1000m³ of water could save you $4,342 per year (by using 2011 tariffs).

Type	Quantity (m³)	Tariff	Total Cost
A: Ingoing Potable Water	32,395	$1.58/m³	$51,026.10
B: Outgoing Wastewater	24,221 (75% of A)	$3.797/m³	$91,968.09
C: Annual Service Charge	2 x meter	$81/meter	$162.00
D: Total Cost (A + B + C)			$143,156.19

Table 4: Tariff Structures 2010 (please note 2011 tariff structures differ).

From undertaking the site-visits and analysing the provided building and water data, a number of suggestions can be made. These are outlined below in Table 5.

Area	Suggestions
Water Management	Begin recording water bills and meter readings into a separate spreadsheet. Track each period against the same period for the previous year(s) to identify ambiguities and/or misreading. To enable quick identification of leaks and/or unusual consumption peaks, sub-metering is highly recommended as the first step towards good water management practices.
Appliances	The restrooms currently employ microwave sensor urinal flushing, with trials underway for waterless mechanisms. In-line dual flush toilets are installed, however, the most efficient flush available is 6/3L flush. Mixer tap wash-hand basins could be upgraded to either infrared-sensor or self-closing taps. Showers should be fitted with 5-star WELS rated roses, as saving hot water also means saving the energy required to heat the water.
HVAC	The HVAC system currently in place employs water as its heat rejection mechanism. Due to the vast size of the building, this may be the best method of cooling. The dead-band temperature range within the building should be maximised to reduce the need for cooling (and heating), this goes hand-in-hand with reduced energy demands.
Lease Agreements	Most of the water bill is influenced by the end-users (the tenants), yet they are not aware of their usage. A proven conservation practice is restructuring your lease agreements to allow for this, net leasing. There are two methods: A) bill tenants based on their proportion of lettable floor area; or B) bill tenants based on sub-meter readings.
Maintenance	The most common sources of leakage in a building occur around taps, valves, ball flaps, cisterns, and pumps. A single dripping tap can cost you over 24m³/year, or $110 per year! A regular maintenance inspection should be written into the maintenance schedule.

Table 5: Improvement Suggestions.

C7: REPORT TEMPLATE – page 3

BUILDINGS A89 & A90:
Street Addresses, Auckland Central

The Building Names at Street Addresses was audited on DD-MMMM-YYYY as part of the 'Water & Office Buildings' study, a PhD project at Victoria University of Wellington. The following page outlines the findings specific to the Building Names.

Water	NLA	Water Use Index	Occupancy	Year Built	Percentile	Lease
15,598m^3	26,141m^2	0.60	1,800	1990	29	Net

Table 3: Building Names Data.

Billing history (from 2007-2010) shows that the water consumption has troughs during mid-year, and then peaks from January to April. The peak period is generally assumed to be due to the increased need for irrigating garden areas, and evaporation caused by water features, swimming pools, and heat rejection systems, such as cooling towers.

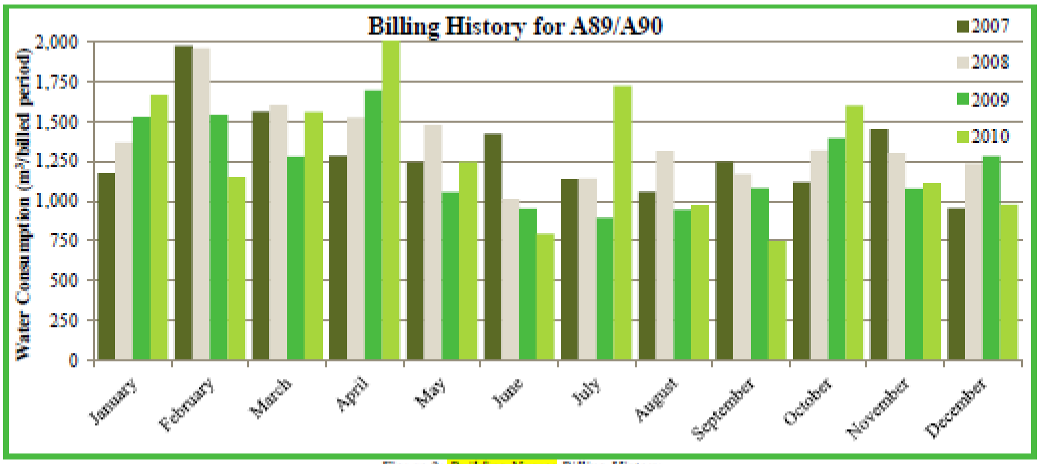


Figure 2: Building Names Billing History.

The present Auckland tariff structure is made up of ingoing potable water + outgoing wastewater as a percentage (75%) of ingoing potable water, and an annual service charge. This structure presents increased opportunities for financial savings through water efficiency means. Saving just 1000m^3 of water could save you $4,342 per year (by using 2011 tariffs).

Water Charge	2010 Quantity (m^3/year)	2010 Tariff	2010 Total Annual Cost
A: Ingoing Potable Water	15,567	$1.58/m^3	$24,595.86
B: Outgoing Wastewater	11,675 (75% of A)	$3.797/m^3	$44,330.92
C: Annual Service Charge	1 x meter	$81/meter	$81
D: Total Cost (A + B + C)			$69,007.78

Table 4: Tariff Structures 2010 (please note 2011 tariff structures differ).

From undertaking the site visits and analysing the provided building and water data, a number of suggestions can be made. These are outlined below in Table 5.

Area	Suggestions
Water Management	Begin recording water bills and meter readings into a separate spreadsheet. Track each period against the same period for the previous year(s) to identify ambiguities and/or misreading. To enable quick identification of leaks and/or unusual consumption peaks, sub-metering is highly recommended as the first step towards good water management practices.
Appliances	The restrooms currently employ a large number of single flush toilets; the most water efficient set-up available is the 6/3L flush toilet (depending on drainage complexities). Cyclically flushing urinals are very wasteful, sensor (either by microwave or infrared sensor) are very effective water saving devices, with manual flush offering the highest saving opportunity (with increased cleaning in low-use areas). Mixer tap wash-hand basins could be upgraded to either infrared-sensor or self-closing taps. All showers should be fitted with a 5-star WELS rated rose, as saving hot water also means saving the energy required to heat the water.
HVAC	The HVAC system currently in place employs water as its heat rejection mechanism. Due to the size of the building, this could be altered to an air-based system. The dead-band temperature range within the building should be maximised to reduce the need for cooling (and heating), this goes hand-in-hand with reduced energy demands.
Lease Agreements	Most of the water bill is influenced by the end-users (the tenants), yet they are not aware of their usage. A proven conservation practice is restructuring your lease agreements to allow for this, net leasing. There are two methods: A) bill tenants based on their proportion of lettable floor area; or B) bill tenants based on sub-meter readings.
Maintenance	The most common sources of leakage in a building occur around taps, valves, ball flaps, cisterns, and pumps. A dripping tap can cost you over 24m^3/year, or $110 per year! A regular maintenance inspection should be written into the maintenance schedule.

Table 5: Improvement Suggestions.

C7: REPORT TEMPLATE – page 4

BUILDING A65:
Street Address, Auckland Central

The Building Name at Street Address was audited on DD-MMMM-YYYY as part of the 'Water & Office Buildings' study, a PhD project at Victoria University of Wellington. The following page outlines the findings specific to Building Name.

Water	NLA	Water Use Index	Occupancy	Year Built	Percentile	Lease
8,059m³	17,229m²	0.47	1,230	1989	14	Gross

Table 3: Building Name Data.

Billing history (from 2009-2011) shows that the water consumption peaked over February to March of 2010, with a notable jump in the recorded data. The seasonal analysis shows that the highest consuming period is January through to April.

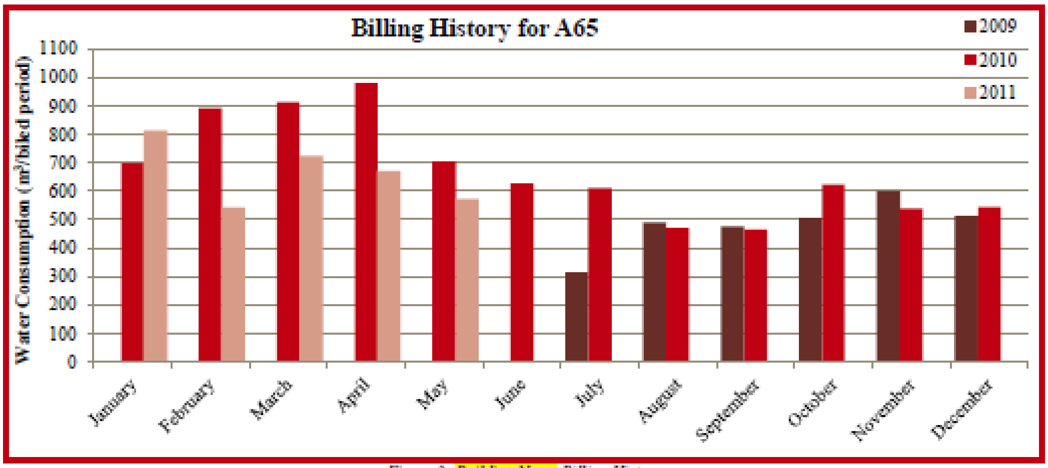


Figure 2: Building Name Billing History.

The present Auckland tariff structure is made up of ingoing potable water + outgoing wastewater as a percentage (75%) of ingoing potable water, and an annual service charge. This structure presents increased opportunities for financial savings through water efficiency means. Saving just 1000m³ of water could save you $4,342 per year (by using 2011 tariffs).

Water Charge	2010 Quantity (m³/year)	2010Tariff	2010 Total Annual Cost
A: Ingoing Potable Water	8,059	$1.58/m³	$12,733.22
B: Outgoing Wastewater	6,044 (75% of A)	$3.797/m³	$22,949.07
C: Annual Service Charge	1 x meter	$81/meter	$81.00
D: Total Cost (A + B + C)			$35,762.29

Table 4: Tariff Structures 2010 (please note 2011 tariff structures differ).

From undertaking the site visits and analysing the provided building and water data, a number of suggestions can be made. These are outlined below in Table 5.

Area	Suggestions
Water Management	Begin recording water bills and meter readings into a separate spreadsheet. Track each period against the same period for the previous year(s) to identify ambiguities and/or misreading. To enable quick identification of leaks and/or unusual consumption peaks, sub-metering is highly recommended as the first step towards good water management practices.
Appliances	The restrooms currently employ a mixture of toilet flushing mechanisms; the most efficient method (depending on drainage complexities) is the dual flush (6/3L) system. Showers should be fitted with 5-star WELS rated roses, as saving hot water also means saving the energy required to heat the water. Manual flushing urinals and infrared-sensor wash-hand basins are excellent water efficient devices.
HVAC	The HVAC system currently in place employs water as its heat rejection mechanism. Due to the size of the building, this may be the best method for cooling (with relevant maintenance). The dead-band temperature range within the building should be maximised to reduce the need for cooling (and heating), this goes hand-in-hand with reduced energy demands.
Lease Agreements	Most of the water bill is influenced by the end-users (the tenants), yet they are not aware of their usage. A proven conservation practice is restructuring your lease agreements to allow for this, net leasing. There are two methods: A) bill tenants based on their proportion of lettable floor area; or B) bill tenants based on sub-metered readings.
Maintenance	The most common sources of leakage in a building occur around taps, valves, ball flaps, cisterns, and pumps. A single dripping tap can cost you over 24m³/year, or $110 per year! A regular maintenance inspection should be written into the maintenance schedule. Although no leaks were identified while on site.

Table 5: Improvement Suggestions.

C7: REPORT TEMPLATE – page 5

OTHER RESULTS & INFORMATION

The 'Water & Office Building' study results:
This study analysed the performance data from 93 commercial office buildings in the Auckland (37) and Wellington (56) centres. The study compared the CBD results against a number of non-CBD office buildings to determine if the results and benchmarks are relevant across all office buildings within the regions. Below is an outline of the range in the study buildings included.

Characteristic	Minimum	Median	Mean	Maximum
Water Consumption (m^3)	520	7,896	10,011	32,671
Net Lettable Area (m^2)	1,636	8,951	10,633	39,490
Storeys	3	14	15	42
Occupancy	13	464	591	2,820
Year Built	1917	1982	1978	2009
Footprint Area (m^2)	145	762	893	3,213
Hours of HVAC Operation	0	55	48	65

Table A: Range in Sample Characteristics.

The benchmarks were separated by location due to the statistical difference in their means. After further analysis, it appears that the biggest water efficiency and/or conservation influence was the tariff structures and therefore visible incentives for reducing water consumption were higher in Auckland.

The resultant benchmarks for both regions are outlined below. These benchmarks went through statistical testing to determine their applicability to different characteristics of the buildings, this included age, size, location, height, and HVAC methods.

Auckland ($m^3/m^2/year$)	Benchmark	Wellington ($m^3/m^2/year$)
0.57	Best Case	0.73
0.76	Typical	1.03
0.97	Excessive Use	1.33

Table A: Regional Benchmarks

An Australian study (Quinn et al, 2006) showed that 31% of total annual consumption was used in building cooling (HVAC), 37% goes to domestic appliances (toilet flushing, washing, cooking, drinking, other), another 6% going to other tasks, and the remaining 26% being attributed to leakage/baseflow.

Workshop results:
During late August 2011, two workshops were hosted, one in Auckland followed by another in Wellington. These were undertaken to A) present the 'Water & Office Buildings' study results back to the people who have supported this study, B) determine practical industry challenges and struggles, and possible solutions in the water, building, and related industries, and C) demonstrate the use of the Water Efficiency Rating Tool (WERT), which has been developed as the end-product from this study.

The results from the table discussions and questionnaires included education, both to the managers and the end-users of water, on benchmarks, performance targets, and general water efficiency/conservation. The desire for support to incentivise the installation of sub-metering and therefore educating on consumption issues was voiced. Educating on tariff structures to local water agencies/government, to provide these real visual incentives to their customers was also highlighted.

Future work:
This study has found further research is needed for other building types and locations. Currently the only data available on wasted (leaked) water is from Australia, further research is needed to determine the New Zealand figures.

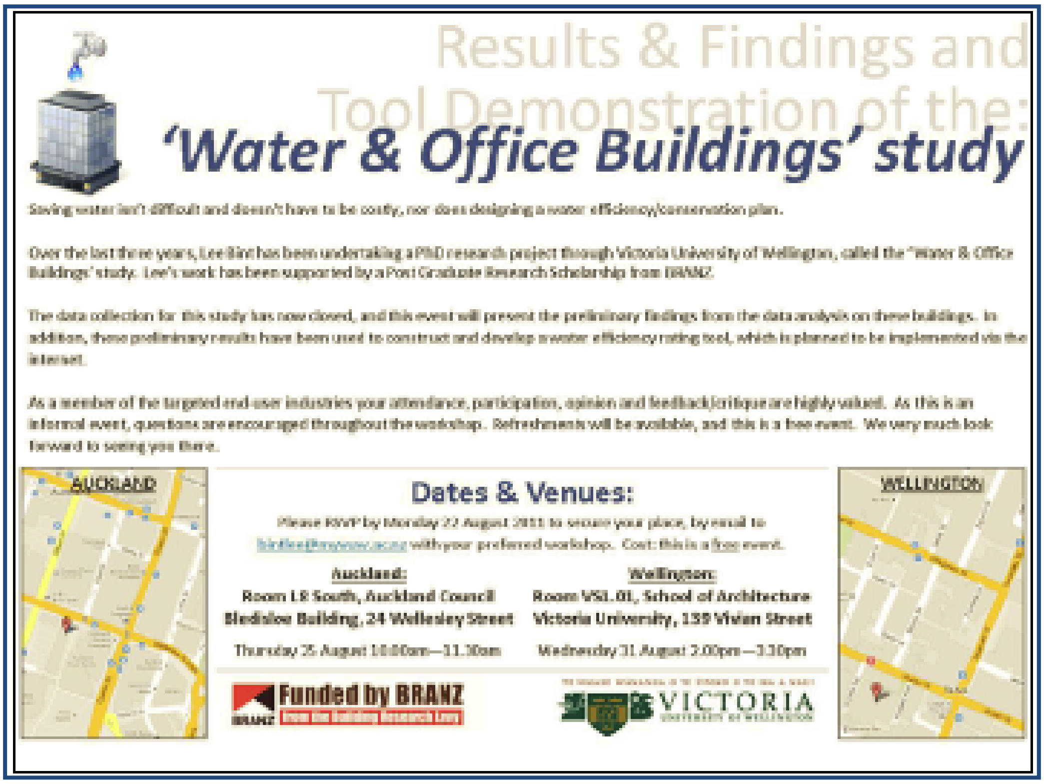
This PhD study will be completed in March 2012. Further work to develop and commercialise the WERT could include pilot trials and additional monitoring studies.

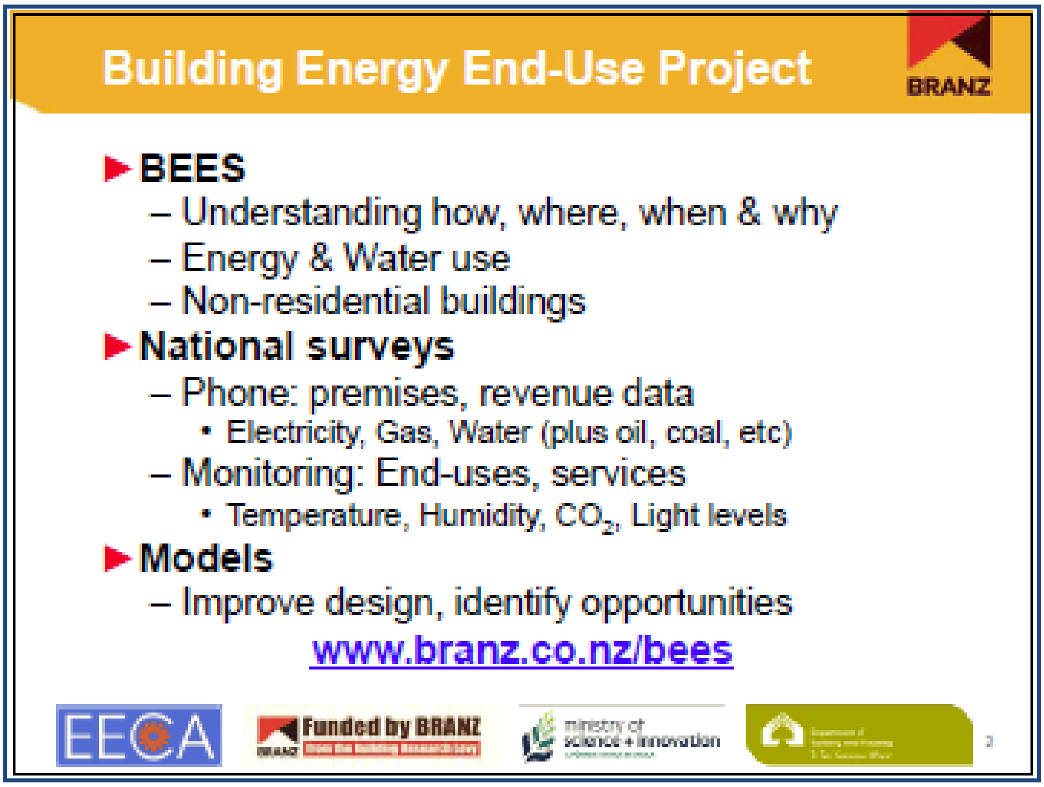
For further information or expressions of interest to further partake in these pilot studies, please contact Lee Bint by using the details outlined on the cover page.

Reference:
Standards New Zealand. (2005). *AS/NZS 6400: 2005 Water Efficient Products – Rating and Labelling*. Standards New Zealand, New Zealand.

Quinn, R., Bannister, P., Munzinger, M., and Bloomfield, C. (2006). *Water Efficiency Guide: Office and Public Buildings*, Australian Government, Department of the Environment and Heritage, Australia. [Online].

C8: WORKSHOP PRESENTATION – pages 1 & 2

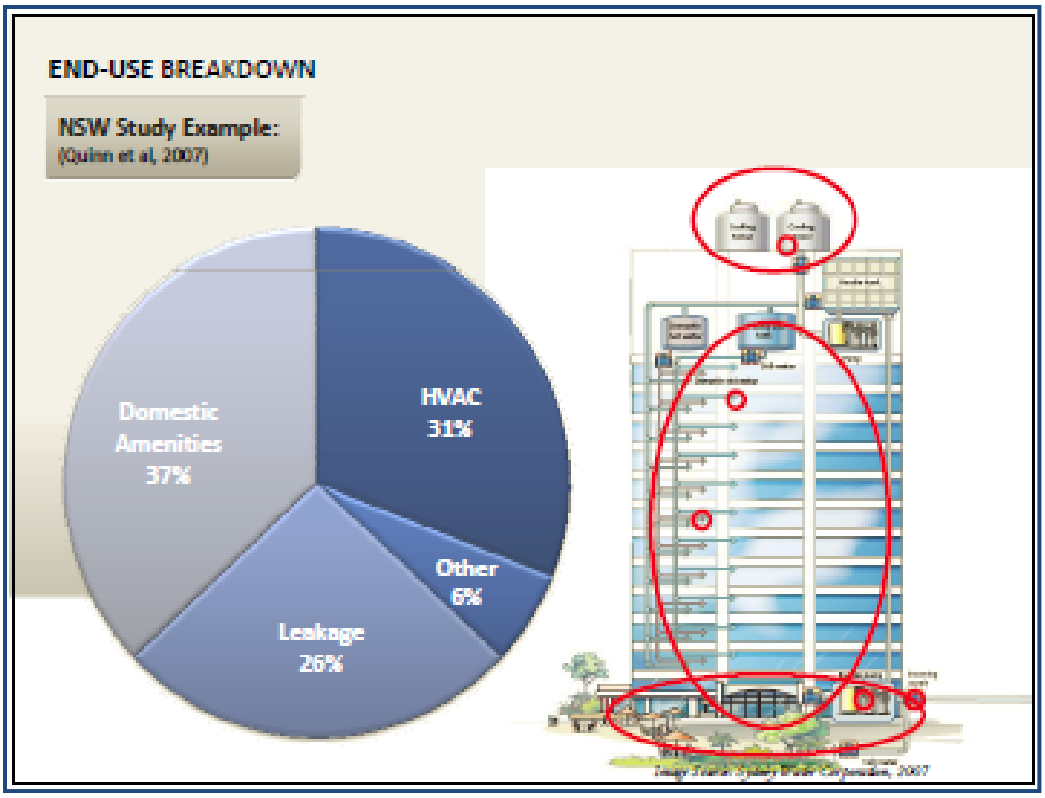




C8: WORKSHOP PRESENTATION – pages 3 & 4

C8: WORKSHOP PRESENTATION – pages 5 & 6

C8: WORKSHOP PRESENTATION – pages 7 & 8

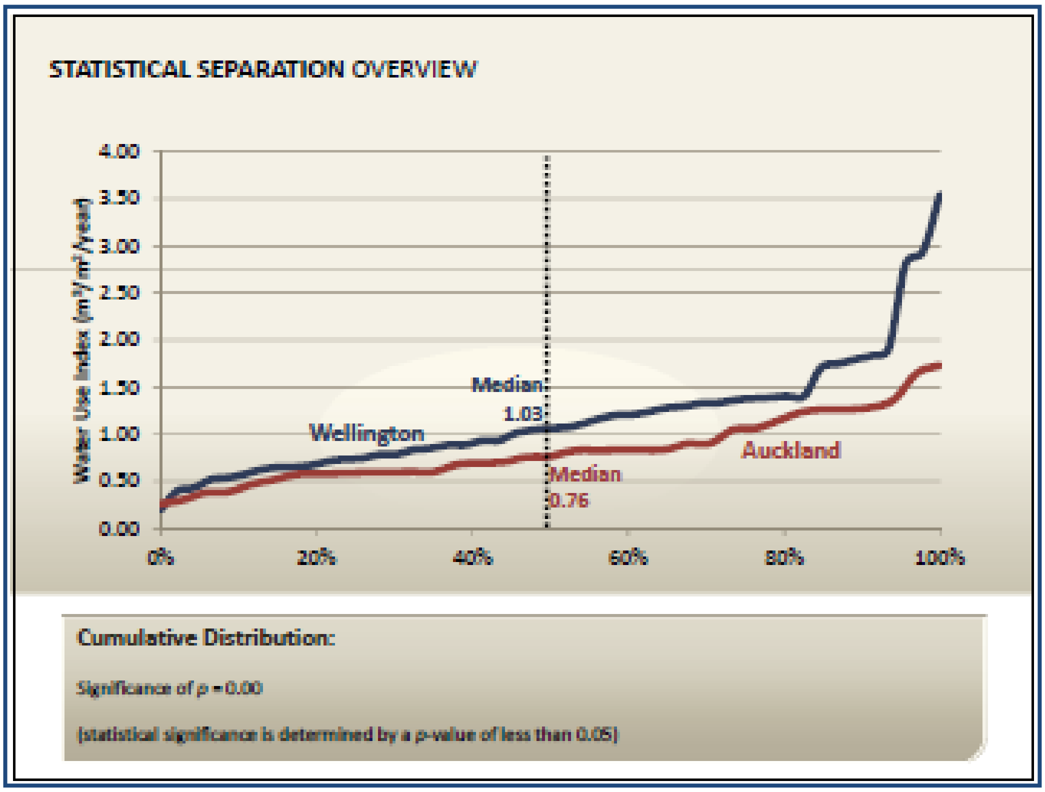


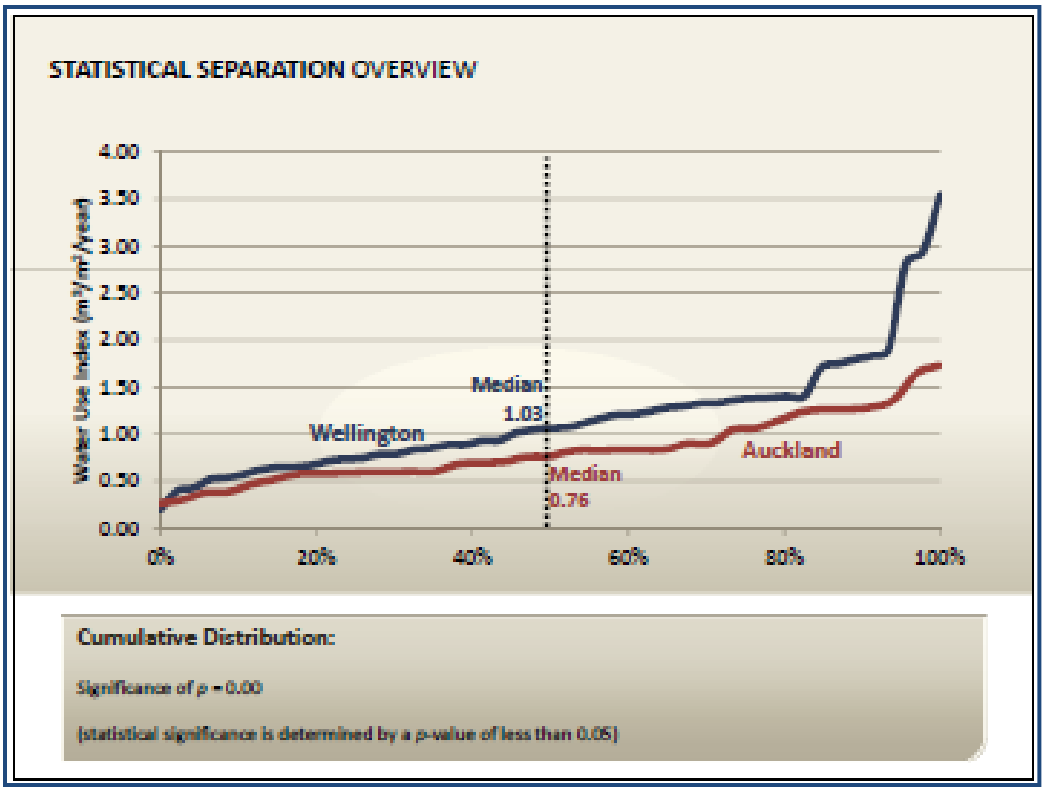
'WATER & OFFICE BUILDINGS' STUDY OVERVIEW

Variable	Minimum	Median	Maximum
Net Lettable Area (m^2)	1,636	8,951	32,671
Building Age (year constructed)	1917	1982	2009
Number of Storeys	3	14	42
Number of Domestic Amenities	51	193	699
Full Time Equivalent Occupants	13	210	2,820
Hours of Operation	40	52	65
Annual Water Consumption (m^3)	520	6,952	39,490

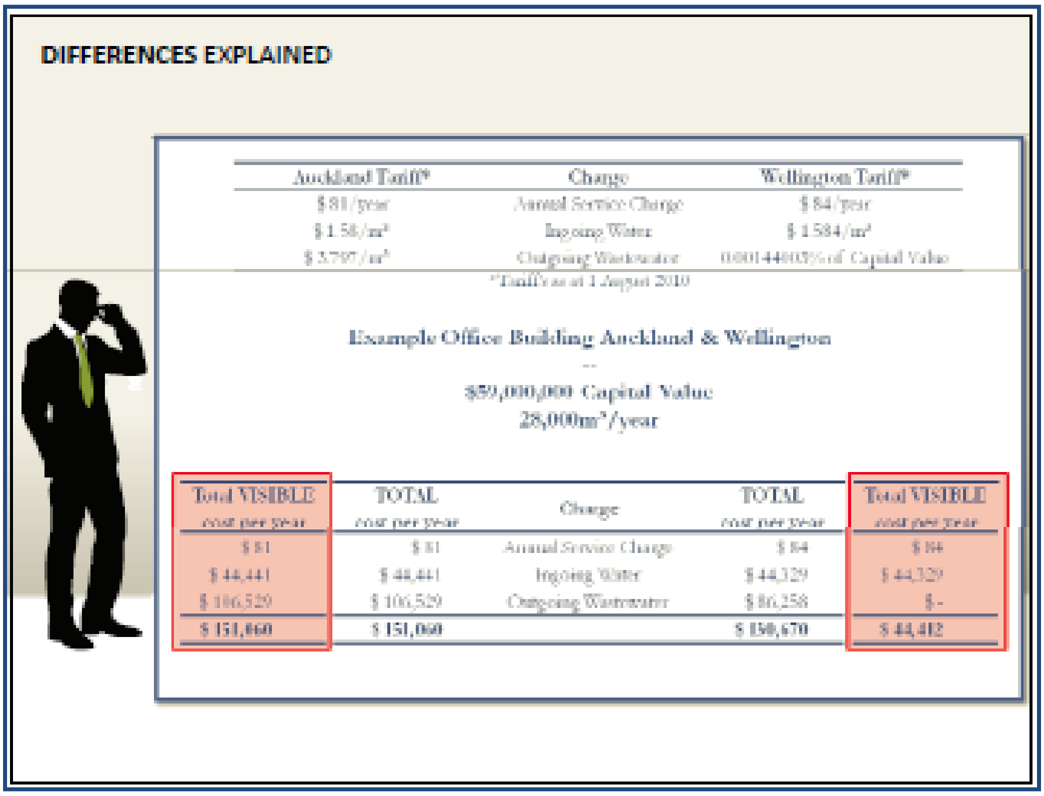
Sample Statistics:
n = 93

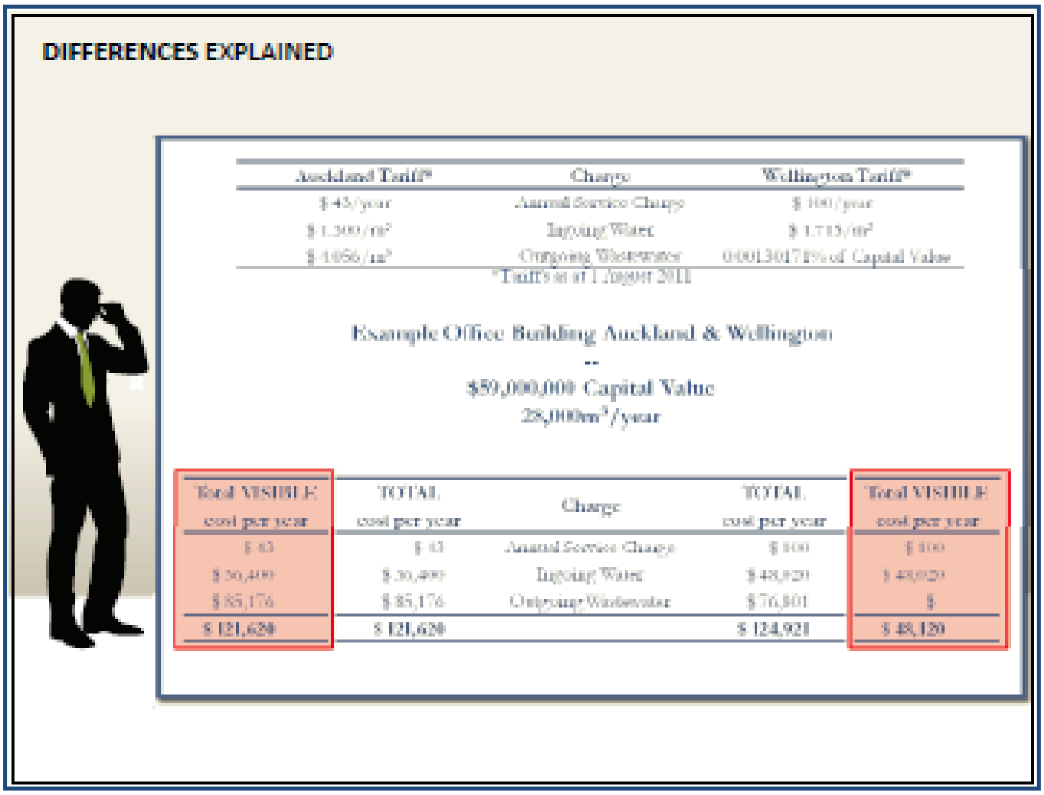
C8: WORKSHOP PRESENTATION – pages 9 & 10



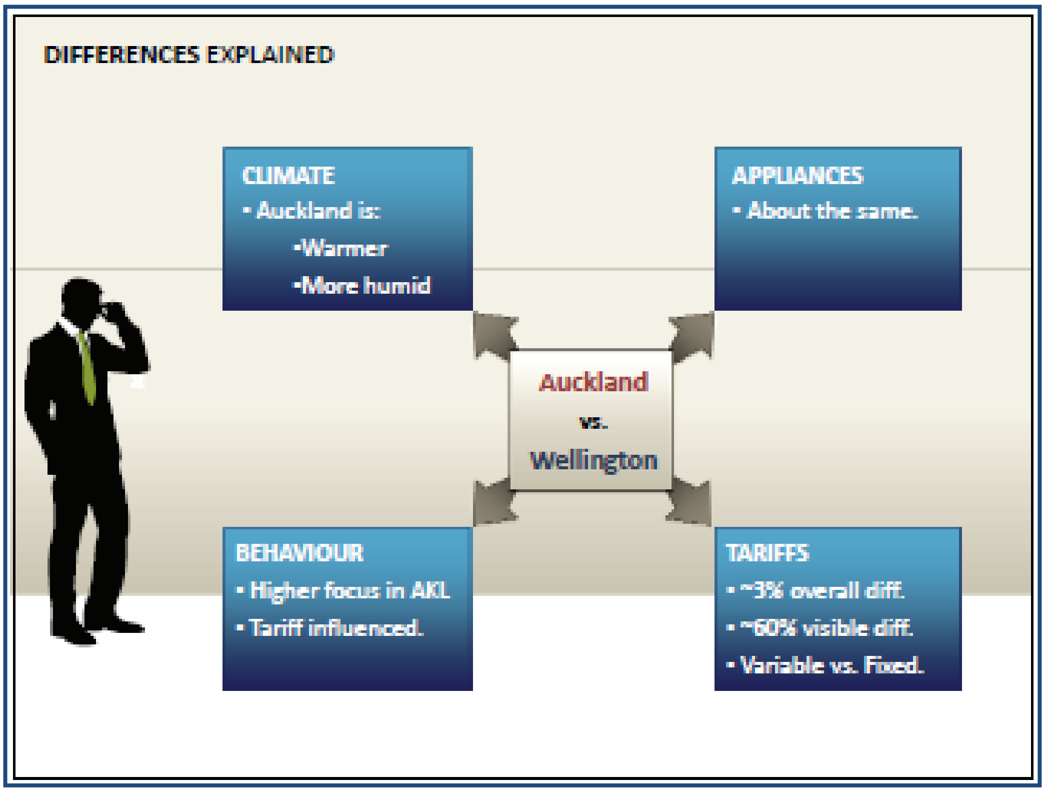


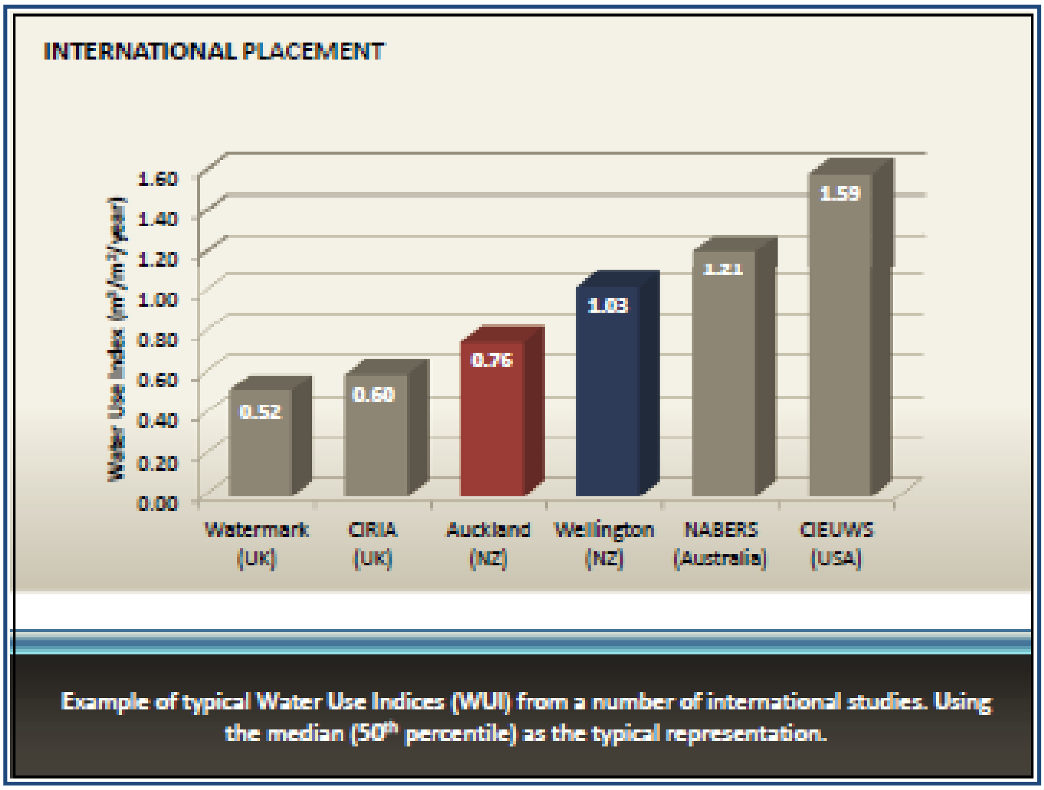
C8: WORKSHOP PRESENTATION – pages 11 & 12





C8: WORKSHOP PRESENTATION – pages 13 & 14



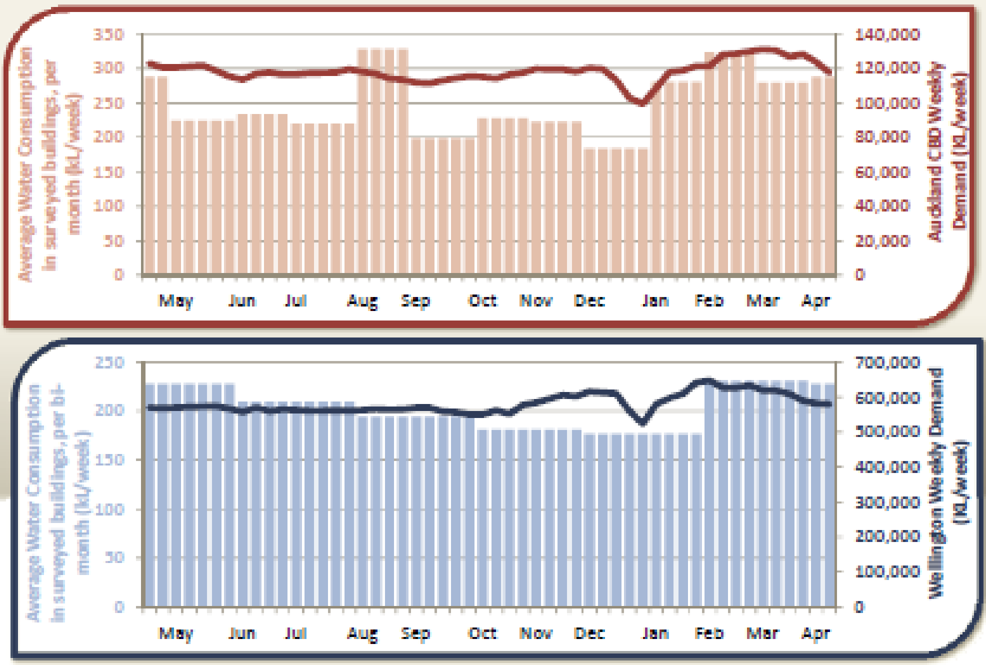


C8: WORKSHOP PRESENTATION – pages 15 & 16

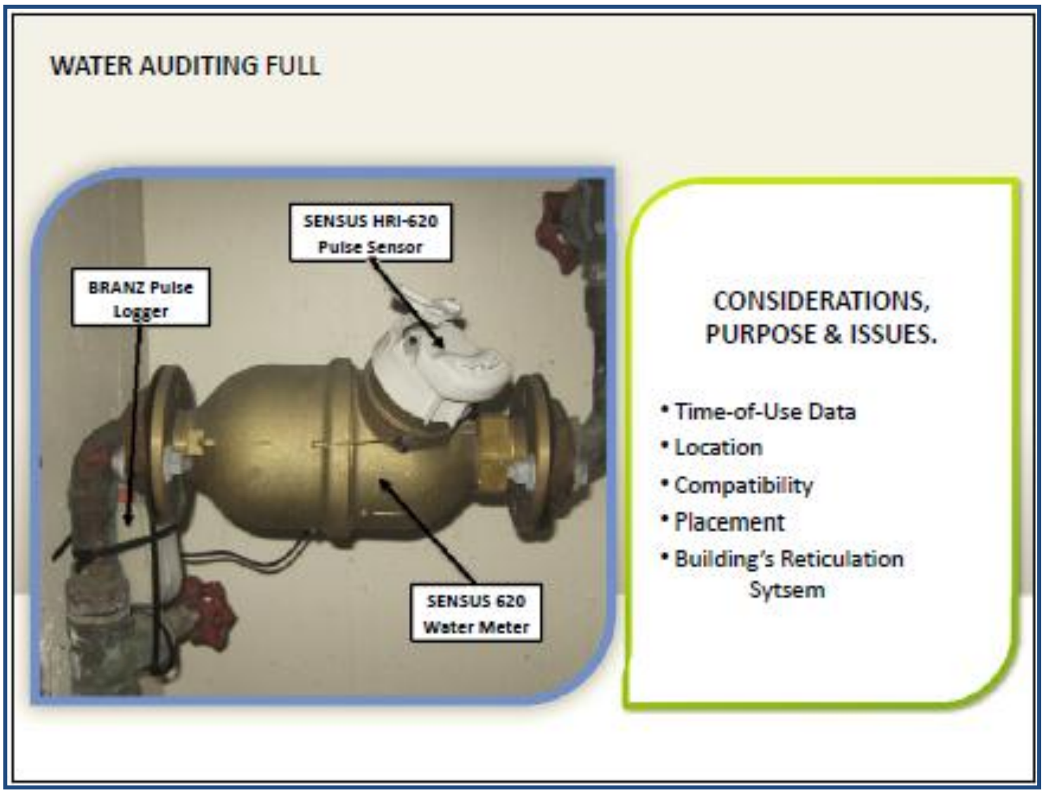
BENCHMARKS CALCULATED

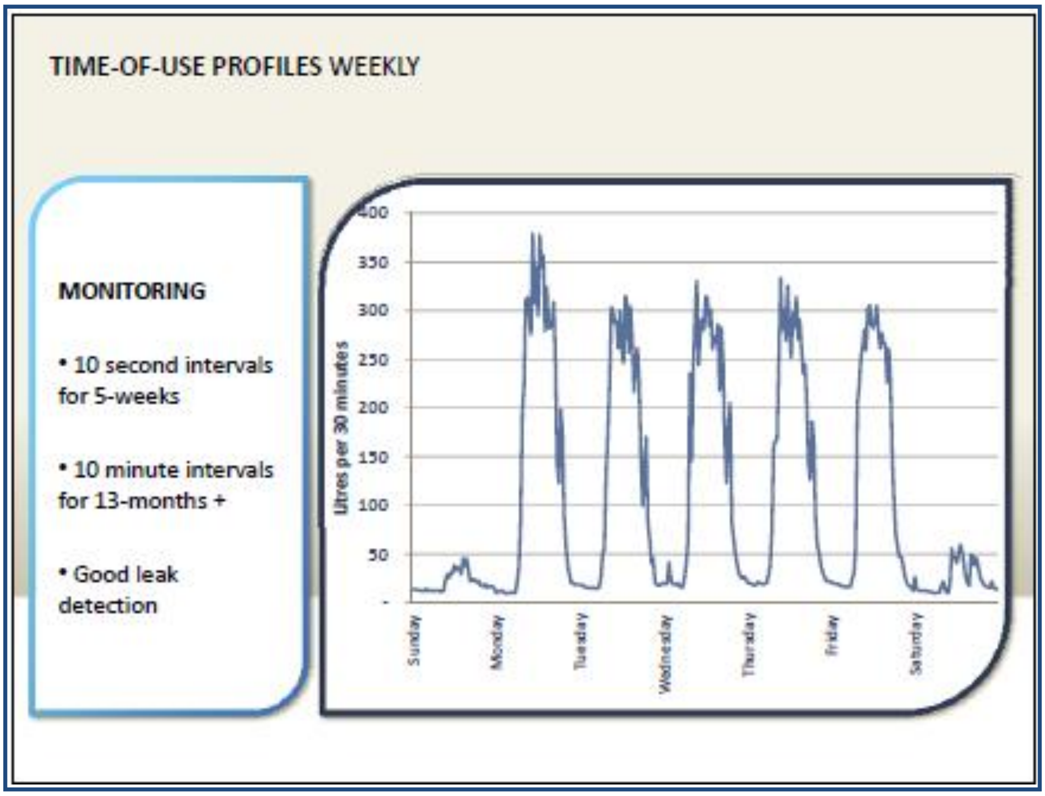
BENCHMARK	AUCKLAND	WELLINGTON
Best Case (25%)	0.57 $m^3/m^2/year$	0.73 $m^3/m^2/year$
Typical (50%)	0.76 $m^3/m^2/year$	1.03 $m^3/m^2/year$
Excessive Use (75%)	0.97 $m^3/m^2/year$	1.33 $m^3/m^2/year$

DATA BILLING VS. DEMAND

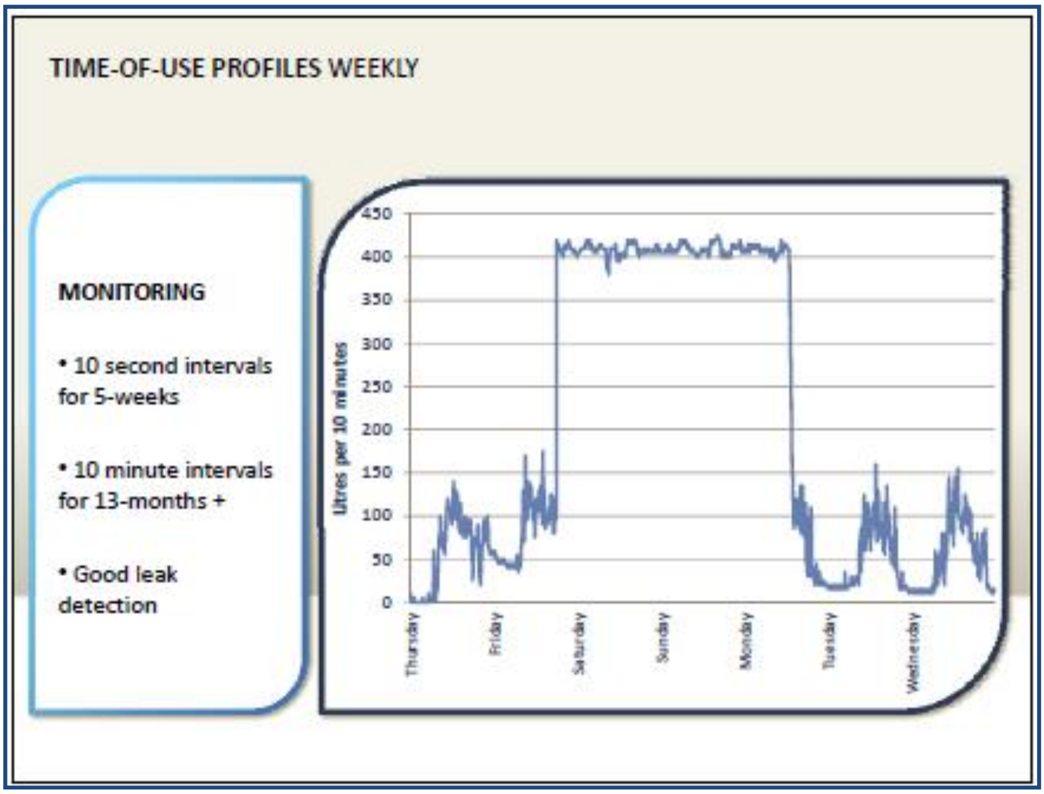


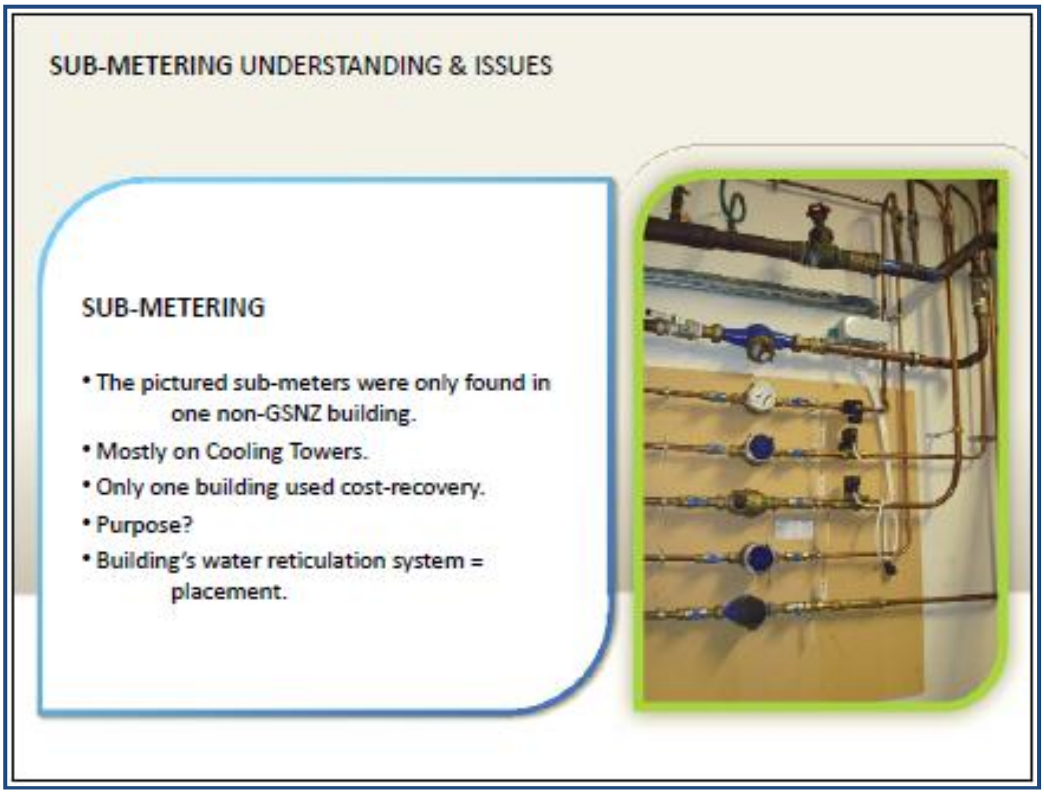
C8: WORKSHOP PRESENTATION – pages 17 & 18



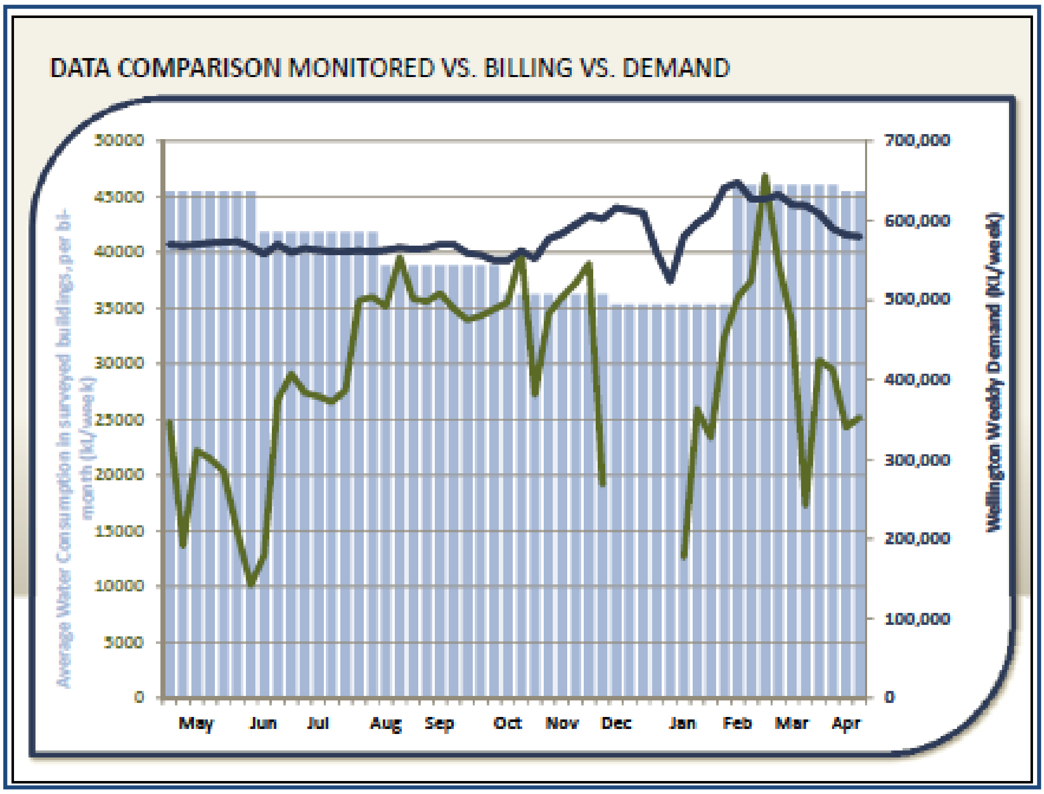


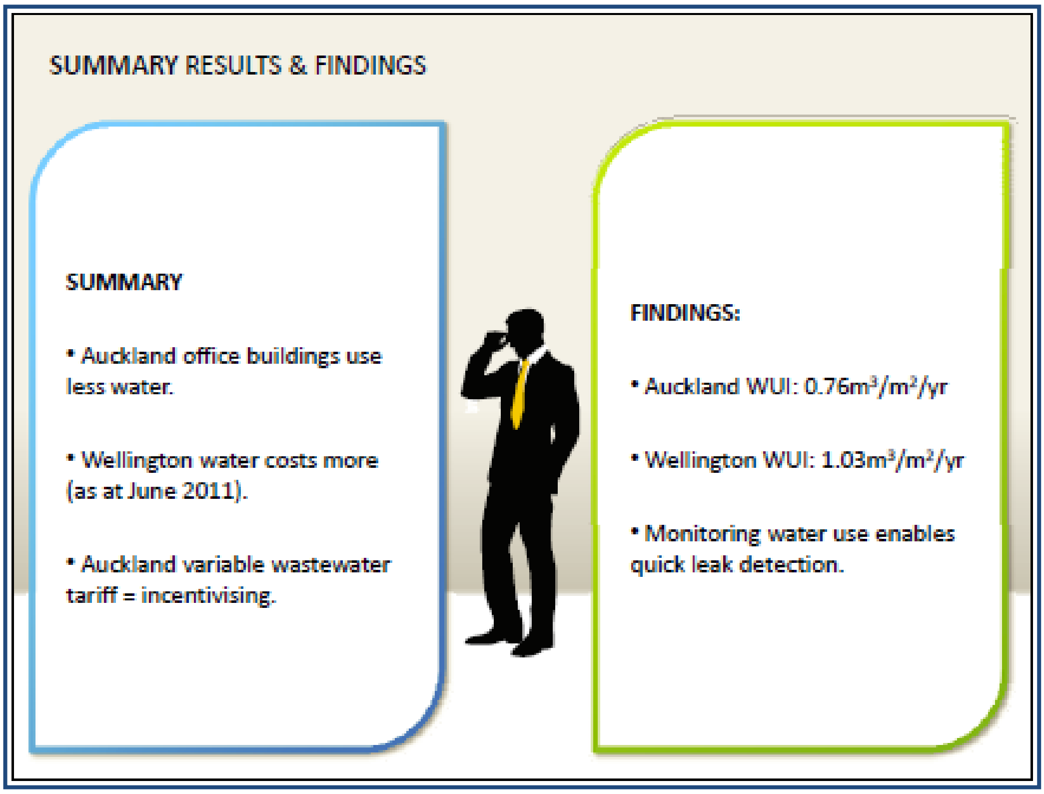
C8: WORKSHOP PRESENTATION – pages 19 & 20





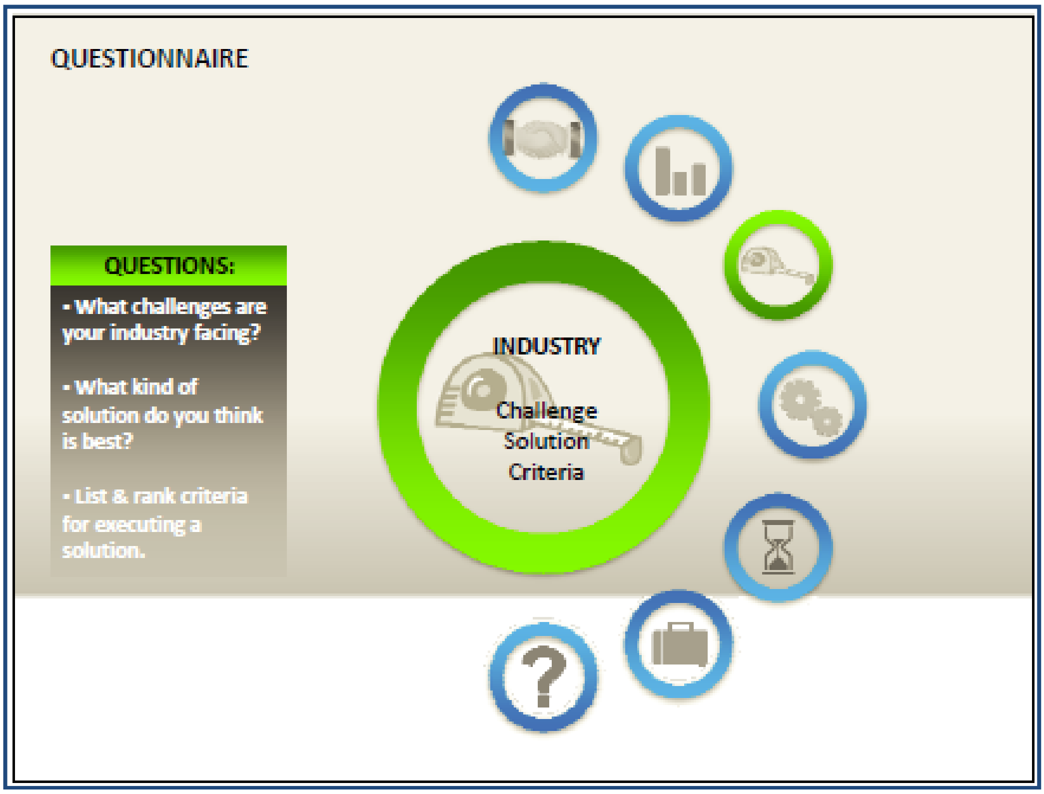
C8: WORKSHOP PRESENTATION – pages 21 & 22





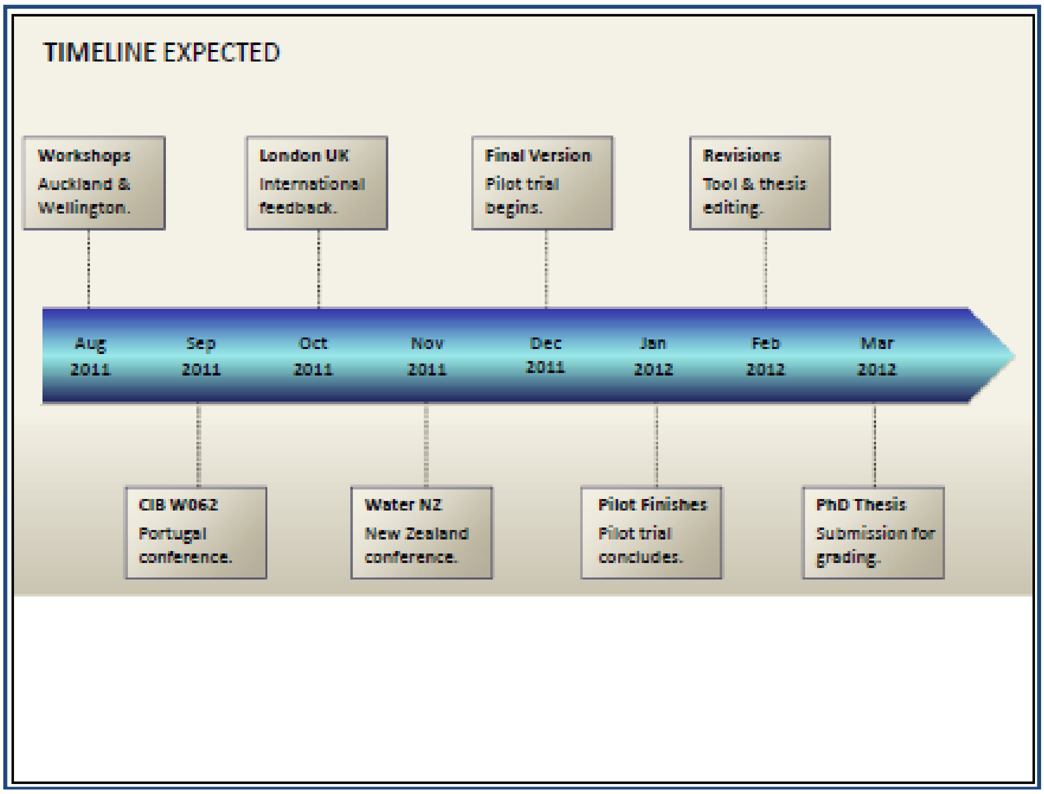
C8: WORKSHOP PRESENTATION – pages 23 & 24

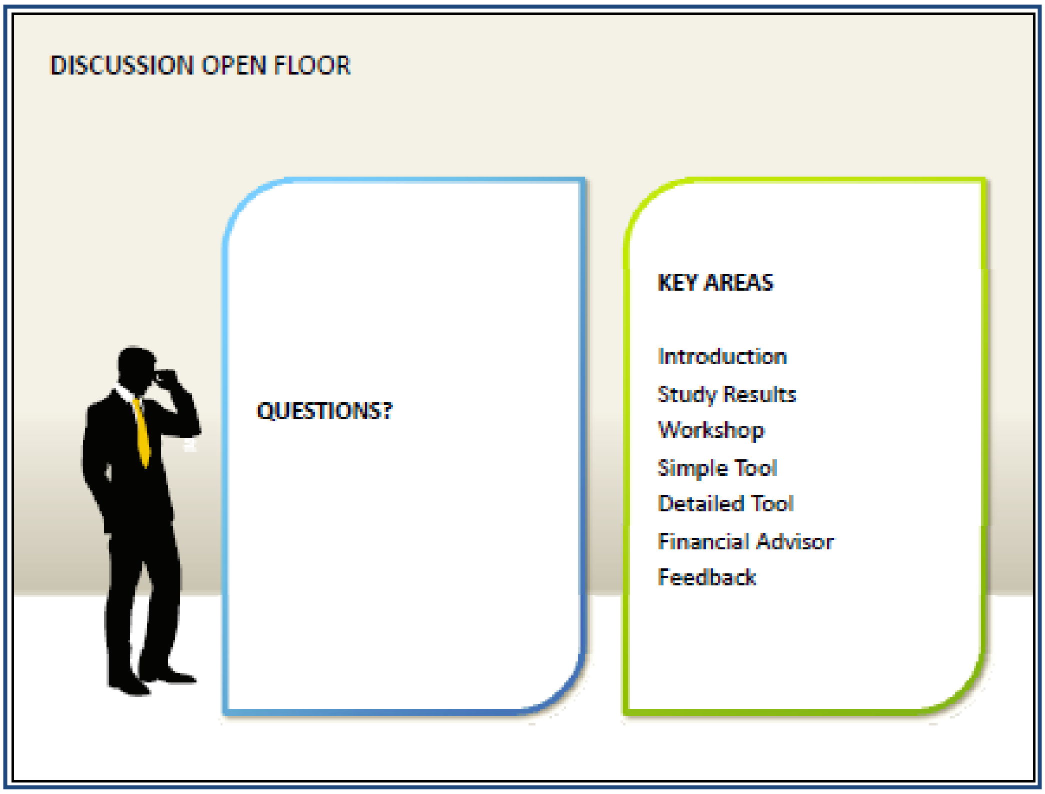
C8: WORKSHOP PRESENTATION – pages 25 & 26



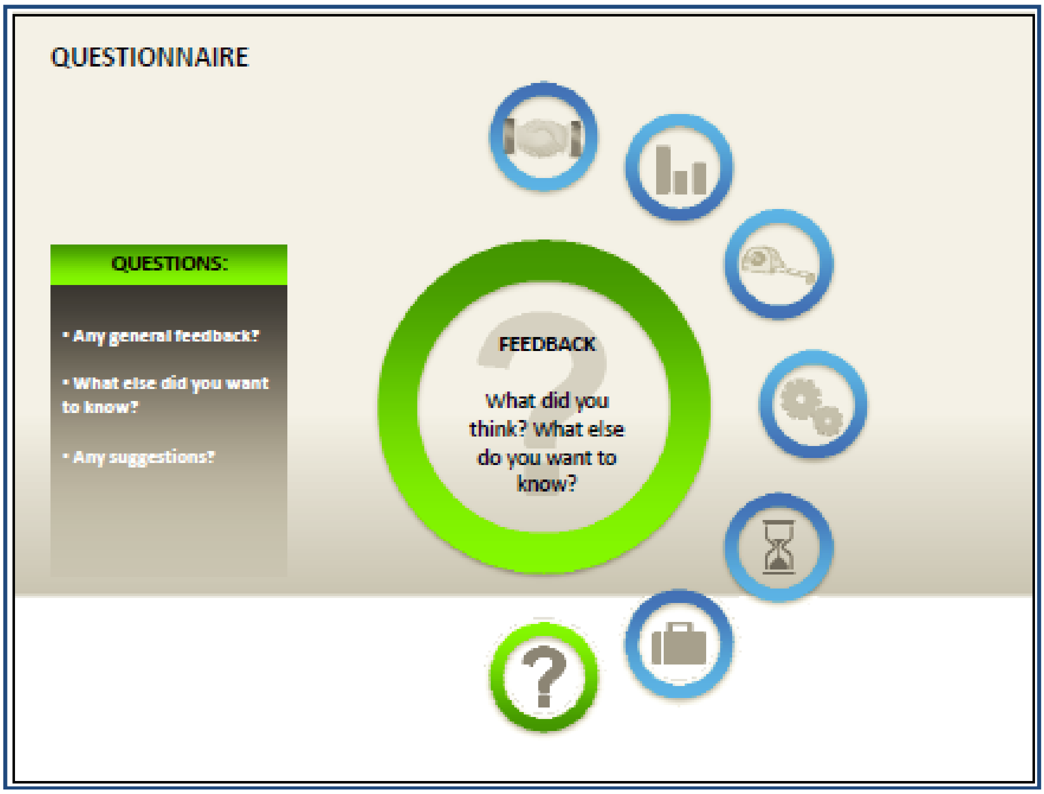
C8: WORKSHOP PRESENTATION – pages 27 & 28

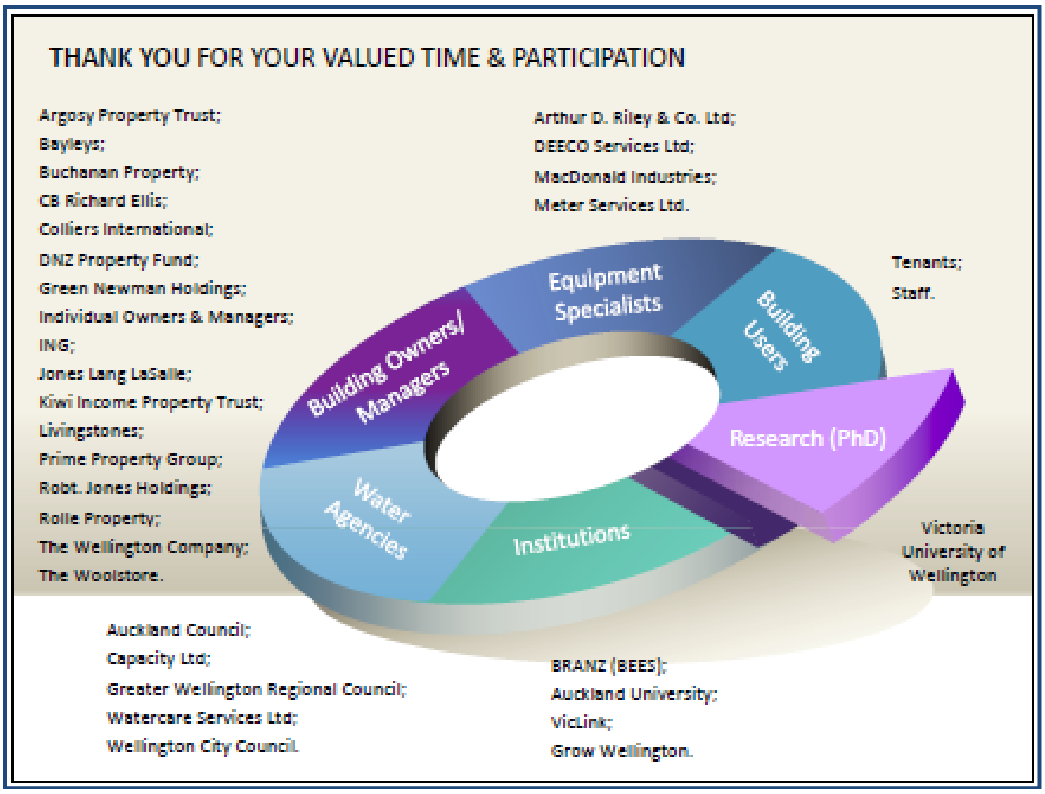
C8: WORKSHOP PRESENTATION – pages 29 & 30





C8: WORKSHOP PRESENTATION – pages 31 & 32





C8: WORKSHOP PRESENTATION – page 33

C9: WORKSHOP QUESTIONNAIRE TEMPLATE – page 1

INTRODUCTION	Please select industry category:	☐ Local Authority ☐ Water Service ☐ Building/Property/Facilities Management ☐ Consultant/Engineer/Designer/Advisor ☐ Research/Academic Institution ☐ Other
	Affiliation:	
	Name & Email (optional):	
	Reason for attending:	
RESULTS	Did you find this information useful?	
	What was most important?	
	What was least important?	
	What would you like to know more about?	
	Any general comments/ questions/ feedback?	
WORKSHOP	CHALLENGES	
	SOLUTIONS	
	Rank in order of importance any CRITERIA for executing a solution in your industry: (1 being the most important – 10 being the least important)	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

C9: WORKSHOP QUESTIONNAIRE TEMPLATE – page 2

SIMPLE TOOL	Usefulness/Relevance	
	Worth?	
	Reason for worth estimation?	
	Additional comments?	
DETAILED TOOL	Usefulness/Relevance	
	Worth?	
	Reason for worth estimation?	
	Additional comments?	
FINANCIAL ADVISOR	Usefulness/Relevance	
	Worth & justification?	
	Advantages?	
	Disadvantages?	
	Additional comments?	
	Pilot Trial?	☐ (tick if willing to participate)
FEEDBACK	Comment on usefulness in your industry category?	
	Comment on usefulness in other industry categories?	
	Any general feedback?	
	What else did you want to know?	
	Any further suggestions?	

C10: OVERALL WORKSHOP FEEDBACK – attendance and general results

ID	Target Market	Reason for Attendance	Results Useful	Most Important	Least Important	More Information	Additional Feedback
1	Local Authority	Water Efficiency Opportunities & Benchmarking	Yes	Benchmark for Auckland	-	Leakage in New Zealand = more information	Benchmarking for other buildings
2	Property Management	Manage a number of buildings studied	Yes	Benchmarking information	-	Actual use in and outside buildings	-
3	Property Management	Future project water use reduction	Yes	Monitoring highlights quick leak detection	-	Remote measurement of water use	-
4	Property Management	Tool & results of study	Yes	Sub-metering and usage	-	-	-
5	Property Management	Benchmarking results	Yes	All	Nothing	Monitoring methods, water rating cost tool cost	-
6	Research/ Academic	Commercialise	Yes	Benchmarks and their differences, and tariff differences	Methodology and statistics	Best practice, incentives for metering	-
7	Water Service Provider	Results & next steps	Yes	Discussion, benchmarking, details in fact, all of it	NA	Appliances & cooling tower quality/efficiency, tariff change influences end-uses	-
8	Local Authority	Sustainability in built environment	Reasonably	Change in Watercare charging = Wellington now more expensive	Time-of-use profiles	Opportunity for innovation	Role of water in cooling tower vs. energy cost
9	Local Authority	Upskilling	Yes	Tariff incentivizing effect	-	Incentives for tenants	-
10	Water Service Provider	Understand water efficiency for commercial buildings	-	-	-	-	-
11	Property Management	Benchmarks	-	Benchmark	-	-	-
12	Property Management	GSNZ info	More data required	Cost from Auckland/Wellington	Yearly data, no answer to spikes	GSNZ operational data	-
13	Equipment Specialist	Research interest, networking	Yes	-	-	-	-
14	Consultant	Learn about water use	Extremely	Benchmark	General Wellington consumption	More detail about what uses water in a building	Very well done
15	Equipment Specialist	Interest in water conservation	Yes	Difference between Auckland and Wellington	-	-	-
16	Property Management	Industry related	Yes	Tariff structure difference, high leakage factor	-	What influenced WCC tariff changes	-
17	Consultant	Understanding water in existing buildings	Yes	Minimal seasonal variance, high leakage factor	Nothing	Leakages, leak detection, monitoring, GSNZ vs. non-GSNZ	-
18	Consultant	Interested in commercial water use	Yes	Comparison between Auckland and Wellington, bill structure, leak detection	-	How to reduce Wellington water consumption	Some data should be clarified a bit more
19	Property Management	Topic interest	Yes	Building modelling, potential savings	Difference between Auckland and Wellington	Building modelling	-
20	Property Management	Learn about water conservation	Yes	Wellington tariff structures, benchmarks	-	Cost/work involved for installing loggers	Good work, it is clear a lot of work has been undertaken
21	Water Service Provider	Community water conservation	Yes, very	Leakage, leak detection, difference in Benchmarks	-	Monitoring, leak detection, sub-metering	-

Information on Attendance and General Study Results

C10: OVERALL WORKSHOP FEEDBACK – industry challenges and possible solutions

ID	Challenges	Solutions	Ranking of Solutions						
			1	2	3	4	5	6	7
1	Budget constraints: capex separate to opex, building size vs. budget, some solutions implemented but not best practice, more information needed	Monitoring, research use and solutions, new building/retrofit guides, CFO capex/opex sustainable solutions	Reliability of water meter	Reliable consumption data	Good usage info for tenants	Where is water going	Good data overall	Perception of water as an issue in NZ	Capex / Opex
2	-	-	-	-	-	-	-	-	-
3	Budget constraints, political decisions, capex vs. opex, treatment of rainwater	Standard for water use from rainwater harvesting, and monitoring of current systems	-	-	-	-	-	-	-
4	Capital for improvements ROI	Government grants	Reliable meters	Leakage	Good data	Perception of water in NZ	Information to tenants	-	-
5	Implementation and monitoring	Open to any	-	-	-	-	-	-	-
6	Building manager = occupants, tenants = lack of info, can't find meter/data, who in council has data/info	Role of billing/ energy manager, staff knowledge, H&S, someone's job, education, qualified decision making	-	-	-	-	-	-	-
7	Cost-benefit of data collection, monitoring of savings	Sustainability type drivers which add value to savings	-	-	-	-	-	-	-
8	Feedback loops in users	Education, ownership by building manager	Job description for water conservatio n	-	-	-	-	-	-
9	Information and education feedback loops	Better data and organisational responsibility trail	Better data	Manage & communicate the data	Training occupants	-	-	-	-
10	Availability, accuracy of data informing efficiency options and cost benefits, finding losses	-	-	-	-	-	-	-	-
11	Capital expenditure of installing meters	-	-	-	-	-	-	-	-
12	Learning Auckland trend path	Using trend data on older buildings	-	-	-	-	-	-	-
13	Buy-in from building owners, seems to be wanted: audit services	Promote WELS on a commercial level	Contact with building managers	Reinforce relationship	Expose new product	-	-	-	-
14	Determining priorities, incentives are not great relative to priorities	Pay Lee to do them, change Wellington tariff to a usage rate	-	-	-	-	-	-	-
15	-	-	Education to owner	Education to plumber	Education to merchant	-	-	-	-
16	Tariffs, behaviour	Wellington tariff structure, education	-	-	-	-	-	-	-
17	Education, visible costs, leaks, monitoring	-	-	-	-	-	-	-	-
18	Change awareness of water to break usage habits	Wellington billing structure, sub-meter tenants = take on cost	-	-	-	-	-	-	-

		and try to break employee habits, educate people							
19	Not a priority = incentives, environmental benefits, education on possible savings areas, paybacks	Education, promotion of remedial/payback business cases	Data/ modelling	Education	Environment	Implications if there are not reductions/ cost aside	-	-	-
20	Not enough incentives, little knowledge of most effective options	Wellington tariff structure, education	Incentives	Education	Cost recovery. Education & incentivisatio n	-	-	-	-
21	Pay for water, wastewater	-	-	-	-	-	-	-	-

Information on Industry Challenges & Possible Solutions

C10: OVERALL WORKSHOP FEEDBACK – WUI calculator

ID	WUI Use	WUI Worth	WUI Justification	WUI Comments
1	Useful to organisations with no in house energy management system, or to compare with other organisations	Inter-organisation benchmarking	Compare to own outcomes to other organisations	Ask energy & technical services if they benchmark water with other customers, similar to energy
2	Yes	Dependent on business drivers	-	-
3	-	-	-	-
4	Good	High	Easy to view and standard reporting format	-
5	Yes	Yes	Cost & consumption controls analysis	-
6	Yes	-	Knowing benchmark	-
7	Gives you benchmark data	Little worth to water service provider or input, but outputs may have a value if you have a good sample	-	-
8	Quite useful but depends on having meters in place	Free, online	Other tools on market	-
9	Useful and relevant	Moderate	Benchmark only	-
10	Relevant to water service provider if data available to identify high users vs. benchmarks	-	-	-
11	This tool would provide valuable information	Based on realistic return on investment per building	Based on realistic return on investment per building	In use tools are critical to improve building sustainability
12	-	-	-	Why men/women data?
31	We need to provide good info to any user	-	-	Great potential
14	Unsure	-	-	-
15	-	-	-	-
16	The tool looks great	Great for building managers, final cost comparisons against the default (best case) is good	-	Does it have cost/saving water saving initiatives options? It would be good for them to see what they could potentially save if they incorporated them and FCBA.
17	Good, quick tool easily shows building owners where they are now	Really worthwhile	Like Homestar, WERT can be used to self assess	-
18	Pretty useful in regards to building science, relevant to the industry	Looks worthwhile	Can be used to persuade clients to head in a more sustainable direction	Simple for clients to use
19	Very useful	-	Overview of building from basic data	If we adopt a rating scheme like NABERS, anything a management company uses should be similar
20	Very, but likely more useful for an energy contractor etc to use than a building owner	-	-	Would perhaps be useful if it could ‘plug-in’ or be compatible with other popular building management programmes
21	Great	-	-	Building licence/WOF requirements

Information on Water Use Index (WUI) Calculator

C10: OVERALL WORKSHOP FEEDBACK – end-use estimator tool

ID	End-Use Estimator Use	End-Use Estimator Worth	End-Use Estimator Justification	End-Use Estimator Comments
1	Detailed breakdown of water usage at site	Will help target initiatives and benchmark results	-	Better value tool, would be interested in using
2	Yes, more so than the simple tool	Clarity regarding performance of building	-	-
3	-	-	-	-
4	Good	High	Showing end-use monitoring is a must have	Does it match up with GSNZ tool, if same will ease use
5	Yes	Yes	Cost & consumption controls analysis	-
6	-	-	-	Useful benchmark of end-uses
7	-	-	-	This concerns me a little as it includes a high number of assumptions
8	More useful	Maybe $$	Could be more robust = GSNZ	-
9	More useful	Moderate	Increased cost	-
10	A water service provider would not have detailed information, would assume hugely useful to building managers	-	-	-
11	This tool would provide valuable information	-	-	-
12	-	-	-	-
31	Increased metering will be costly	High	-	-
14	Very interesting	Potentially worthwhile	Gives specific information about usage by different appliances, so even if not totally accurate, it will help decide where usage is and hence priorities to address them	-
15	-	-	-	-
16	-	-	-	-
17	Great for water audits	Very valuable	Identification of priority areas = key for retrofitting	-
18	Useful for building scientists to use on behalf of client	Good	Good for separating elements out when looking at upgrading/retrofitting a building	I like the level of detail provided, can be very useful to separate out elements of concern
19	-	-	-	As its % based of appliance numbers, doe the tool take into account appliance type, e.g. more efficient tapware, etc, the tool should be able to realise savings types
20	Very, great for creating priority list of features to be replaced, etc	-	-	-
21		-	-	WELS, is right thing but be wise about it

Information on End-Use Estimator Tool

C10: OVERALL WORKSHOP FEEDBACK – financial cost-benefit advisor tool

ID	FCBA Use	FCBA Worth	FCBA Advantages	FCBA Disadvantages	FCBA Comments
1	Prioritising water efficiency incentives	Help with business case development	Provides details and benchmarking options	-	-
2	-	-	-	-	-
3	-	-	-	-	-
4	Good	-	Visible returns on investments	-	-
5	-	-	-	-	-
6	-	-	Better decision making	-	NZGBC, NABERS tool adaption
7	Looks to have value to property owners	For a water service provider, need to be able to consider portfolio, may be able to adopt	-	-	Include new theoretical pie chart and new WUI chart
8	More useful	-	In use tool, could be adopted by GSNZ	-	-
9	Very	Depends on priorities and water costs	User friendly	Time of use	-
10	Demonstrating payback/cost benefits vital to supporting business case for upgrade	-	-	-	-
11	-	-	Convenience of tool	-	-
12	-	-	-	-	-
31	-	-	-	-	-
14	A good step to follow on from previous tool	Yes	Gives ideas on potential things to consider when spending money	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	Very useful	Because it is awesome	Analysis of compromises, use of matrix + recommended changes	Don't promise the change in WUI, maybe say 'potentially' or 'estimated' or people might be grumpy when it doesn't work out	I think I like drop-list option more, more interactive as you can combine options for recommended changes
18	Clients love seeing savings so it is relevant	Worthwhile to persuade clients	Showing a client an actual figure	Unsure on the pricing estimate side, where do the costs come from	Do the fixture prices update? Can it offer alternate solutions?
19	Fantastic	-	-	-	Can it produce business case reports?
20	Very, but likely more useful for an energy contractor etc to use than a building owner	-	-	-	-
21	-	The tools are very useful for supporting audits of building facilities, the level of detail might be too much to deliver specific 'shopping lists' of changes to make	-	-	-

Information on Financial Cost-Benefit Advisor (FCBA) Tool

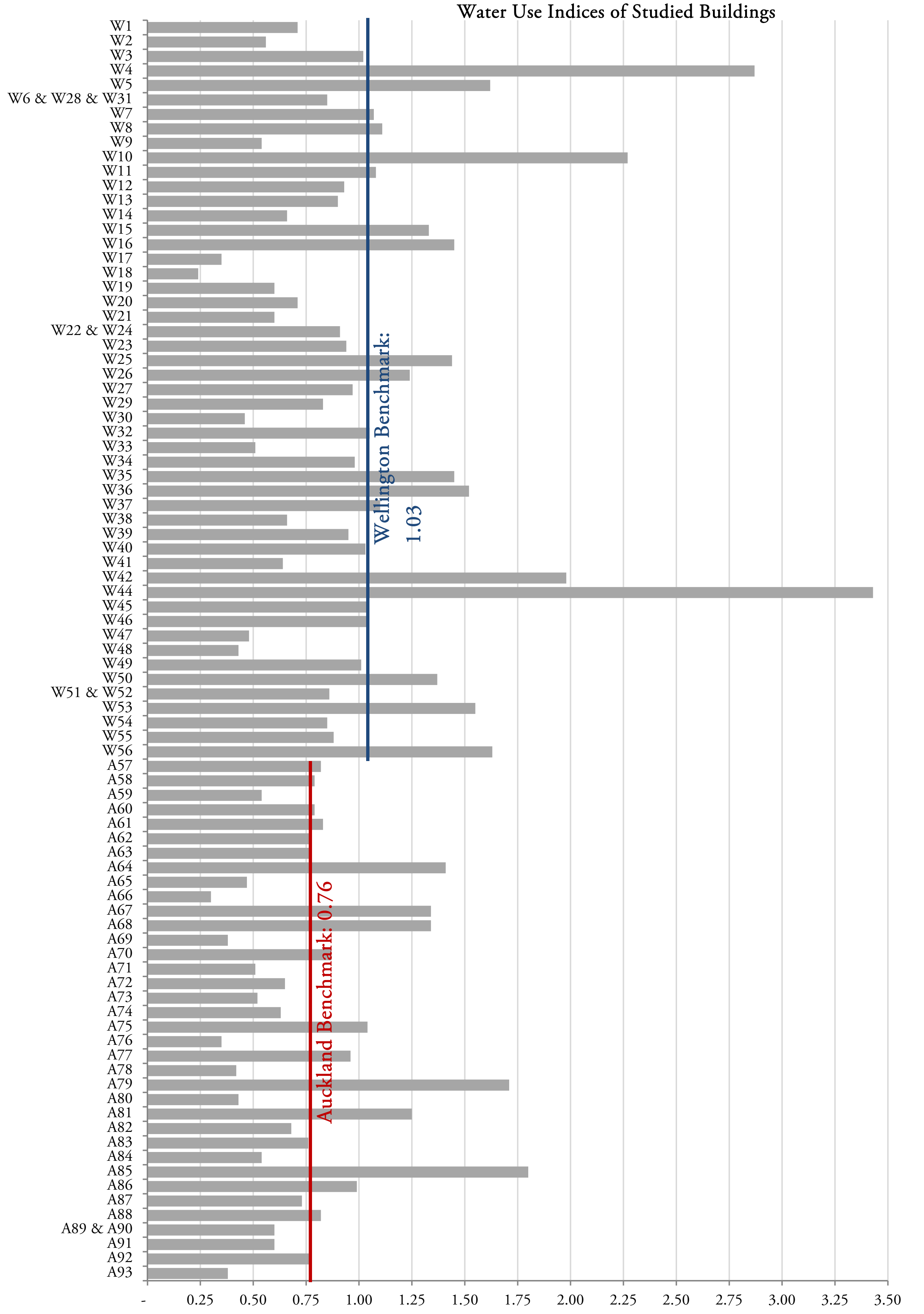
C10: OVERALL WORKSHOP FEEDBACK – overall workshop

ID	Pilot Trial?	WERT Use in Industry	WERT Use in Other Industries	Overall Feedback	Any Other Suggestions
1	Yes	About to benchmark and invest in water efficiency options in 2011/2012 financial year, champion to other local authorities	Libraries, pools, community centres, sports facilities	Surprised about general lack of energy management systems to monitor water invoices, would recommend this option too	-
2	-	-	-	-	-
3	-	-	-	Adaption of excel tool for comparison of options and payback periods	-
4	Yes	-	-	-	-
5	Yes	-	-	-	-
6	-	-	-	-	-
7	-	-	-	Lee, please keep in touch	-
8	-	-	-	-	-
9	-	-	-	Excellent work, please can you speak more clearly in presentations	-
10	Yes	Would use on own facilities, would offer as an option to our commercial customers, promote to customers	Need findings from pilot trial from building owners to understand support and uptake of tool	-	-
11	Yes		-	-	-
12	Yes		-	Not sure, GSNZ or this?	-
31	-		-	-	-
14	-		-	Very interesting, well done	-
15	-		-	-	-
16	Yes		-	-	-
17	Yes	Really useful for existing buildings	Useful across board for all industries	-	-
18	-	-	Maybe installers of systems, educate them so they can bring suggestions to designers	Cost reduction of how water use reduction also?	It would be nice to know if there are nay GSNZ or buildings using sustainable water systems in the data mix and how it effects the data
19	Yes	Very useful – building management	-	-	-
20	-	This tool could also be useful during the planning of a building development	-	-	-
21	-	As an awareness-raising tool, or something to support discussions and action for improvements	-	Adapt WERT for kids/schools to use	-

Information on Overall Workshop

APPENDIX D: BUILDING DETAILS

D1: SUMMARY


Water Use Indices of Studied Buildings
W1
W2
W3
W4
W5
W6 & W28 & W31
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W8
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W14
W15
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A91
A92
A93
Wellington Benchmark: 1.03
Auckland Benchmark: 0.76
-
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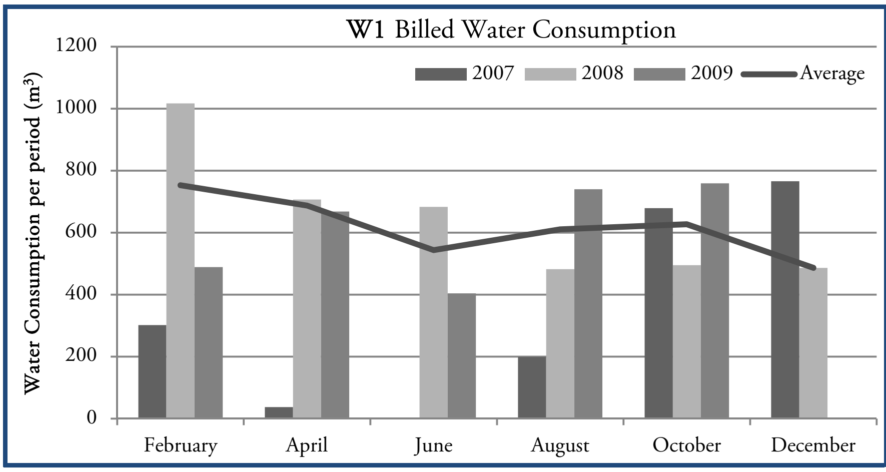
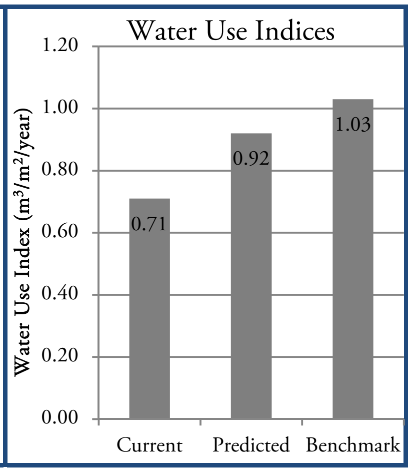
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
2.75
3.00
3.25
3.50

D2: *BUILDING ID CODE* ***W1***





BUILDING ***W1*** *CHARACTERISTICS*

Net Lettable Area	*4,970 m²*	*Average Annual Water Consumption*	*3,546 m³*
Full Time Equivalent Occupants	*300*	*Number Of Storeys*	*13*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1985*
Hours of HVAC Operation (per week)	*58*	*Cost Recovery Method*	*Gross Lease*

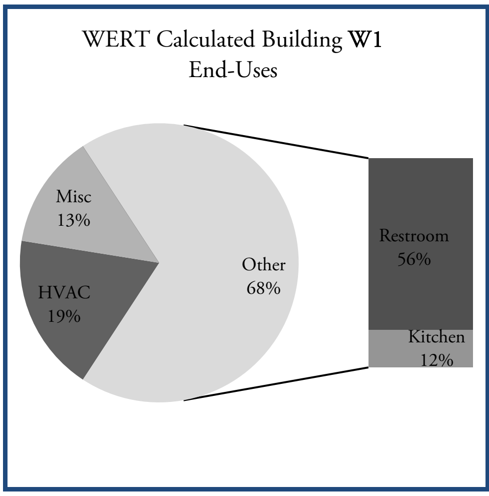
W1 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

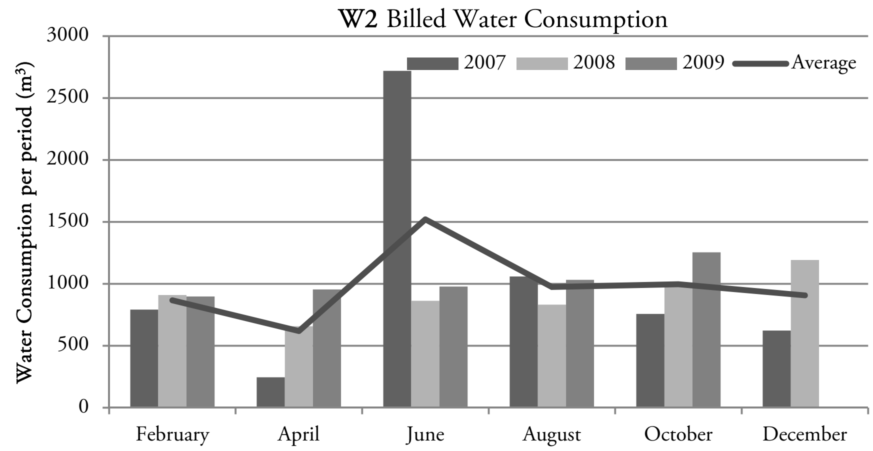
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

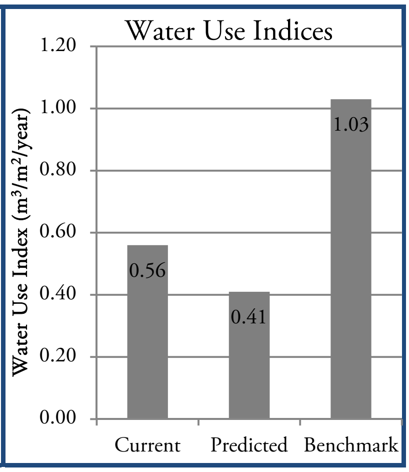


W1 *DOMESTIC END-USES DETAILS*

Toilets	*53*	*Single Flush Cistern*
Urinals	*2*	*Cyclic Flush Trough*
Wash Hand Basins	*30*	*Manual Faucet*
Showers	*3*	
Kitchen Sinks	*13*	
Dishwashers	*13*	*Domestic*
Instant Hot Water	*13*	*Zip*
Other	*13*	*Cleaners Tub*
TOTAL	***140 x Domestic End-Uses***	

D2: *BUILDING ID CODE W2*





BUILDING W2 CHARACTERISTICS

Net Lettable Area	*9,141 m^2*	*Average Annual Water Consumption*	*5,116 m^3*
Full Time Equivalent Occupants	*150*	*Number Of Storeys*	*7*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1927*
Hours of HVAC Operation (per week)	*50*	*Cost Recovery Method*	*Gross Lease*

W2 WATER MANAGEMENT

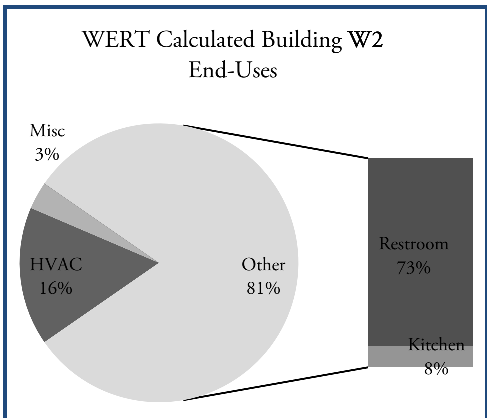
There is currently one observed sub-meter in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

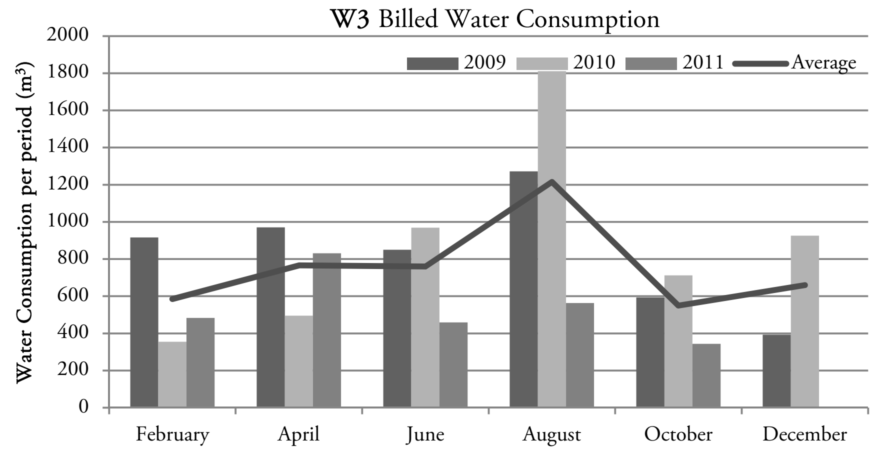
Reading of the one installed sub-meter could benefit in understanding and monitoring the amount of water being used for certain purposes within the building.

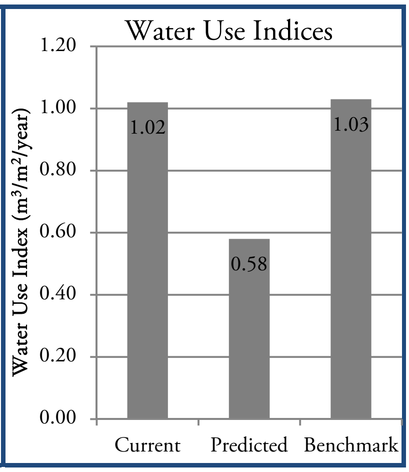


W2 DOMESTIC END-USES DETAILS

Toilets	*44*	*Single Flush Cistern*
Urinals	*14*	*Cyclic Flush Wall-Pod*
Wash Hand Basins	*37*	*Manual Faucet*
Showers	*7*	
Kitchen Sinks	*10*	
Dishwashers	*19*	*Domestic*
Instant Hot Water	*10*	*Billi Tap*
Other	*6*	*Cleaners Tub / Espresso*
TOTAL	*137 x Domestic End-Uses*	

D2: *BUILDING ID CODE W3*





*BUILDING **W3** CHARACTERISTICS*

Net Lettable Area	*5,141 m²*	*Average Annual Water Consumption*	*5,268 m³*
Full Time Equivalent Occupants	*171*	*Number Of Storeys*	*17*
Heat Rejection Method	*Air Condenser*	*Year Built*	*1987*
Hours of HVAC Operation (per week)	*53*	*Cost Recovery Method*	*Gross Lease*

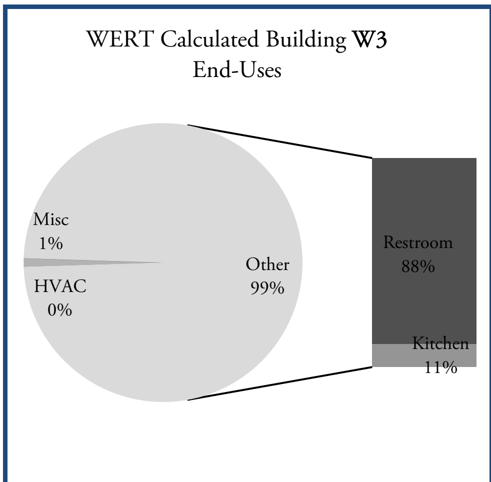
W3 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

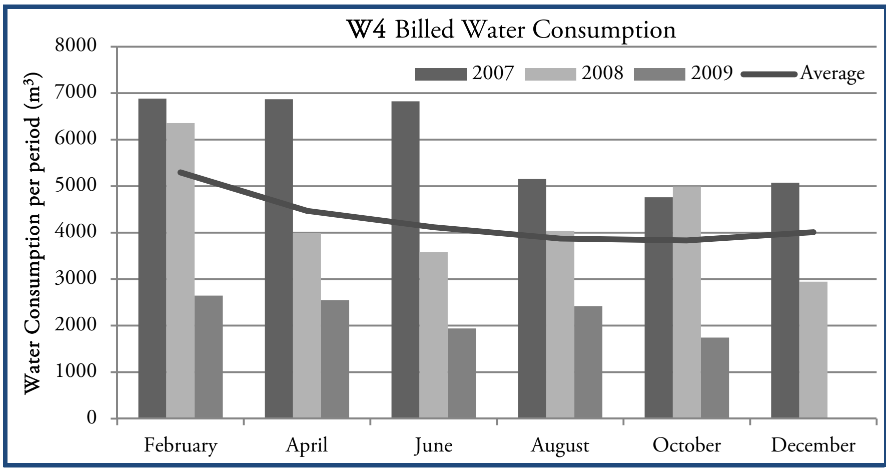
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

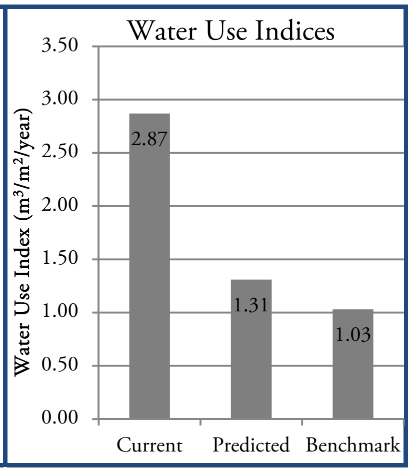


W3 *DOMESTIC END-USES DETAILS*

Toilets	*44*	*Single Flush Cistern*
Urinals	*14*	*Group Sensor Trough*
Wash Hand Basins	*58*	*Manual Faucet*
Showers	*3*	
Kitchen Sinks	*17*	
Dishwashers	*10*	*Domestic*
Instant Hot Water	*15*	*Zip*
Other	*1*	*Cleaners Tub*
TOTAL	*162 x Domestic End-Uses*	

D2: *BUILDING ID CODE* ***W4***





BUILDING ***W4*** *CHARACTERISTICS*

Net Lettable Area	*9,024 m²*	*Average Annual Water Consumption*	*31,949 m³*
Full Time Equivalent Occupants	*480*	*Number Of Storeys*	*17*
Heat Rejection Method	*Air Condenser*	*Year Built*	*1980*
Hours of HVAC Operation (per week)	*55*	*Cost Recovery Method*	*Net Lease*

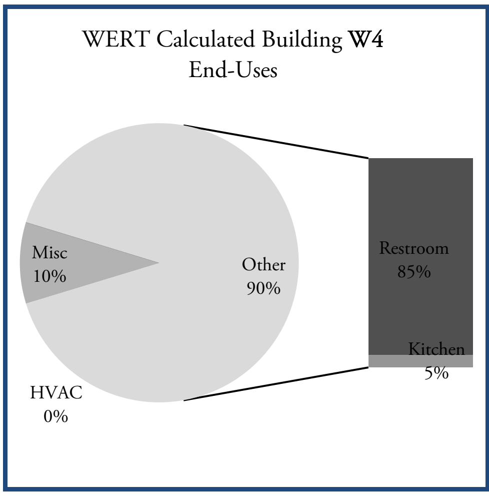
W4 *WATER MANAGEMENT*

There are currently six sub-meters in place.

The cost recovery method is through a Net Lease, i.e. resource consumption is charged via sub-meter readings for each tenancy.

There are no water efficiency or water management strategies or targets in place, other than monitoring each tenancy against the average for each period.

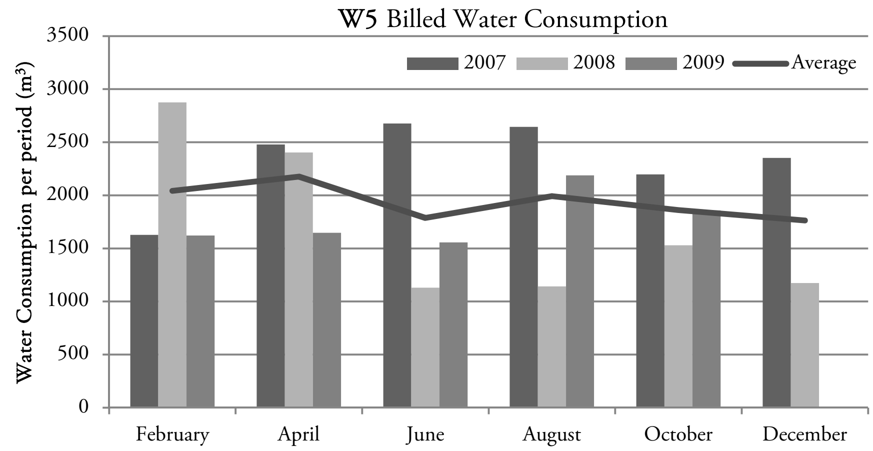
This building manager kept very good records of their water consumption history, from both mains supply and sub-meters.

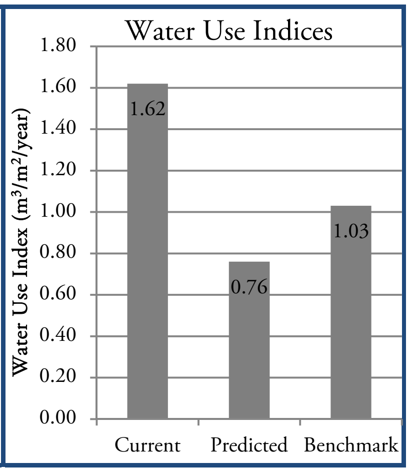


W4 *DOMESTIC END-USES DETAILS*

Toilets	*85*	*Single Flush Valve / Cistern*
Urinals	*15*	*Cyclic Flush Trough*
Wash Hand Basins	*83*	*Manual Faucet*
Showers	*10*	
Kitchen Sinks	*29*	
Dishwashers	*5*	*Commercial / Domestic*
Instant Hot Water	*16*	*Zip*
Other	*37*	*Cleaners Tub / Espresso / Other*
TOTAL	***280 x Domestic End-Uses***	

D2: *BUILDING ID CODE W5*





BUILDING W5 CHARACTERISTICS

Net Lettable Area	*6,317 m²*	*Average Annual Water Consumption*	*11,570 m³*
Full Time Equivalent Occupants	*210*	*Number Of Storeys*	*14*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1980*
Hours of HVAC Operation (per week)	*50*	*Cost Recovery Method*	*Gross Lease*

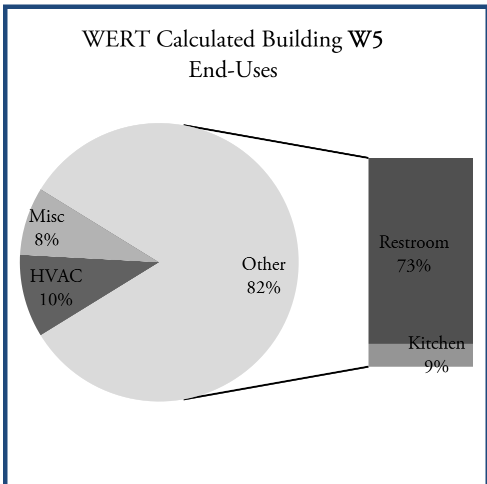
W5 WATER MANAGEMENT

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

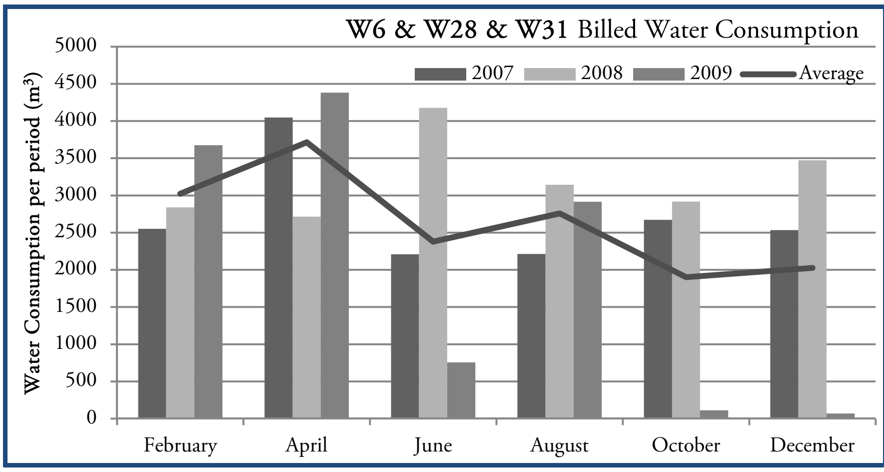
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

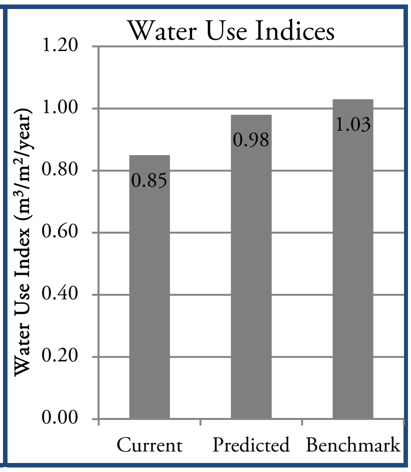


W5 DOMESTIC END-USES DETAILS

Toilets	*35*	*Single Flush Cistern*
Urinals	*7*	*Group Sensor Trough*
Wash Hand Basins	*28*	*Manual Faucet*
Showers	*1*	
Kitchen Sinks	*14*	
Dishwashers	*14*	*Domestic*
Instant Hot Water	*14*	*Zip*
Other	*1*	*Cleaners Tub*
TOTAL	*114 x Domestic End-Uses*	

D2: *BUILDING ID CODE* ***W6 & W28 & W31***





BUILDING ***W6 & W28 & W31*** *CHARACTERISTICS*

Net Lettable Area	*22,758 m²*	*Average Annual Water Consumption*	*24,199 m³*
Full Time Equivalent Occupants	*1,528*	*Number Of Storeys*	*41*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1985*
Hours of HVAC Operation (per week)	*50*	*Cost Recovery Method*	*Gross Lease*

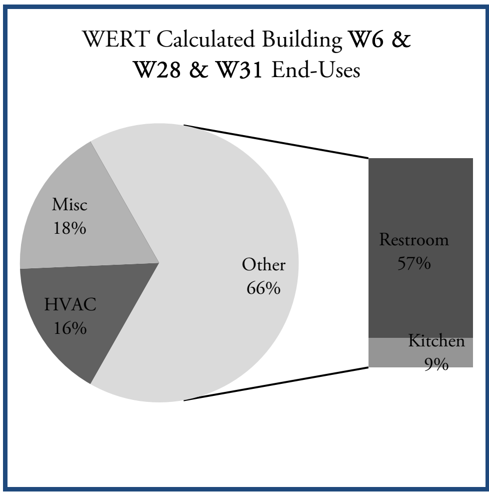
W6 & W28 & W31 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

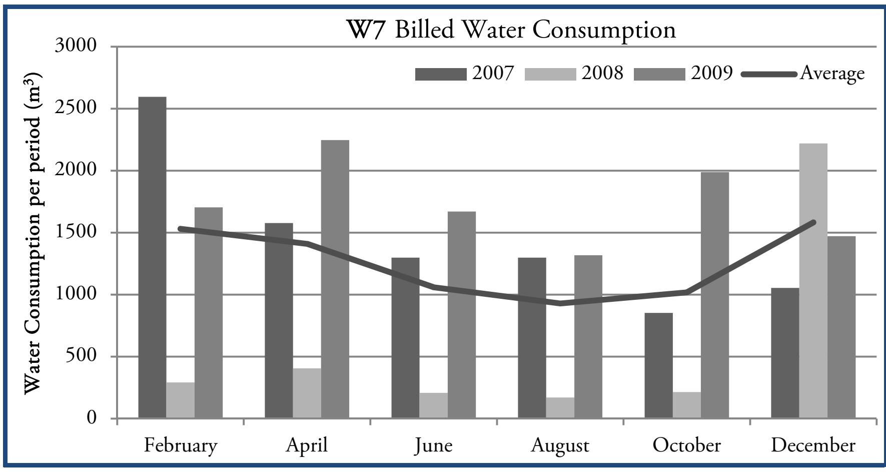
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

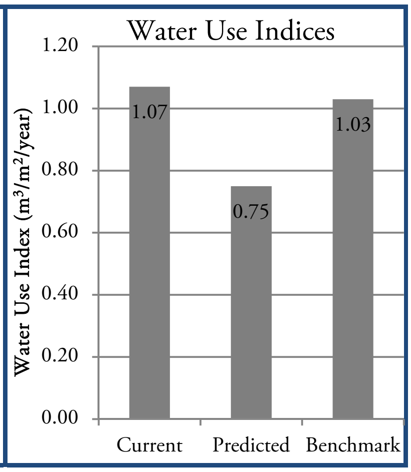


W6 & W28 & W31 *DOMESTIC END-USES DETAILS*

Toilets	*206*	*Combination*
Urinals	*46*	*Cyclic Flush Trough*
Wash Hand Basins	*183*	*Manual Faucet*
Showers	*9*	
Kitchen Sinks	*55*	
Dishwashers	*48*	*Domestic / Commercial*
Instant Hot Water	*44*	*Zip / Billi Tap*
Other	*32*	*Cleaners Tub / Espresso*
TOTAL	***623 x Domestic End-Uses***	

D2: *BUILDING ID CODE W7*





BUILDING W7 CHARACTERISTICS

Net Lettable Area	*9,938 m²*	*Average Annual Water Consumption*	*10,644 m³*
Full Time Equivalent Occupants	*720*	*Number Of Storeys*	*14*
Heat Rejection Method	*Air Condenser*	*Year Built*	*1985*
Hours of HVAC Operation (per week)	*58*	*Cost Recovery Method*	*Gross Lease*

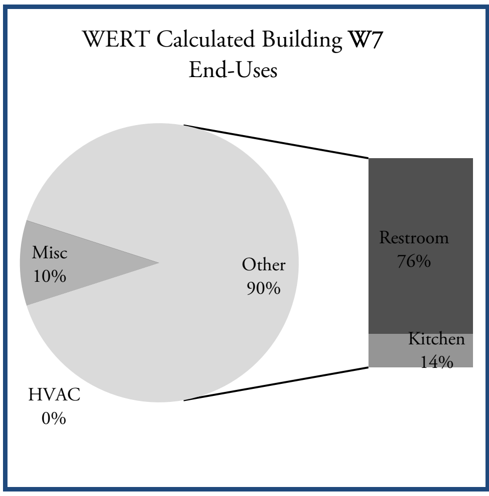
W7 WATER MANAGEMENT

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

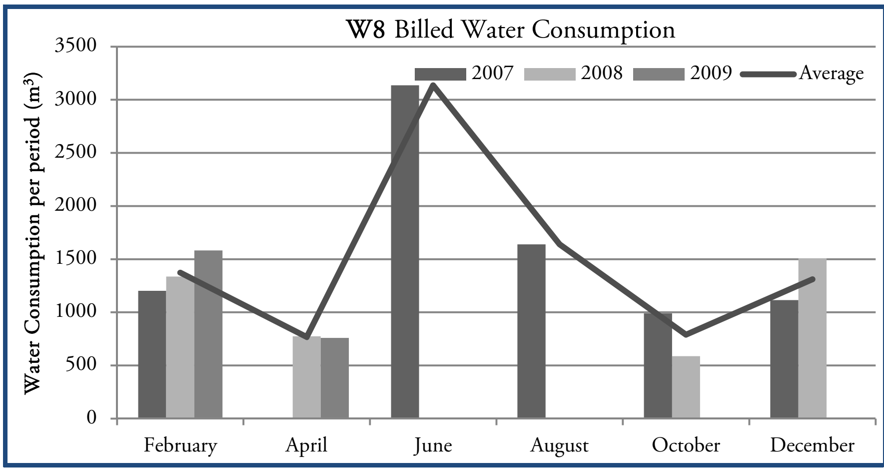
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

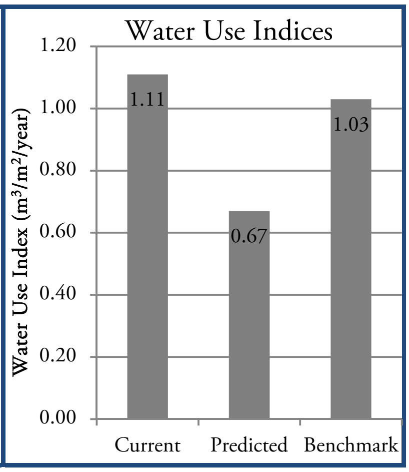


W7 DOMESTIC END-USES DETAILS

Toilets	*77*	*Single Flush Cistern*
Urinals	*26*	*Infrared Sensor Wall-Pod*
Wash Hand Basins	*49*	*Manual Faucet*
Showers	*6*	
Kitchen Sinks	*26*	
Dishwashers	*22*	*Domestic / Commercial*
Instant Hot Water	*14*	*Billi Tap / Zip*
Other	*20*	*Cleaners Tub / Espresso*
TOTAL	*240 x Domestic End-Uses*	

D2: *BUILDING ID CODE* ***W8***





BUILDING ***W8*** *CHARACTERISTICS*

Net Lettable Area	*6,243 m²*	*Average Annual Water Consumption*	*6,952 m³*
Full Time Equivalent Occupants	*170*	*Number Of Storeys*	*13*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1982*
Hours of HVAC Operation (per week)	*56*	*Cost Recovery Method*	*Gross Lease*

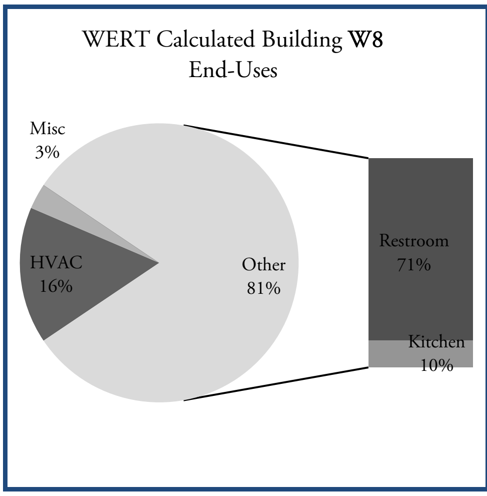
W8 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

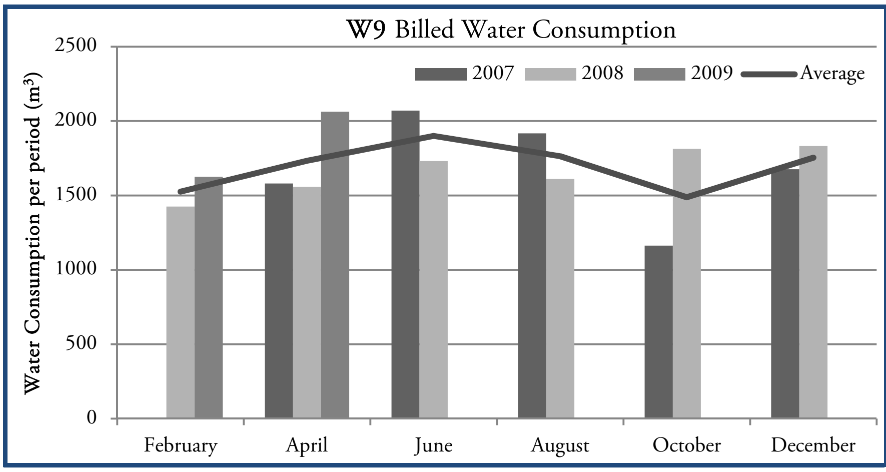
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

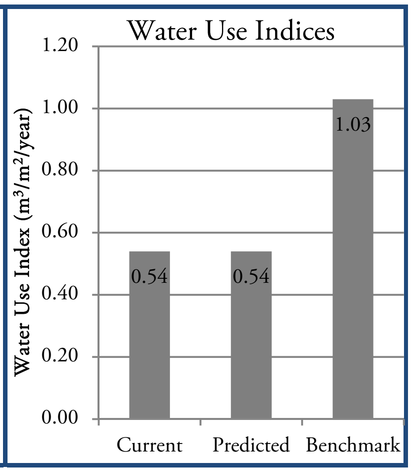


W8 *DOMESTIC END-USES DETAILS*

Toilets	*58*	*Single / Dual Flush Cistern*
Urinals	*13*	*Group Sensor Trough*
Wash Hand Basins	*32*	*Manual Faucet*
Showers	*-*	
Kitchen Sinks	*13*	
Dishwashers	*13*	*Domestic*
Instant Hot Water	*13*	*Zip*
Other	*-*	
TOTAL	***142 x Domestic End-Uses***	

D2: *BUILDING ID CODE **W9***





*BUILDING **W9** CHARACTERISTICS*

Net Lettable Area	*18,462 m²*	*Average Annual Water Consumption*	*7,956 m³*
Full Time Equivalent Occupants	*923*	*Number Of Storeys*	*19*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1979*
Hours of HVAC Operation (per week)	*58*	*Cost Recovery Method*	*Gross Lease*

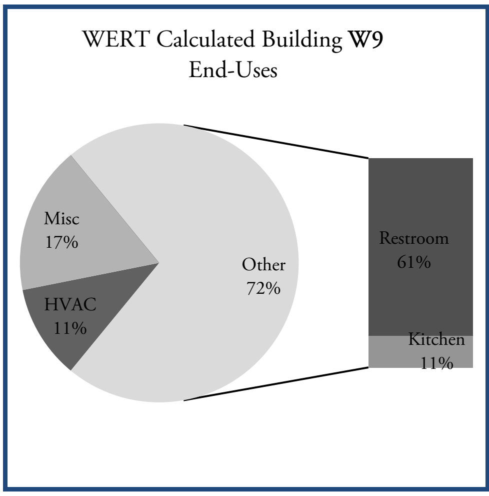
W9 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

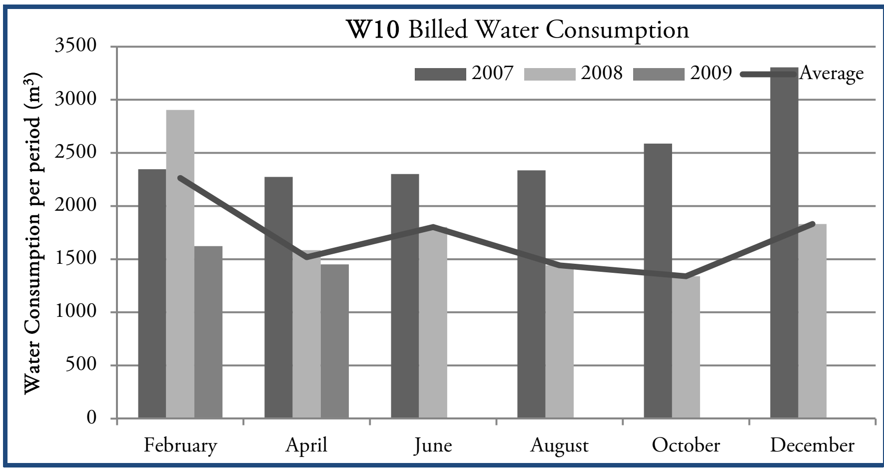
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

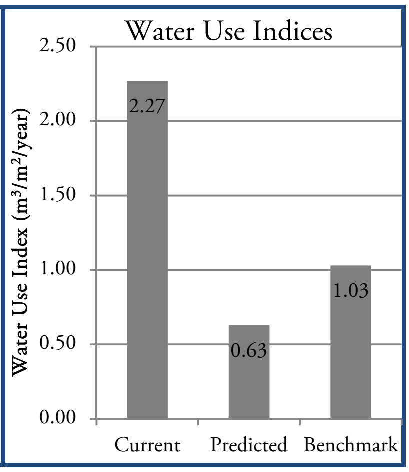


W9 DOMESTIC END-USES DETAILS

Toilets	*136*	*Combination*
Urinals	*46*	*Infrared Sensor Wall-Pod*
Wash Hand Basins	*133*	*Manual Faucet*
Showers	*17*	*Water Efficient*
Kitchen Sinks	*11*	
Dishwashers	*10*	*Domestic / Commercial*
Instant Hot Water	*9*	*Billi Tap*
Other	*19*	*Cleaners Tub / Espresso*
TOTAL	***381 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***W10***





BUILDING ***W10*** *CHARACTERISTICS*

Net Lettable Area	*4,800 m²*	*Average Annual Water Consumption*	*13,477 m³*
Full Time Equivalent Occupants	*93*	*Number Of Storeys*	*14*
Heat Rejection Method	*Heat Pump*	*Year Built*	*1960*
Hours of HVAC Operation (per week)	*56*	*Cost Recovery Method*	*Gross Lease*

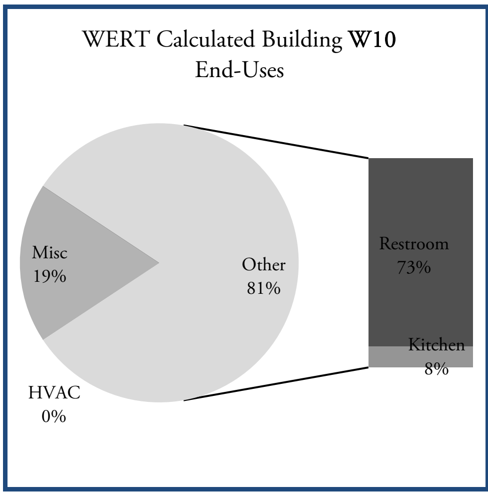
W10 *WATER MANAGEMENT*

There is currently one observed sub-meter in place. This meter is not read.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

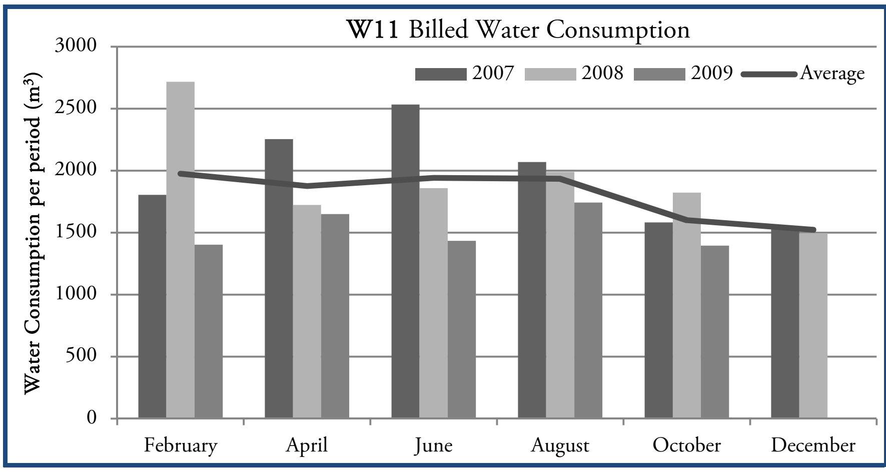
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

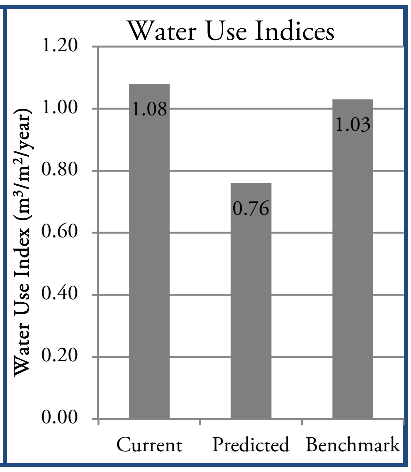


W10 *DOMESTIC END-USES DETAILS*

Toilets	*43*	*Single Flush Valve*
Urinals	*10*	*Cyclic Flush Wall-Pod*
Wash Hand Basins	*46*	*Manual Faucet*
Showers	*7*	
Kitchen Sinks	*21*	
Dishwashers	*19*	*Domestic / Commercial*
Instant Hot Water	*14*	*Zip*
Other	*14*	*Cleaners Tub / Espresso*
TOTAL	***174 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***W11***





BUILDING ***W11*** *CHARACTERISTICS*

Net Lettable Area	*10,736 m²*	*Average Annual Water Consumption*	*13,374 m³*
Full Time Equivalent Occupants	*550*	*Number Of Storeys*	*16*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1984*
Hours of HVAC Operation (per week)	*57*	*Cost Recovery Method*	*Gross Lease*

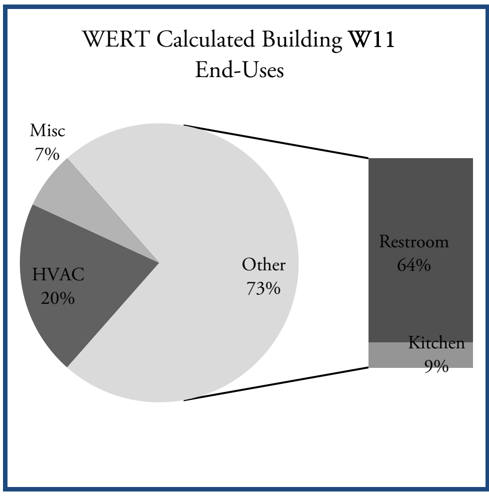
W11 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

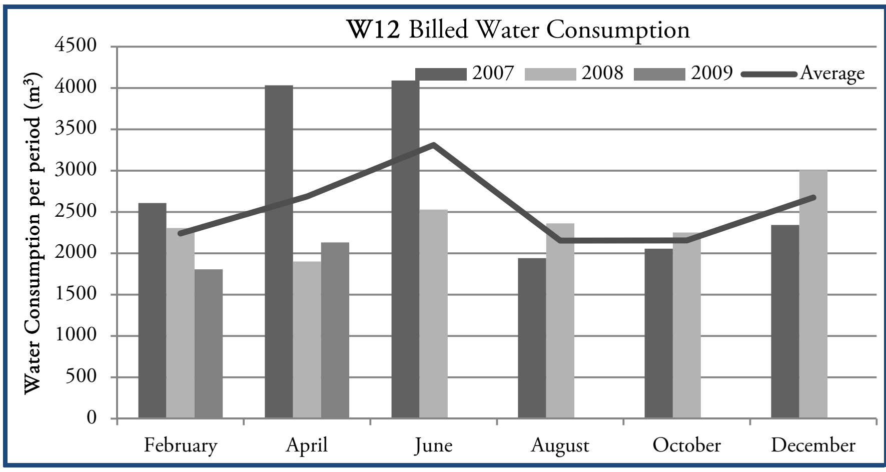
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

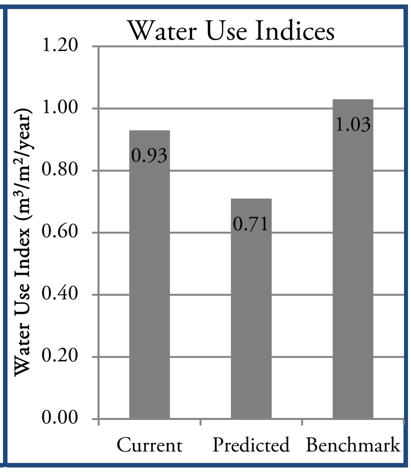


W11 *DOMESTIC END-USES DETAILS*

Toilets	*83*	*Single Flush Cistern*
Urinals	*15*	*Cyclic Flush Wall-Pod*
Wash Hand Basins	*68*	*Manual Faucet*
Showers	*5*	
Kitchen Sinks	*18*	
Dishwashers	*16*	*Domestic*
Instant Hot Water	*17*	*Billi Tap / Zip*
Other	*31*	*Espresso / Cleaners Tub*
TOTAL	***253 x Domestic End-Uses***	

D2: *BUILDING ID CODE **W12***





*BUILDING **W12** CHARACTERISTICS*

Net Lettable Area	*15,455 m²*	*Average Annual Water Consumption*	*15,630 m³*
Full Time Equivalent Occupants	*773*	*Number Of Storeys*	*18*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1973*
Hours of HVAC Operation (per week)	*60*	*Cost Recovery Method*	*Gross Lease*

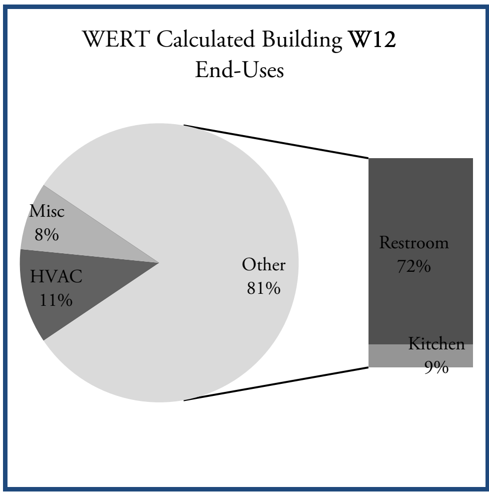
***W12** WATER MANAGEMENT*

There is currently one observed sub-meter in place. This meter is not read, building manager unaware of installation.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

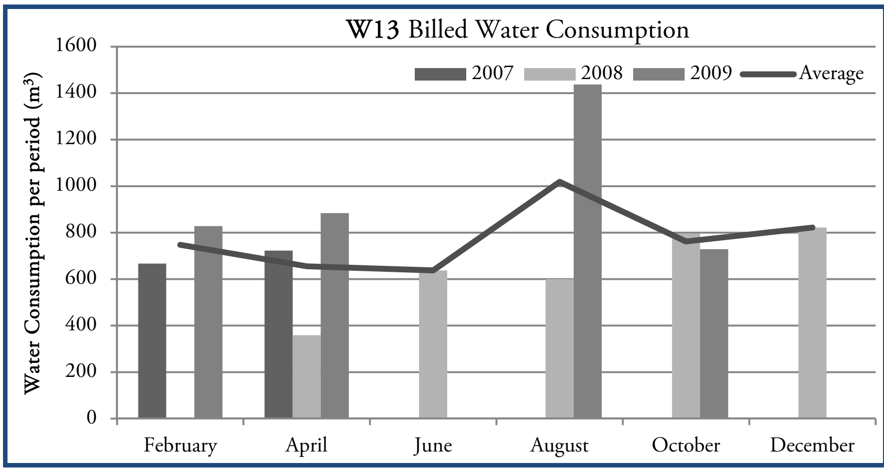
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

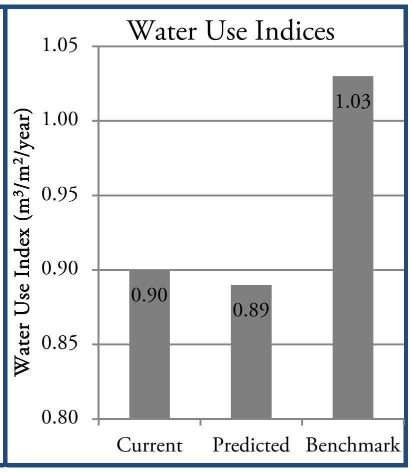


__W12__ DOMESTIC END-USES DETAILS

Toilets	*90*	*Single Flush Cistern*
Urinals	*36*	*Infrared Sensor Wall-Pod*
Wash Hand Basins	*75*	*Manual Faucet*
Showers	*8*	
Kitchen Sinks	*20*	
Dishwashers	*1*	*Domestic*
Instant Hot Water	*19*	*Billi Tap*
Other	*19*	*Cleaners Tub / Espresso*
TOTAL	***268 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***W13***





BUILDING ***W13*** *CHARACTERISTICS*

Net Lettable Area	*4,301 m^2*	*Average Annual Water Consumption*	*6,037 m^3*
Full Time Equivalent Occupants	*202*	*Number Of Storeys*	*9*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1950*
Hours of HVAC Operation (per week)	*50*	*Cost Recovery Method*	*Gross Lease*

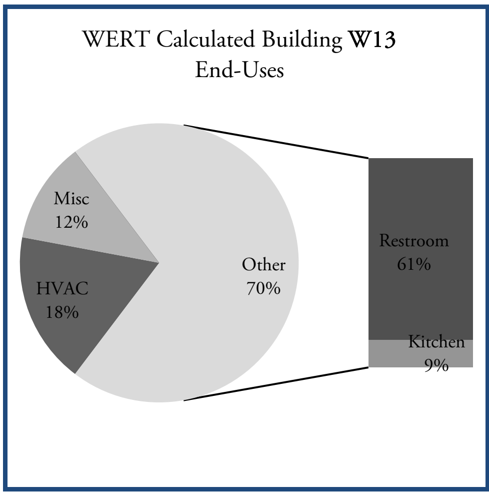
W13 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

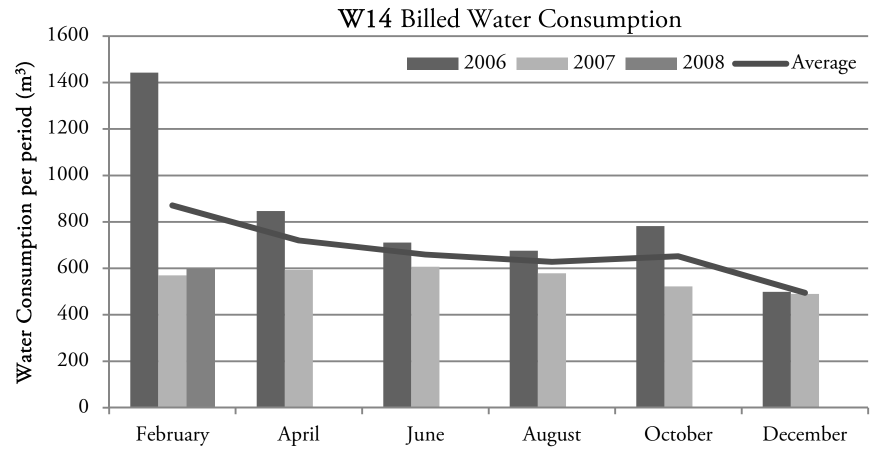
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

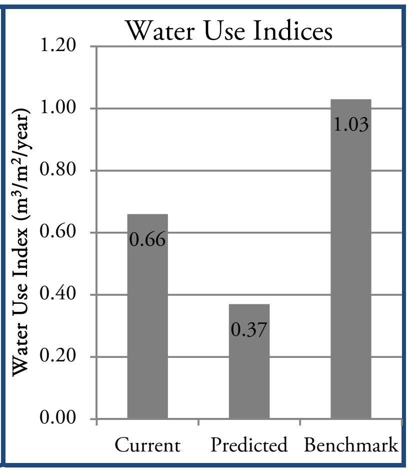


W13 *DOMESTIC END-USES DETAILS*

Toilets	*35*	*Flush Valve / Dual Fl Cistern*
Urinals	*4*	*Cyclic Flush Trough*
Wash Hand Basins	*19*	*Manual Faucet*
Showers	*1*	
Kitchen Sinks	*13*	
Dishwashers	*13*	*Domestic*
Instant Hot Water	*13*	*Zip*
Other	*8*	*Cleaners Tub*
TOTAL	***106 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***W14***





BUILDING ***W14*** *CHARACTERISTICS*

Net Lettable Area	*5,110 m^2*	*Average Annual Water Consumption*	*4,274 m^3*
Full Time Equivalent Occupants	*105*	*Number Of Storeys*	*7*
Heat Rejection Method	*Air Condenser*	*Year Built*	*1980*
Hours of HVAC Operation (per week)	*56*	*Cost Recovery Method*	*Gross Lease*

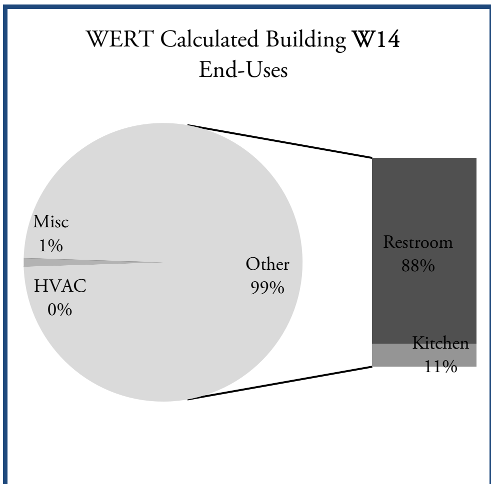
W14 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

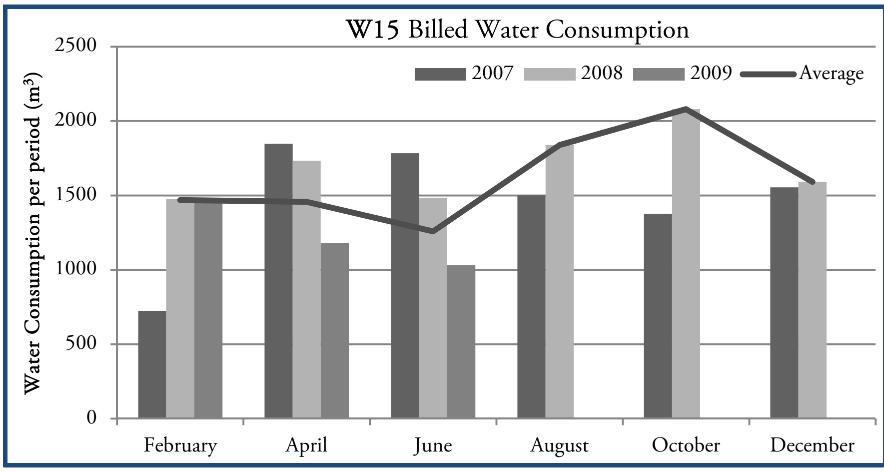
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

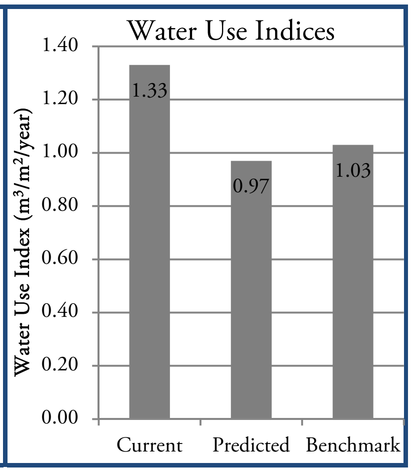


W14 *DOMESTIC END-USES DETAILS*

Toilets	*28*	*Single Flush Cistern*
Urinals	*7*	*Cyclic Flush Wall-Pod*
Wash Hand Basins	*28*	*Manual Faucet*
Showers	*-*	
Kitchen Sinks	*9*	
Dishwashers	*8*	*Domestic / Commercial*
Instant Hot Water	*7*	*Zip*
Other	*15*	*Cleaners Tub / Other / Espresso*
TOTAL	***102 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***W15***





BUILDING ***W15*** *CHARACTERISTICS*

Net Lettable Area	*6,537 m^2*	*Average Annual Water Consumption*	*8,714 m^3*
Full Time Equivalent Occupants	*215*	*Number Of Storeys*	*14*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1970*
Hours of HVAC Operation (per week)	*50*	*Cost Recovery Method*	*Gross Lease*

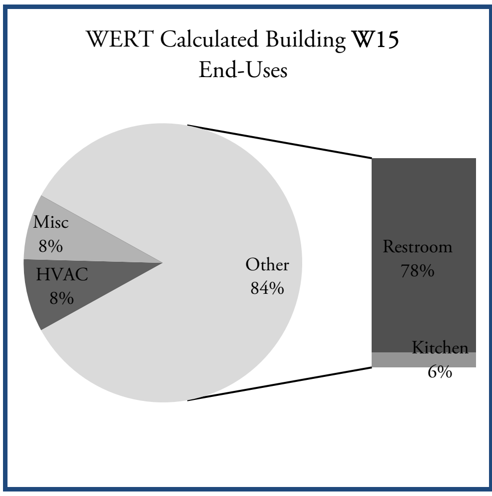
W15 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

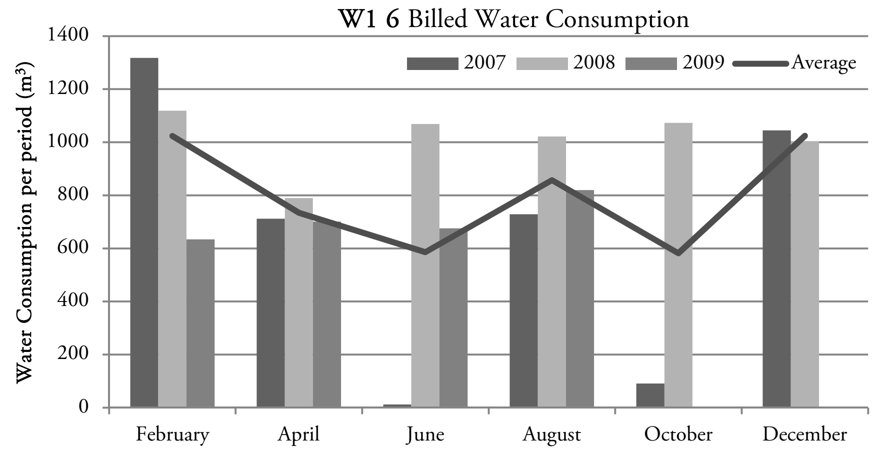
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

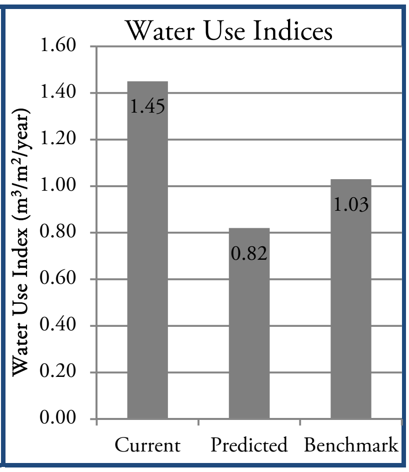


W15 *DOMESTIC END-USES DETAILS*

Toilets	*62*	*Combination*
Urinals	*16*	*Cyclic Fl Trough / Manual WP*
Wash Hand Basins	*55*	*Manual Faucet*
Showers	*14*	
Kitchen Sinks	*14*	
Dishwashers	*16*	*Domestic / Commercial*
Instant Hot Water	*14*	*Zip*
Other	*19*	*Other / Cleaners Tub / Espresso*
TOTAL	***210 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***W16***





BUILDING ***W16*** *CHARACTERISTICS*

Net Lettable Area	*2,962 m²*	*Average Annual Water Consumption*	*5,173 m³*
Full Time Equivalent Occupants	*116*	*Number Of Storeys*	*10*
Heat Rejection Method	-	*Year Built*	*1966*
Hours of HVAC Operation (per week)	-	*Cost Recovery Method*	*Gross Lease*

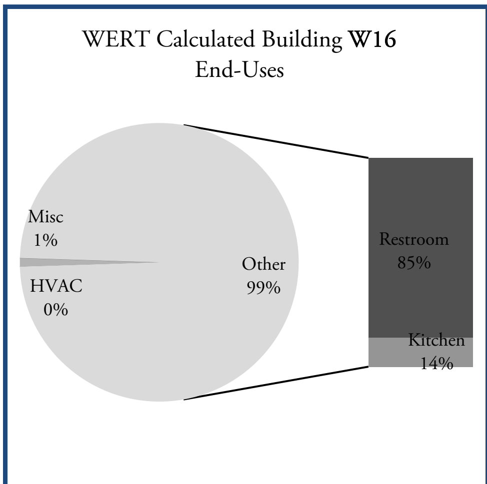
W16 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

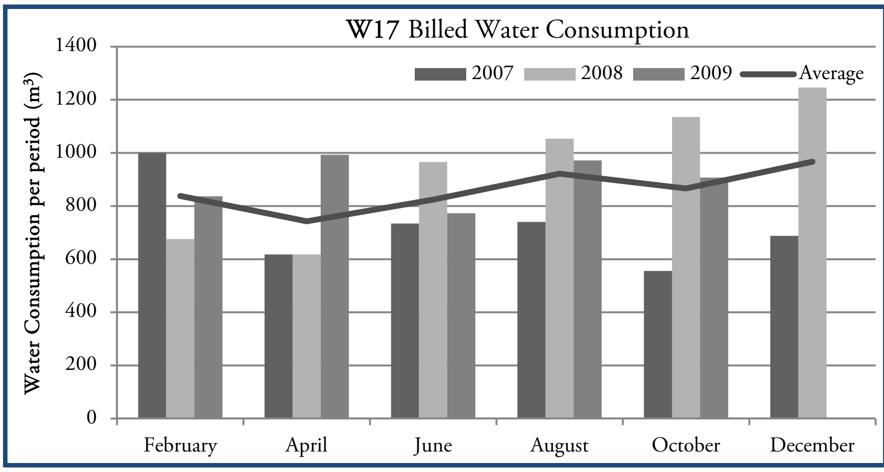
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

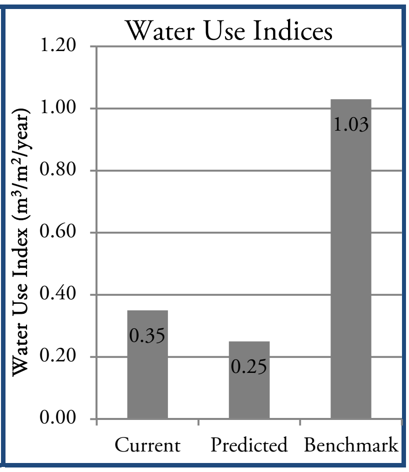


W16 *DOMESTIC END-USES DETAILS*

Toilets	*46*	*Single Flush Cistern / Valve*
Urinals	*9*	*Cyclic Flush Trough*
Wash Hand Basins	*39*	*Manual Faucet*
Showers	*3*	
Kitchen Sinks	*16*	
Dishwashers	*21*	*Domestic*
Instant Hot Water	*12*	*Billi Tap / Zip*
Other	*9*	*Other / Espresso*
TOTAL	***156 x Domestic End-Uses***	

D2: *BUILDING ID CODE **W17***





*BUILDING **W17** CHARACTERISTICS*

Net Lettable Area	*12,977 m²*	*Average Annual Water Consumption*	*5,114 m³*
Full Time Equivalent Occupants	*502*	*Number Of Storeys*	*18*
Heat Rejection Method	*Air Condenser*	*Year Built*	*1983*
Hours of HVAC Operation (per week)	*60*	*Cost Recovery Method*	*Gross Lease*

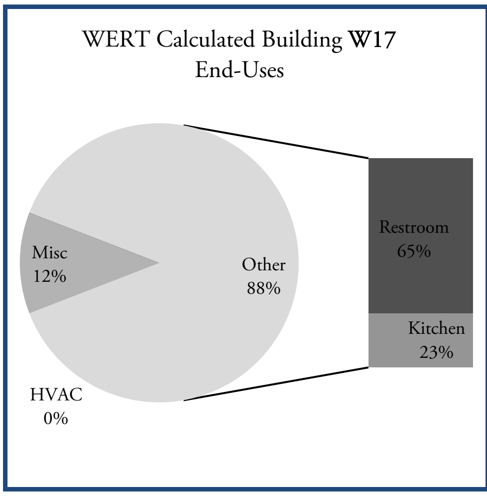
W17 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

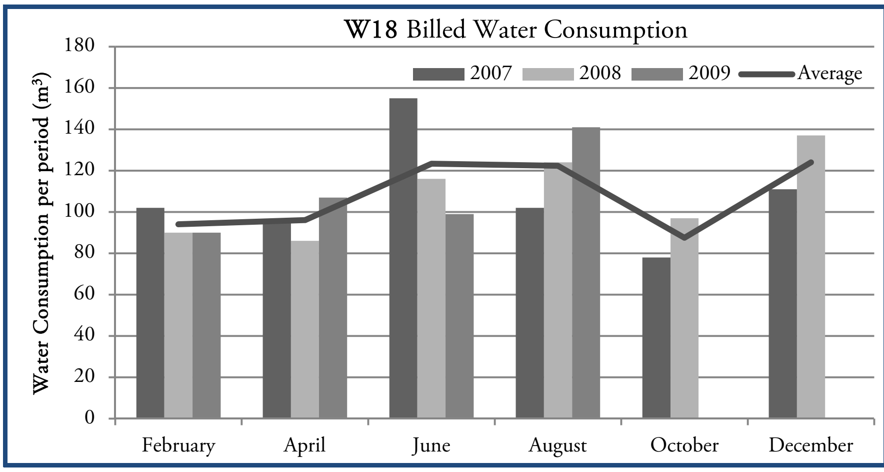
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

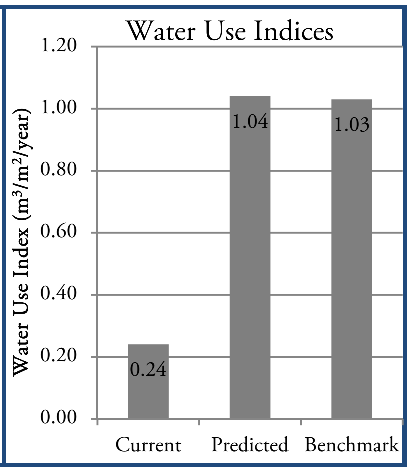


W17 DOMESTIC END-USES DETAILS

Toilets	*80*	*Dual Flush Cistern*
Urinals	*32*	*Manual Flush Wall-Pod*
Wash Hand Basins	*66*	*Manual Faucet*
Showers	*5*	
Kitchen Sinks	*21*	
Dishwashers	*18*	*Domestic / Commercial*
Instant Hot Water	*18*	*Billi Tap / Zip*
Other	*20*	*Cleaners Tub / Espresso*
TOTAL	***260 x Domestic End-Uses***	

D2: *BUILDING ID CODE **W18***





*BUILDING **W18** CHARACTERISTICS*

Net Lettable Area	*2,750 m²*	*Average Annual Water Consumption*	*520 m³*
Full Time Equivalent Occupants	*136*	*Number Of Storeys*	*6*
Heat Rejection Method	*-*	*Year Built*	*1981*
Hours of HVAC Operation (per week)	*-*	*Cost Recovery Method*	*Gross Lease*

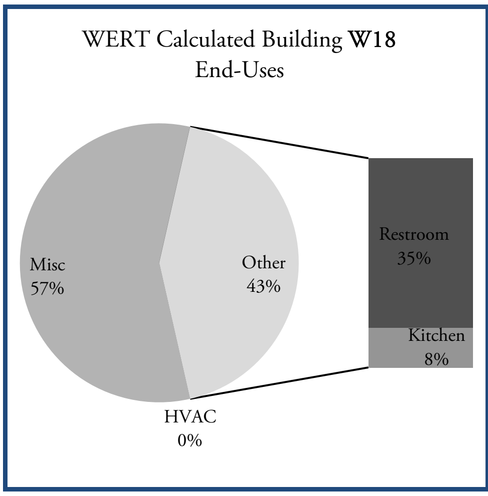
***W18** WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

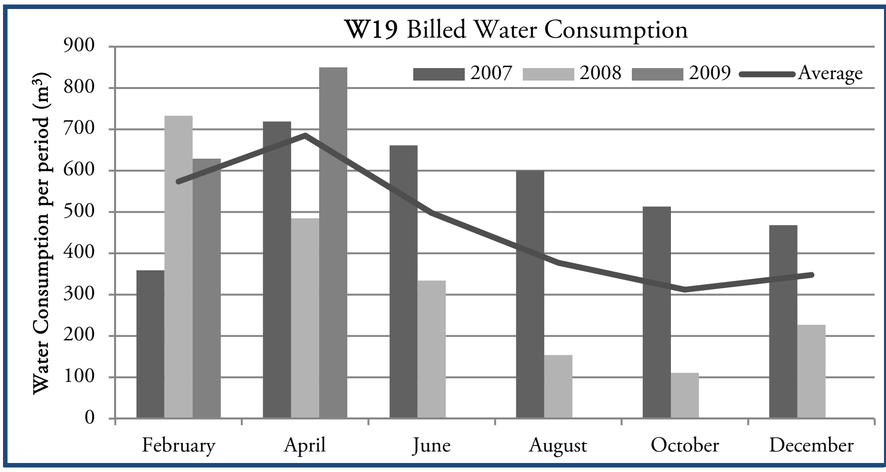
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

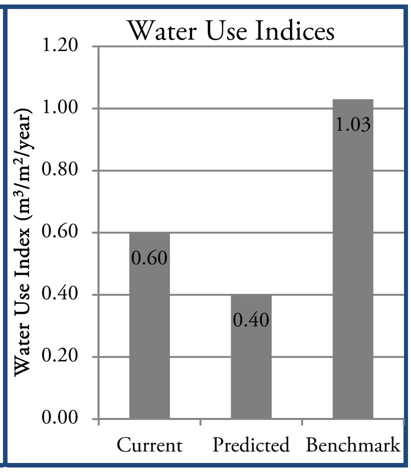


***W18** DOMESTIC END-USES DETAILS*

Toilets	*20*	*Dual Flush Cistern*
Urinals	*5*	*Cyclic Flush Trough*
Wash Hand Basins	*11*	*Manual Faucet*
Showers	*-*	
Kitchen Sinks	*5*	
Dishwashers	*5*	*Domestic*
Instant Hot Water	*5*	*Zip*
Other	*-*	
TOTAL	***51 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***W19***





BUILDING ***W19*** *CHARACTERISTICS*

Net Lettable Area	*3,398 m²*	*Average Annual Water Consumption*	*2,682 m³*
Full Time Equivalent Occupants	*78*	*Number Of Storeys*	*9*
Heat Rejection Method	*Air Condenser*	*Year Built*	*1986*
Hours of HVAC Operation (per week)	*56*	*Cost Recovery Method*	*Gross Lease*

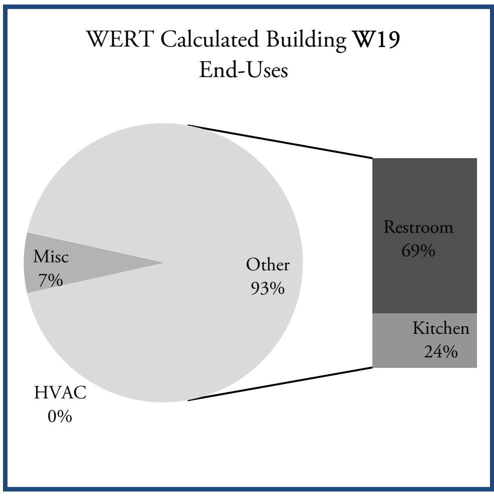
W19 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

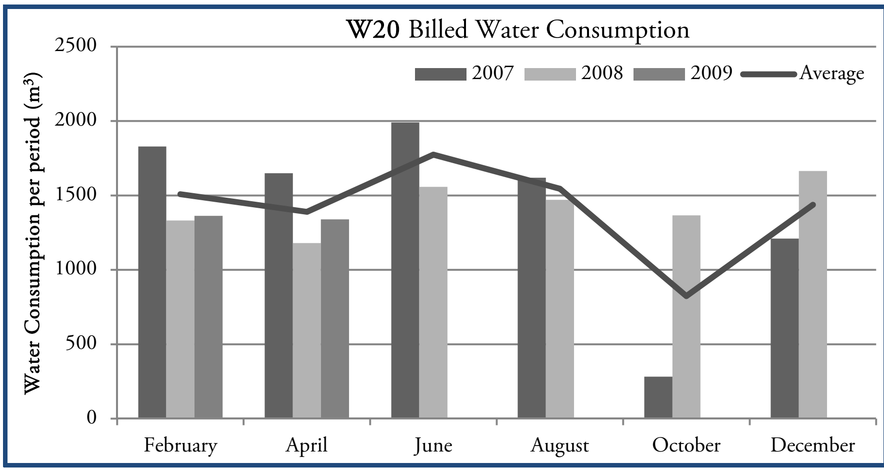
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

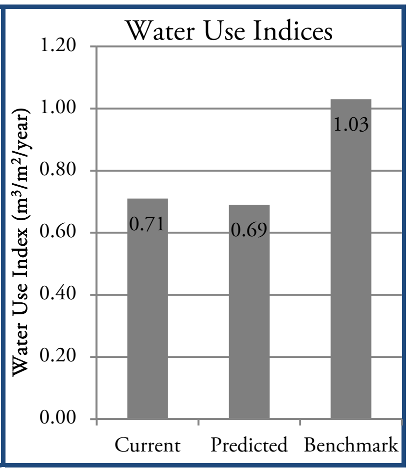


W19 *DOMESTIC END-USES DETAILS*

Toilets	*26*	*Single / Dual Flush Cistern*
Urinals	*8*	*Sensor Wall-Pod / Trough*
Wash Hand Basins	*19*	*Manual Faucet*
Showers	*1*	
Kitchen Sinks	*9*	
Dishwashers	*9*	*Domestic*
Instant Hot Water	*9*	*Zip*
Other	*1*	*Cleaners Tub*
TOTAL	***82 x Domestic End-Uses***	

D2: *BUILDING ID CODE **W20***





*BUILDING **W20** CHARACTERISTICS*

Net Lettable Area	*12,024 m²*	*Average Annual Water Consumption*	*7,868 m³*
Full Time Equivalent Occupants	*601*	*Number Of Storeys*	*14*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1986*
Hours of HVAC Operation (per week)	*55*	*Cost Recovery Method*	*Gross Lease*

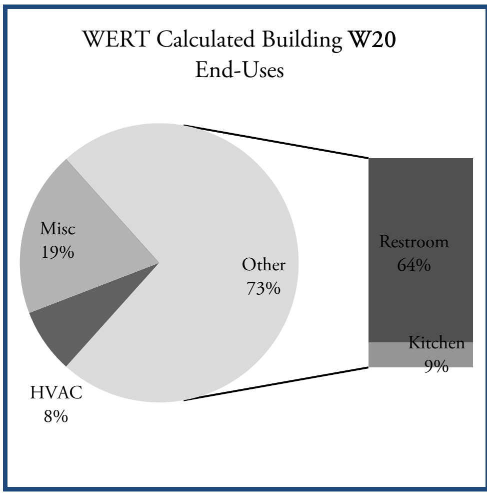
***W20** WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

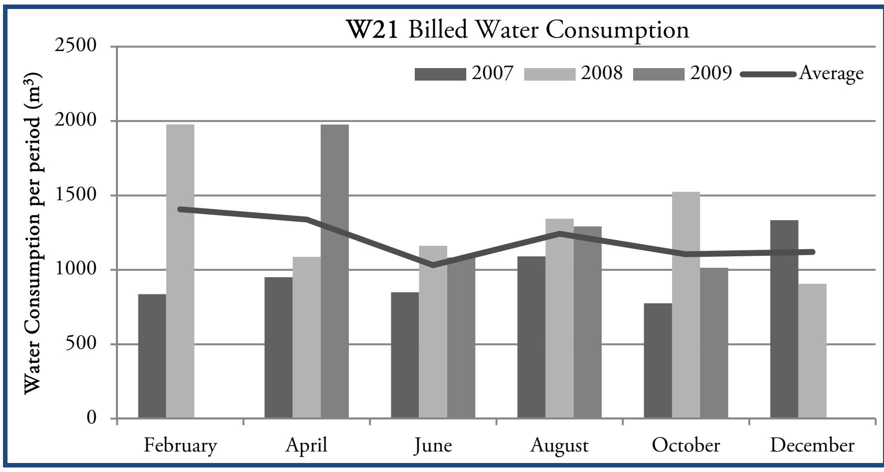
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

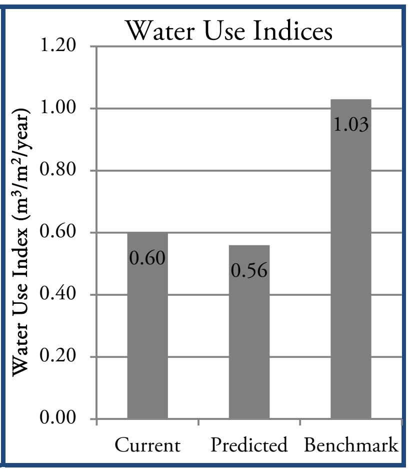


***W20** DOMESTIC END-USES DETAILS*

Toilets	*88*	*Single Flush Valve*
Urinals	*12*	*Cyclic Flush Trough*
Wash Hand Basins	*52*	*Manual Faucet*
Showers	*-*	
Kitchen Sinks	*16*	
Dishwashers	*16*	*Domestic*
Instant Hot Water	*16*	*Zip*
Other	*1*	*Cleaners Tub*
TOTAL	***201 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***W21***





BUILDING ***W21*** *CHARACTERISTICS*

Net Lettable Area	*8,990 m²*	*Average Annual Water Consumption*	*7,653 m³*
Full Time Equivalent Occupants	*490*	*Number Of Storeys*	*8*
Heat Rejection Method	*Air Condenser*	*Year Built*	*1917*
Hours of HVAC Operation (per week)	*55*	*Cost Recovery Method*	*Gross Lease*

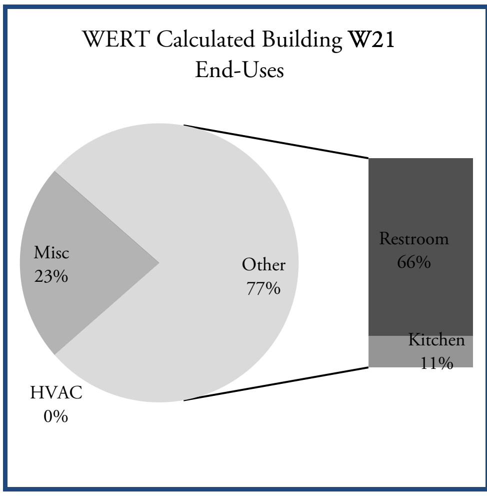
W21 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

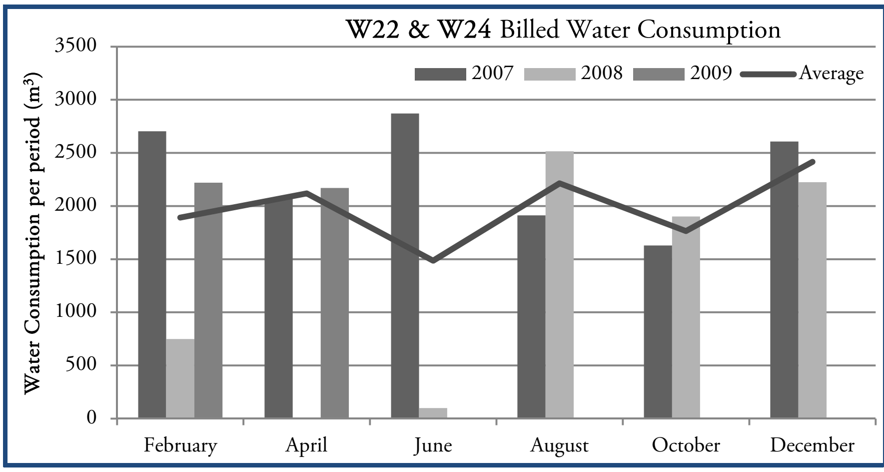
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

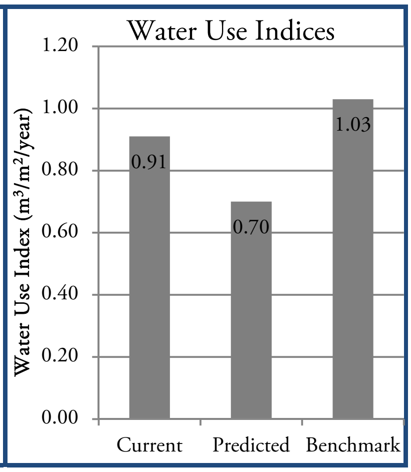


W21 *DOMESTIC END-USES DETAILS*

Toilets	*50*	*Single Flush Cistern*
Urinals	*7*	*Group Sensor Trough*
Wash Hand Basins	*39*	*Manual Faucet*
Showers	*3*	
Kitchen Sinks	*11*	
Dishwashers	*10*	*Domestic*
Instant Hot Water	*10*	*Zip*
Other	*22*	*Other / Cleaners Tub / Espresso*
TOTAL	***152 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***W22 & W24***





BUILDING ***W22 & W24*** *CHARACTERISTICS*

Net Lettable Area	*8,198 m²*	*Average Annual Water Consumption*	*13,949 m³*
Full Time Equivalent Occupants	*447*	*Number Of Storeys*	*23*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1976*
Hours of HVAC Operation (per week)	*60*	*Cost Recovery Method*	*Gross Lease*

W22 & W24 *WATER MANAGEMENT*

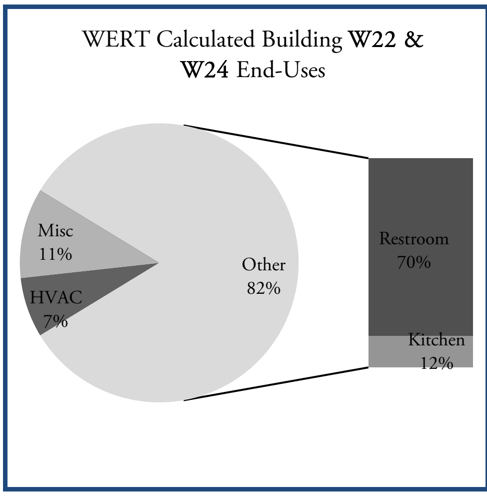
There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

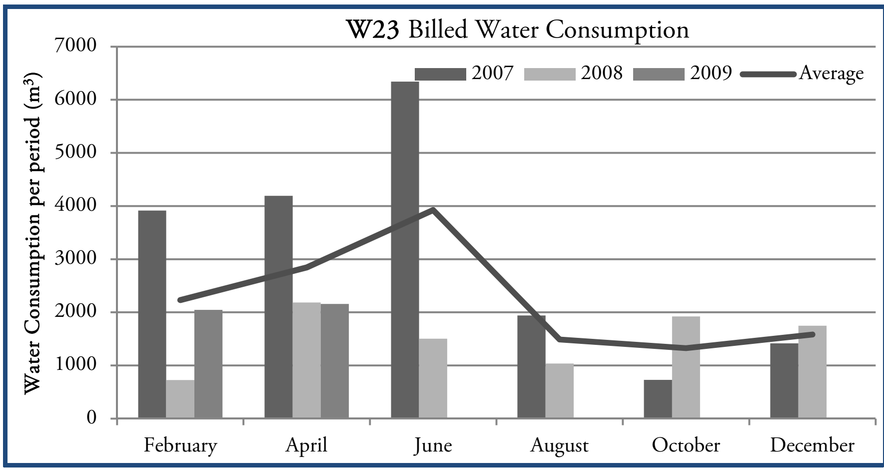
It would be ideal for the two buildings to have their own individual meter. Otherwise, the data must be combined.

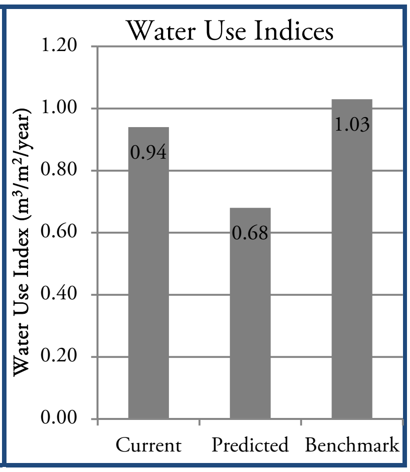


W22 & W24 *DOMESTIC END-USES DETAILS*

Toilets	*82*	*Single / Dual Flush Cistern*
Urinals	*3*	*Group Sensor Trough*
Wash Hand Basins	*84*	*Manual Faucet*
Showers	*3*	
Kitchen Sinks	*34*	
Dishwashers	*24*	*Domestic / Commercial*
Instant Hot Water	*32*	*Zip*
Other	*22*	*Cleaners Tub / Espresso*
TOTAL	***284 x Domestic End-Uses***	

D2: *BUILDING ID CODE **W23***





*BUILDING **W23** CHARACTERISTICS*

Net Lettable Area	*9,745 m²*	*Average Annual Water Consumption*	*18,532 m³*
Full Time Equivalent Occupants	*325*	*Number Of Storeys*	*15*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1970*
Hours of HVAC Operation (per week)	*56*	*Cost Recovery Method*	*Gross Lease*

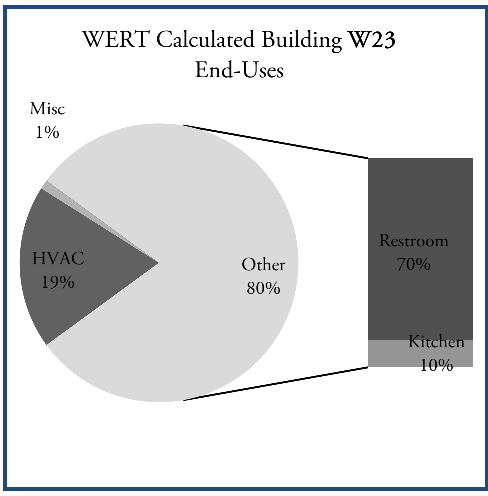
***W23** WATER MANAGEMENT*

There is currently one observed sub-meter in place. This meter is not read.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

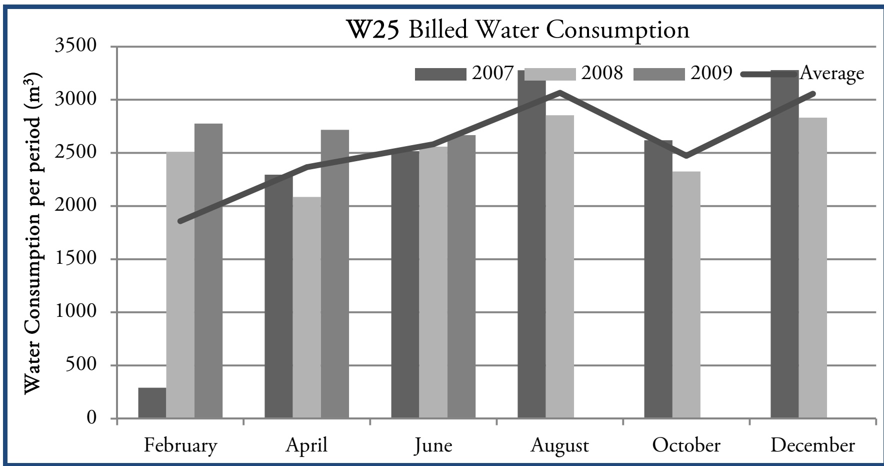
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

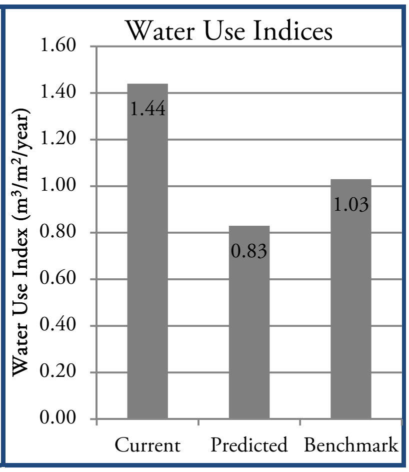


W23 DOMESTIC END-USES DETAILS

Toilets	*81*	*Single Flush Cistern*
Urinals	*28*	*Infrared Sensor Wall-Pod*
Wash Hand Basins	*57*	*Manual Faucet*
Showers	*9*	
Kitchen Sinks	*15*	
Dishwashers	*15*	*Domestic / Commercial*
Instant Hot Water	*15*	*Zip*
Other	*32*	*Other / Cleaners Tub / Espresso*
TOTAL	***252 x Domestic End-Uses***	

D2: *BUILDING ID CODE W25*





BUILDING W25 CHARACTERISTICS

Net Lettable Area	*10,555 m²*	*Average Annual Water Consumption*	*13,527 m³*
Full Time Equivalent Occupants	*550*	*Number Of Storeys*	*17*
Heat Rejection Method	*Air Condenser*	*Year Built*	*1986*
Hours of HVAC Operation (per week)	*65*	*Cost Recovery Method*	*Gross Lease*

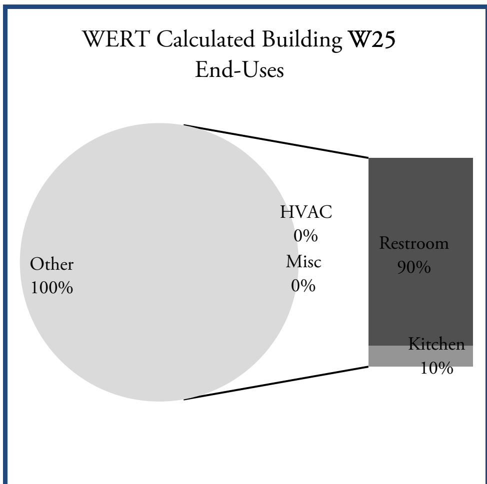
W25 WATER MANAGEMENT

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

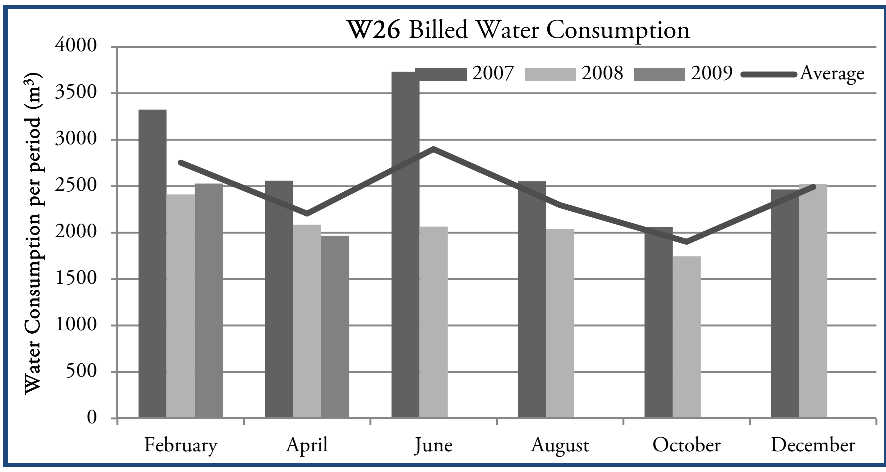
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

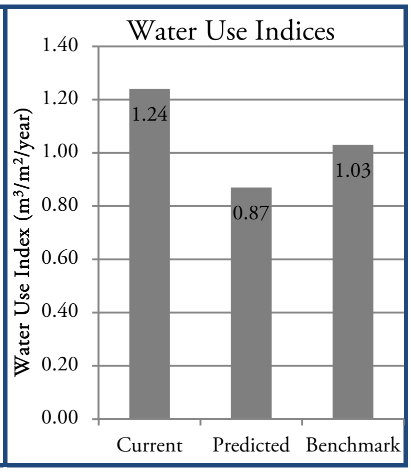


W25 DOMESTIC END-USES DETAILS

Toilets	*56*	*Single Flush Cistern*
Urinals	*14*	*Cyclic Flush Trough*
Wash Hand Basins	*59*	*Manual Faucet*
Showers	*2*	
Kitchen Sinks	*26*	
Dishwashers	*14*	*Domestic*
Instant Hot Water	*22*	*Zip*
Other	*26*	*Cleaners Tub / Other*
TOTAL	***219 x Domestic End-Uses***	

D2: *BUILDING ID CODE **W26***





*BUILDING **W26** CHARACTERISTICS*

Net Lettable Area	*10,376 m²*	*Average Annual Water Consumption*	*14,426 m³*
Full Time Equivalent Occupants	*308*	*Number Of Storeys*	*16*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1976*
Hours of HVAC Operation (per week)	*56*	*Cost Recovery Method*	*Gross Lease*

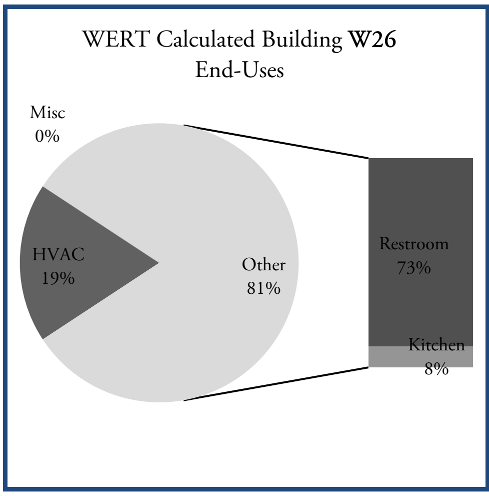
W26 *WATER MANAGEMENT*

There are currently three observed sub-meters in place. These meters are not read.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

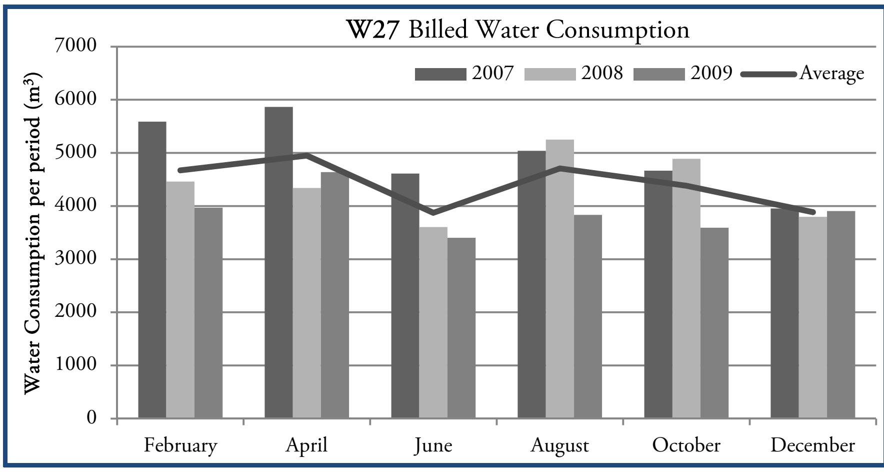
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

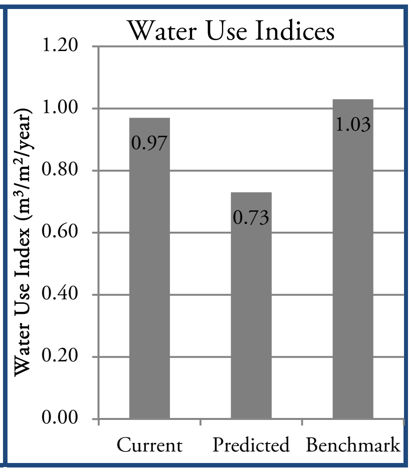


W26 *DOMESTIC END-USES DETAILS*

Toilets	*80*	*Dual Flush Cistern*
Urinals	*16*	*Group Sensor Trough*
Wash Hand Basins	*64*	*Manual Faucet*
Showers	*22*	
Kitchen Sinks	*14*	
Dishwashers	*17*	*Domestic*
Instant Hot Water	*14*	*Zip*
Other	*-*	
TOTAL	***227 x Domestic End-Uses***	

D2: *BUILDING ID CODE **W27***





*BUILDING **W27** CHARACTERISTICS*

Net Lettable Area	*24,007 m^2*	*Average Annual Water Consumption*	*28,056 m^3*
Full Time Equivalent Occupants	*1,450*	*Number Of Storeys*	*32*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1968*
Hours of HVAC Operation (per week)	*60*	*Cost Recovery Method*	*Gross Lease*

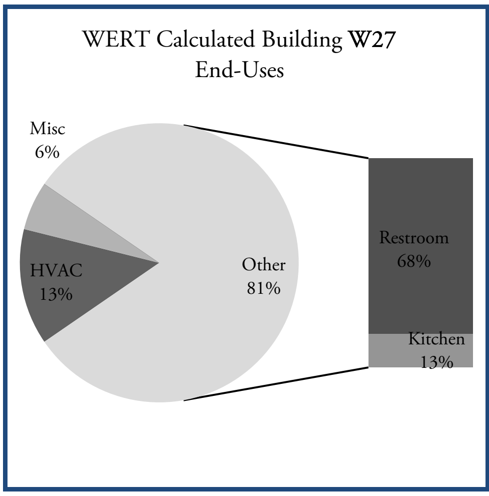
***W27** WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

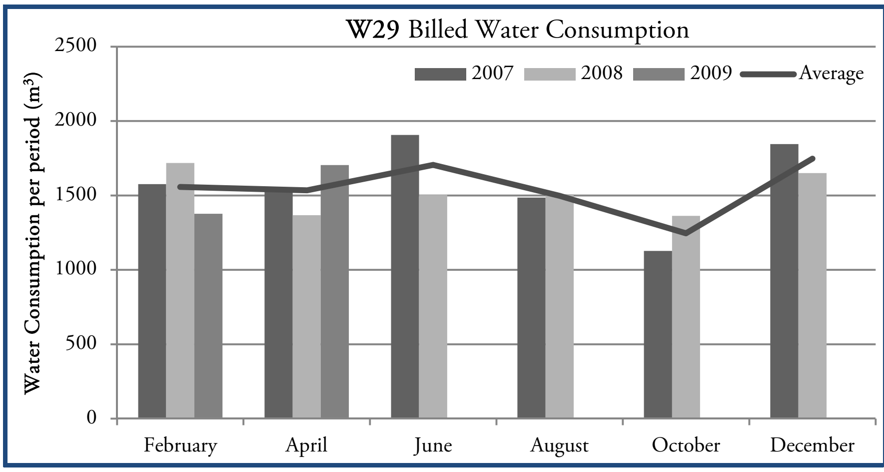
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

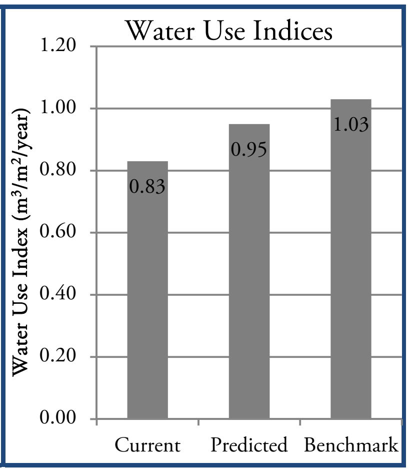


***W27** DOMESTIC END-USES DETAILS*

Toilets	*65*	*Dual Flush Cistern*
Urinals	*44*	*Cyclic Flush Wall-Pod*
Wash Hand Basins	*89*	*Manual Faucet*
Showers	*5*	
Kitchen Sinks	*31*	
Dishwashers	*29*	*Domestic / Commercial*
Instant Hot Water	*29*	*Zip*
Other	*20*	*Cleaners Tub / Espresso*
TOTAL	***312 x Domestic End-Uses***	

D2: *BUILDING ID CODE **W29***





*BUILDING **W29** CHARACTERISTICS*

Net Lettable Area	*11,021 m²*	*Average Annual Water Consumption*	*7,896 m³*
Full Time Equivalent Occupants	*900*	*Number Of Storeys*	*14*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1980*
Hours of HVAC Operation (per week)	*55*	*Cost Recovery Method*	*Gross Lease*

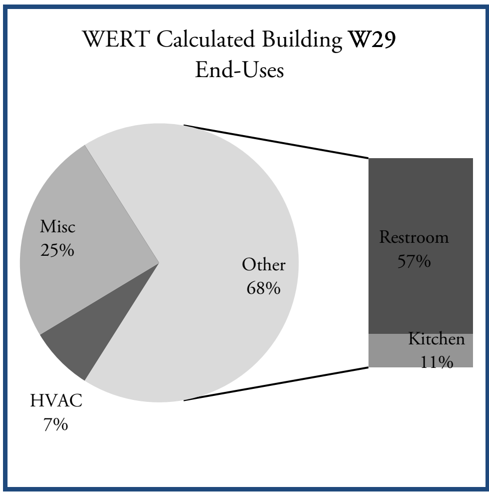
W29 WATER MANAGEMENT

There is currently one observed sub-meter in place. This meter is not read.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

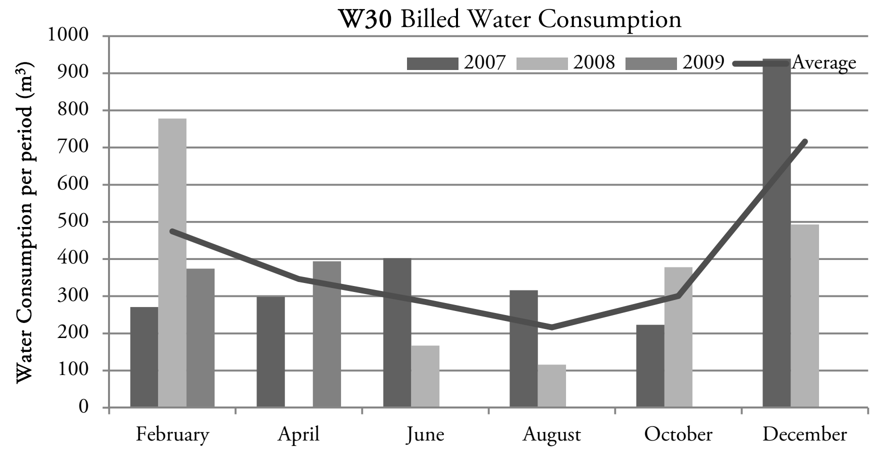
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

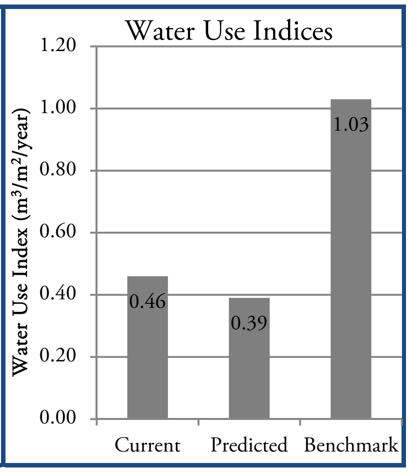


W29 DOMESTIC END-USES DETAILS

Toilets	*75*	*Single / Dual Flush Cistern*
Urinals	*15*	*Cyclic Flush Trough / Wall-Pod*
Wash Hand Basins	*60*	*Manual Faucet*
Showers	*6*	
Kitchen Sinks	*41*	
Dishwashers	*36*	*Domestic / Commercial*
Instant Hot Water	*28*	*Zip*
Other	*9*	*Other / Cleaners Tub / Espresso*
TOTAL	***270 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***W30***





BUILDING ***W30*** *CHARACTERISTICS*

Net Lettable Area	*4,200 m²*	*Average Annual Water Consumption*	*3,855 m³*
Full Time Equivalent Occupants	*140*	*Number Of Storeys*	*9*
Heat Rejection Method	*-*	*Year Built*	*1973*
Hours of HVAC Operation (per week)	*-*	*Cost Recovery Method*	*Gross Lease*

W30 *WATER MANAGEMENT*

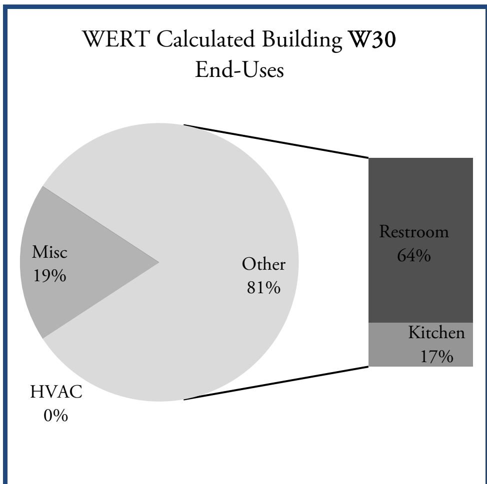
There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

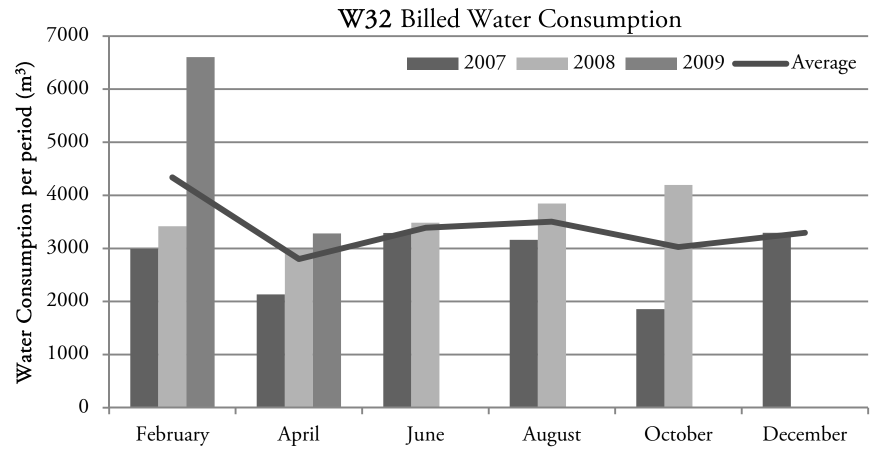
This building had multiple [mains] meter failures, and has had difficulty remedying quantity of payment solutions with the water provider.

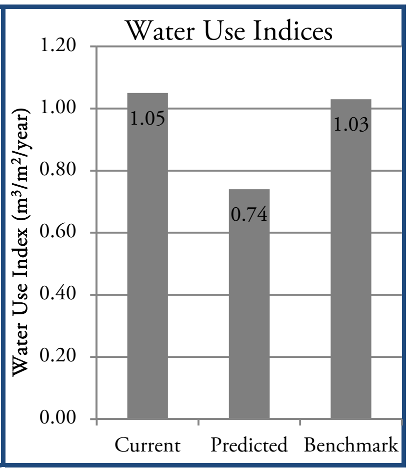


W30 *DOMESTIC END-USES DETAILS*

Toilets	*28*	*Single Flush Cistern*
Urinals	*8*	*Cyclic Flush Trough*
Wash Hand Basins	*36*	*Manual Faucet*
Showers	*-*	
Kitchen Sinks	*19*	
Dishwashers	*18*	*Domestic / Commercial*
Instant Hot Water	*34*	*Zip / Billi Tap*
Other	*9*	*Cleaners Tub / Espresso*
TOTAL	***152 x Domestic End-Uses***	

D2: *BUILDING ID CODE **W32***





*BUILDING **W32** CHARACTERISTICS*

Net Lettable Area	*15,980 m^2*	*Average Annual Water Consumption*	*21,568 m^3*
Full Time Equivalent Occupants	*850*	*Number Of Storeys*	*14*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1969*
Hours of HVAC Operation (per week)	*58*	*Cost Recovery Method*	*Gross Lease*

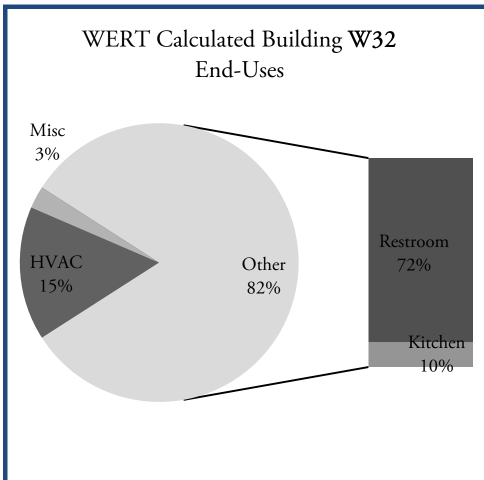
W32 WATER MANAGEMENT

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

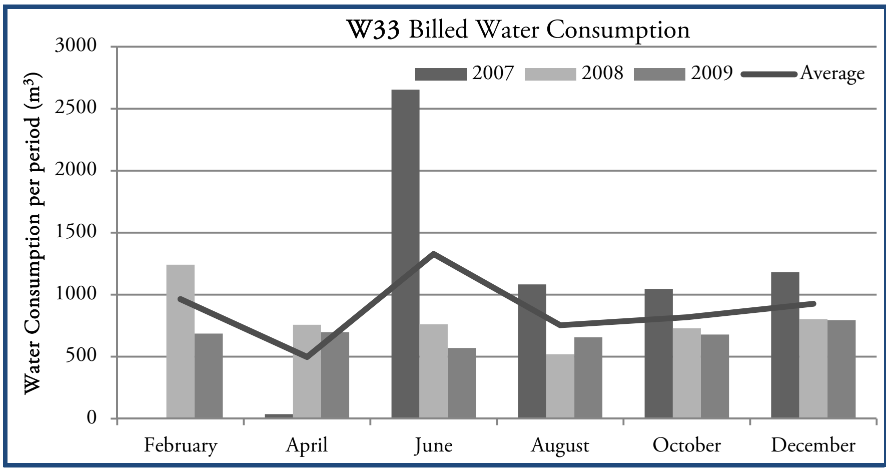
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

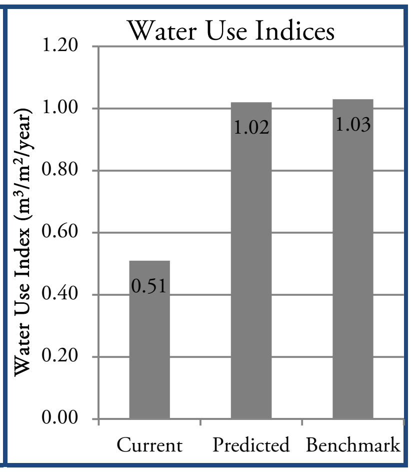


W32 DOMESTIC END-USES DETAILS

Toilets	*86*	*Single Flush Cistern*
Urinals	*19*	*Cyclic Flush Wall-Pod /Trough*
Wash Hand Basins	*74*	*Manual Faucet*
Showers	*18*	
Kitchen Sinks	*25*	
Dishwashers	*24*	*Domestic*
Instant Hot Water	*-*	
Other	*36*	*Other / Espresso*
TOTAL	***282 x Domestic End-Uses***	

D2: *BUILDING ID CODE **W33***





*BUILDING **W33** CHARACTERISTICS*

Net Lettable Area	*9,467 m²*	*Average Annual Water Consumption*	*4,931 m³*
Full Time Equivalent Occupants	*800*	*Number Of Storeys*	*16*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1987*
Hours of HVAC Operation (per week)	*55*	*Cost Recovery Method*	*Gross Lease*

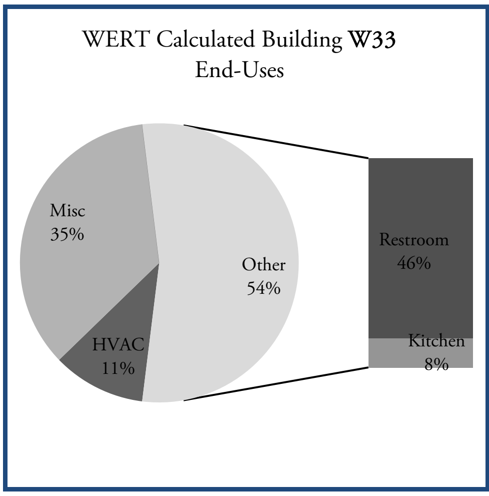
W33 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

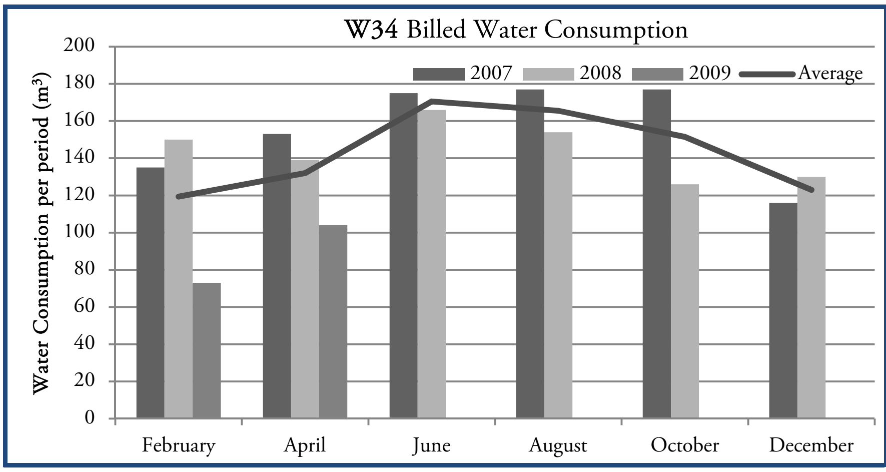
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

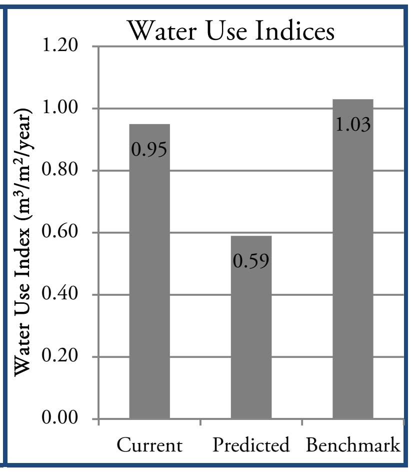


W33 *DOMESTIC END-USES DETAILS*

Toilets	*69*	*Combination*
Urinals	*13*	*Group Sensor Trough*
Wash Hand Basins	*57*	*Manual Faucet*
Showers	*4*	
Kitchen Sinks	*12*	
Dishwashers	*12*	*Domestic*
Instant Hot Water	*12*	*Zip*
Other	*12*	*Cleaners Tub*
TOTAL	***191 x Domestic End-Uses***	

D2: *BUILDING ID CODE **W34***





*BUILDING **W34** CHARACTERISTICS*

Net Lettable Area	*1,636 m^2*	*Average Annual Water Consumption*	*1,101 m^3*
Full Time Equivalent Occupants	*34*	*Number Of Storeys*	*7*
Heat Rejection Method	-	*Year Built*	*1924*
Hours of HVAC Operation (per week)	-	*Cost Recovery Method*	*Gross Lease*

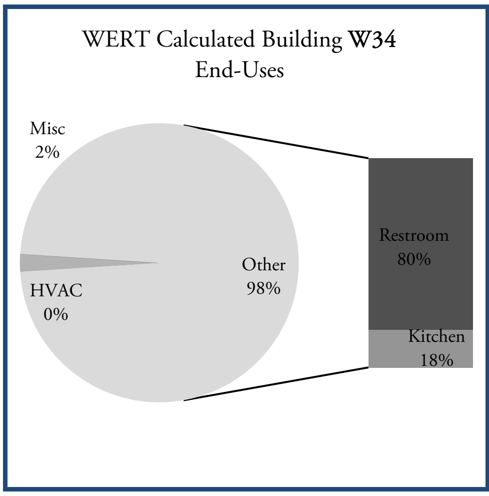
W34 *WATER MANAGEMENT*

There is currently one observed sub-meter in place. This meter is not read.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

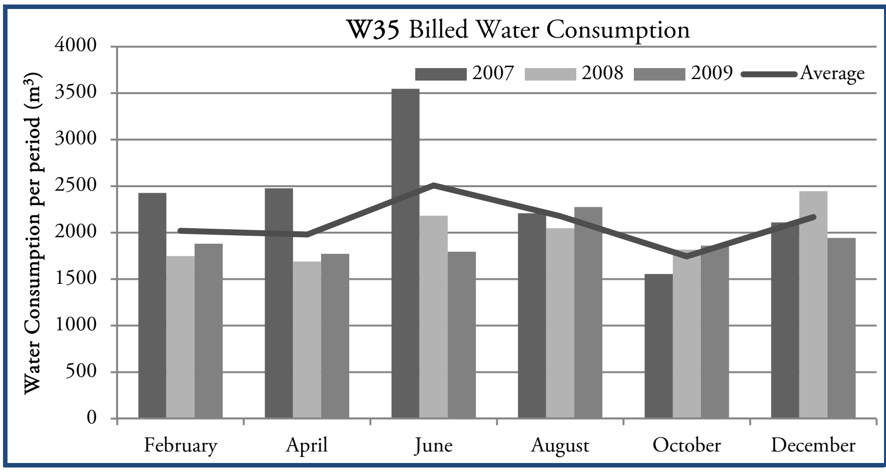
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

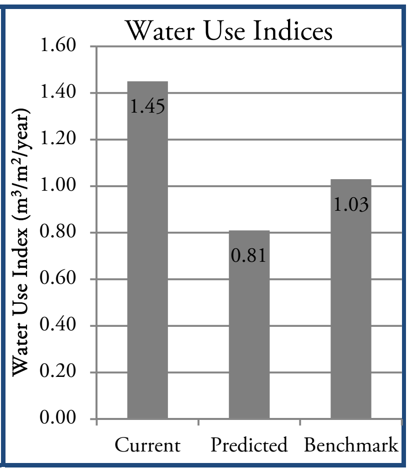


__W34__ DOMESTIC END-USES DETAILS

Toilets	*22*	*Dual / Single Flush Cistern*
Urinals	-	
Wash Hand Basins	*15*	*Manual Faucet*
Showers	*2*	
Kitchen Sinks	*6*	
Dishwashers	*6*	*Domestic*
Instant Hot Water	*6*	*Zip*
Other	*12*	*Cleaners Tub / Other*
TOTAL	***69 x Domestic End-Uses***	

D2: *BUILDING ID CODE W35*





BUILDING W35 CHARACTERISTICS

Net Lettable Area	*8,251 m²*	*Average Annual Water Consumption*	*12,858 m³*
Full Time Equivalent Occupants	*365*	*Number Of Storeys*	*16*
Heat Rejection Method	*Air Condenser*	*Year Built*	*1993*
Hours of HVAC Operation (per week)	*55*	*Cost Recovery Method*	*Gross Lease*

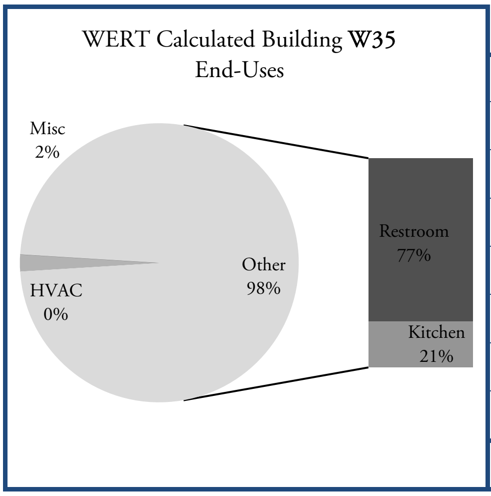
W35 WATER MANAGEMENT

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

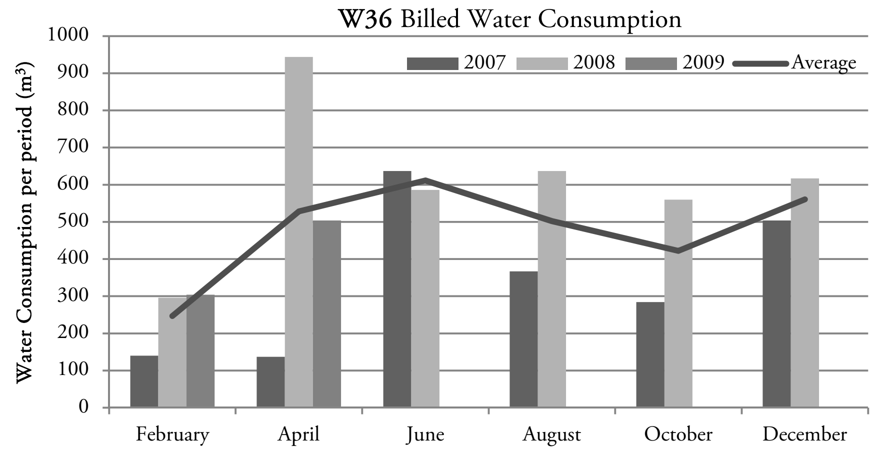
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

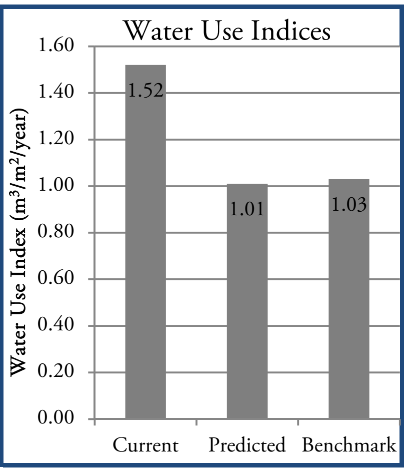


W35 DOMESTIC END-USES DETAILS

Toilets	*64*	*Dual Flush Cistern*
Urinals	*16*	*Cyclic Flush Trough*
Wash Hand Basins	*64*	*Manual Faucet*
Showers	*-*	
Kitchen Sinks	*19*	
Dishwashers	*17*	*Domestic*
Instant Hot Water	*16*	*Zip*
Other	*32*	*Cleaners Tub / Other*
TOTAL	***228 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***W36***





BUILDING ***W36*** *CHARACTERISTICS*

Net Lettable Area	*2,387 m²*	*Average Annual Water Consumption*	*1,937 m³*
Full Time Equivalent Occupants	*125*	*Number Of Storeys*	*10*
Heat Rejection Method	-	*Year Built*	*1970*
Hours of HVAC Operation (per week)	-	*Cost Recovery Method*	*Gross Lease*

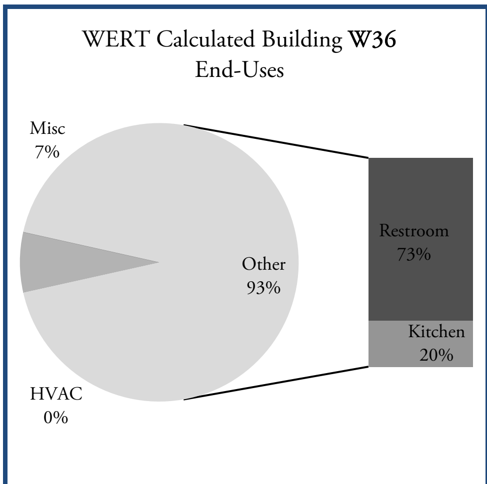
W36 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

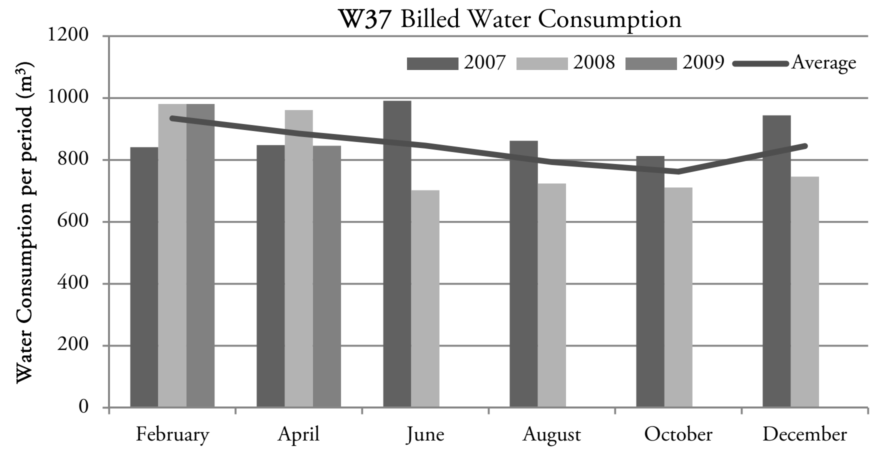
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

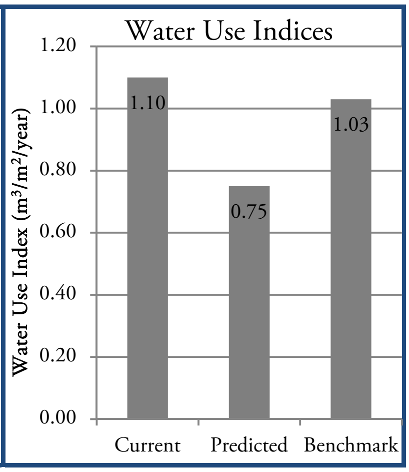


W36 *DOMESTIC END-USES DETAILS*

Toilets	*20*	*Single Flush Valve*
Urinals	*5*	*Group Sensor Trough*
Wash Hand Basins	*20*	*Manual Faucet*
Showers	*4*	
Kitchen Sinks	*11*	
Dishwashers	*11*	*Domestic*
Instant Hot Water	*10*	*Zip*
Other	*20*	*Cleaners Tub / Other*
TOTAL	***101 x Domestic End-Uses***	

D2: *BUILDING ID CODE **W37***





*BUILDING **W37** CHARACTERISTICS*

Net Lettable Area	*4,400 m²*	*Average Annual Water Consumption*	*4,825 m³*
Full Time Equivalent Occupants	*125*	*Number Of Storeys*	*12*
Heat Rejection Method	*Air Condenser*	*Year Built*	*1988*
Hours of HVAC Operation (per week)	*56*	*Cost Recovery Method*	*Gross Lease*

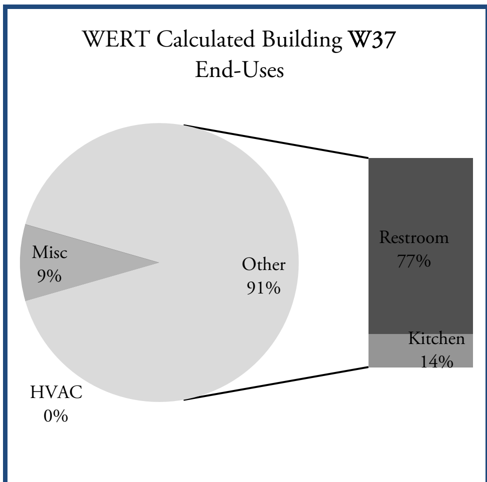
W37 *WATER MANAGEMENT*

There is currently one observed sub-meter in place. This meter is not read.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

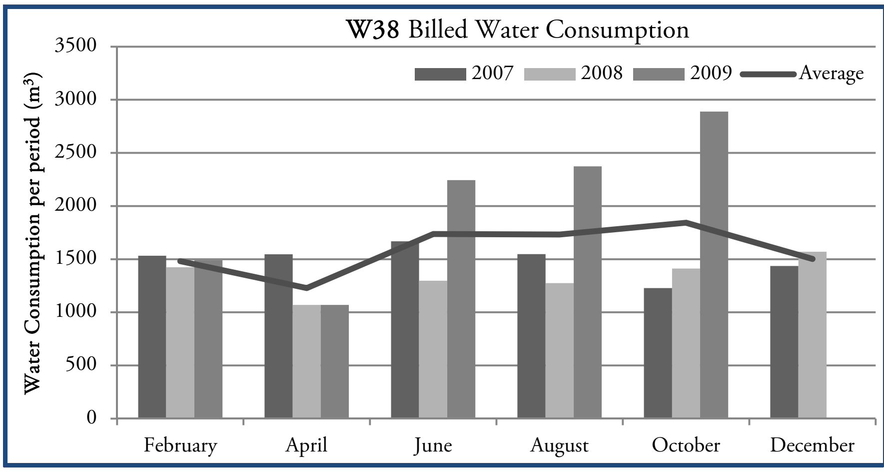
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

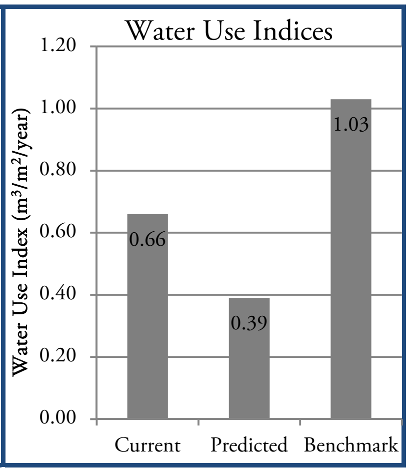


W37 DOMESTIC END-USES DETAILS

Toilets	*33*	*Single Flush Cistern*
Urinals	*11*	*Cyclic Flush Wall-Pod*
Wash Hand Basins	*33*	*Manual Faucet*
Showers	*11*	
Kitchen Sinks	*11*	
Dishwashers	*11*	*Domestic*
Instant Hot Water	*11*	*Zip*
Other	*22*	*Cleaners Tub / Other*
TOTAL	***143 x Domestic End-Uses***	

D2: *BUILDING ID CODE **W38***





*BUILDING **W38** CHARACTERISTICS*

Net Lettable Area	*12,218 m²*	*Average Annual Water Consumption*	*9,567 m³*
Full Time Equivalent Occupants	*455*	*Number Of Storeys*	*7*
Heat Rejection Method	-	*Year Built*	*1929*
Hours of HVAC Operation (per week)	-	*Cost Recovery Method*	*Gross Lease*

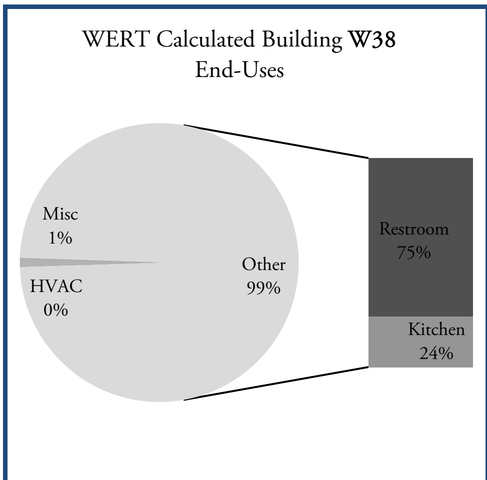
***W38** WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

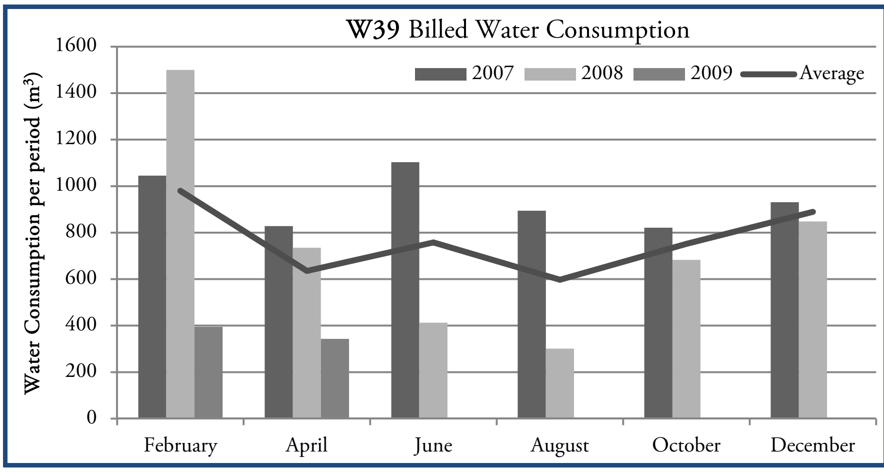
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

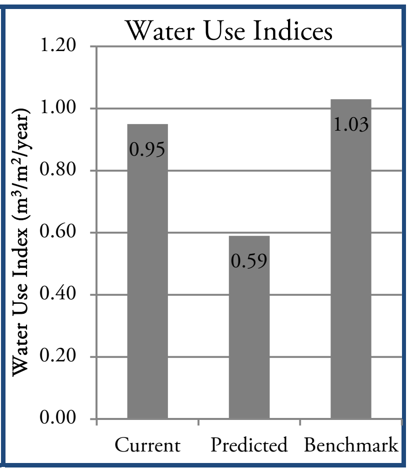


__W38__ DOMESTIC END-USES DETAILS

Toilets	*41*	*Single / Dual Flush Cistern*
Urinals	*7*	*Infrared Sensor Wall-Pod*
Wash Hand Basins	*28*	*Manual Faucet*
Showers	*4*	
Kitchen Sinks	*18*	
Dishwashers	*7*	*Domestic / Commercial*
Instant Hot Water	*5*	*Zip*
Other	*9*	*Cleaners Tub / Espresso*
TOTAL	***119 x Domestic End-Uses***	

D2: *BUILDING ID CODE **W39***





*BUILDING **W39** CHARACTERISTICS*

Net Lettable Area	*4,737 m²*	*Average Annual Water Consumption*	*6,298 m³*
Full Time Equivalent Occupants	*188*	*Number Of Storeys*	*16*
Heat Rejection Method	*Heat Pump*	*Year Built*	*1970*
Hours of HVAC Operation (per week)	*56*	*Cost Recovery Method*	*Gross Lease*

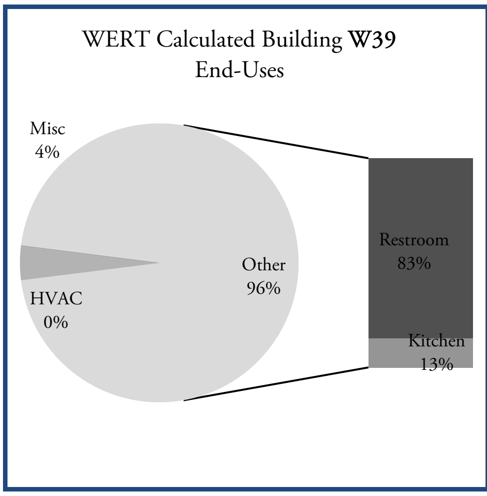
***W39** WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

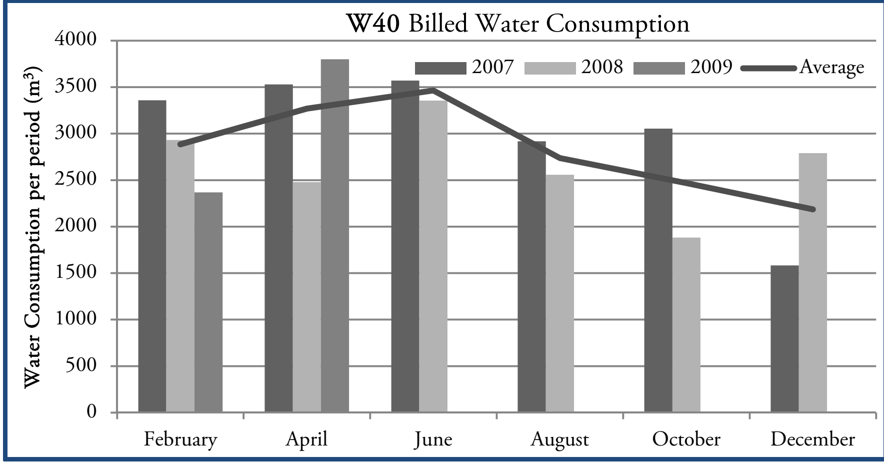
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

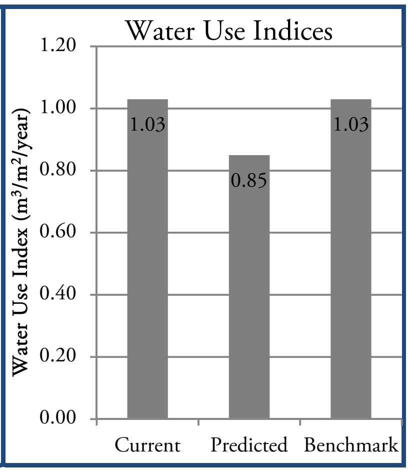


***W39** DOMESTIC END-USES DETAILS*

Toilets	*34*	*Single Flush Cistern*
Urinals	*8*	*Infrared Sensor Wall-Pod*
Wash Hand Basins	*34*	*Manual Faucet*
Showers	*8*	
Kitchen Sinks	*15*	
Dishwashers	*15*	*Domestic*
Instant Hot Water	*15*	
Other	*2*	*Cleaners Tub*
TOTAL	***131 x Domestic End-Uses***	

D2: *BUILDING ID CODE **W40***





*BUILDING **W40** CHARACTERISTICS*

Net Lettable Area	*15,419 m^2*	*Average Annual Water Consumption*	*17,062 m^3*
Full Time Equivalent Occupants	*1,200*	*Number Of Storeys*	*19*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1980*
Hours of HVAC Operation (per week)	*55*	*Cost Recovery Method*	*Gross Lease*

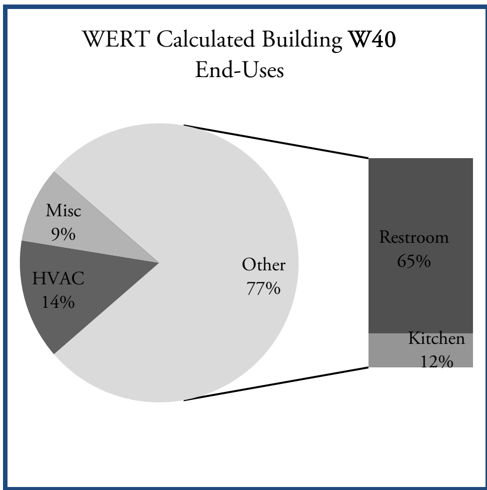
***W40** WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

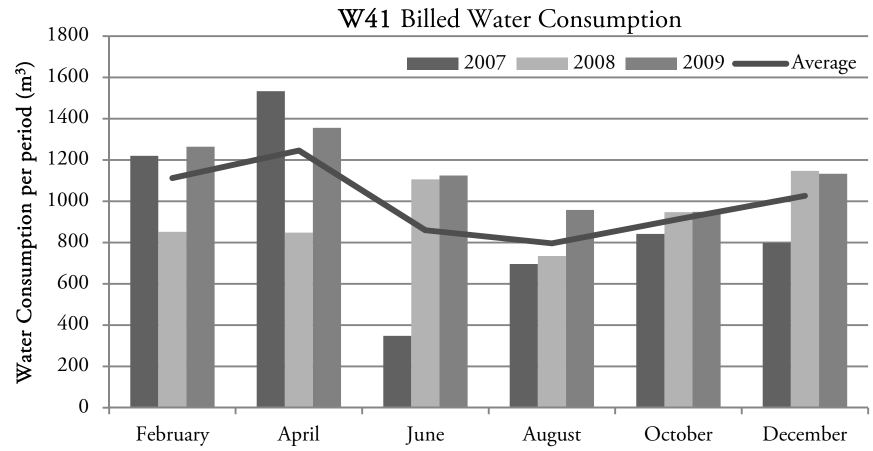
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

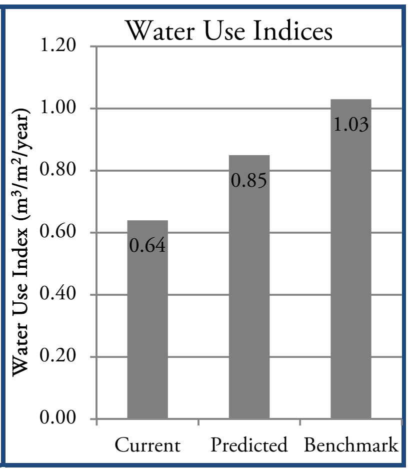


***W40** DOMESTIC END-USES DETAILS*

Toilets	*74*	*Single / Dual Flush Cistern*
Urinals	*26*	*Cyclic Flush Wall-Pod*
Wash Hand Basins	*60*	*Manual Faucet*
Showers	*9*	
Kitchen Sinks	*19*	
Dishwashers	*19*	*Domestic / Commercial*
Instant Hot Water	*13*	*Zip*
Other	*32*	*Cleaners Tub / Other / Espresso*
TOTAL	***252 x Domestic End-Uses***	

D2: *BUILDING ID CODE **W41***





*BUILDING **W41** CHARACTERISTICS*

Net Lettable Area	*8,770 m²*	*Average Annual Water Consumption*	*6,582 m³*
Full Time Equivalent Occupants	*800*	*Number Of Storeys*	*16*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1987*
Hours of HVAC Operation (per week)	*55*	*Cost Recovery Method*	*Gross Lease*

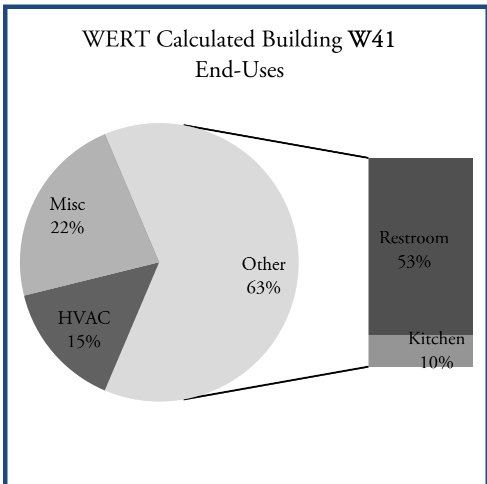
W41 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

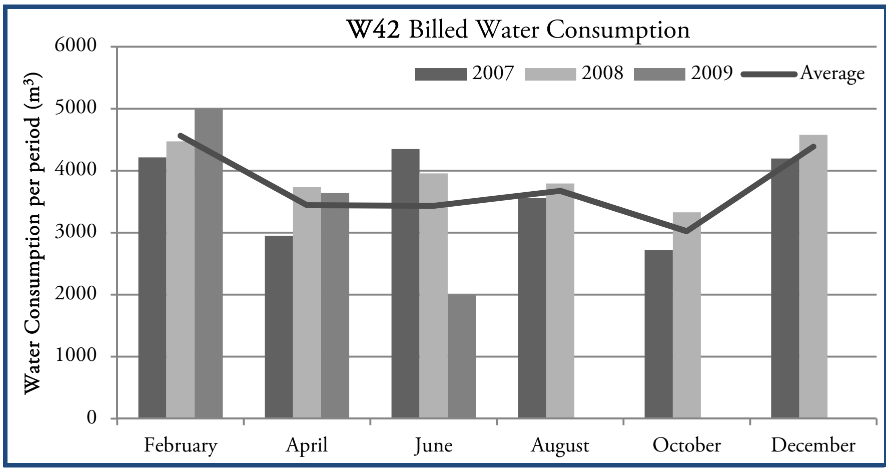
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

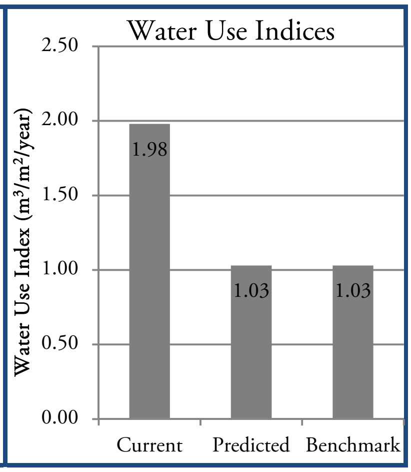


W41 DOMESTIC END-USES DETAILS

Toilets	*62*	*Dual Flush Cistern*
Urinals	*12*	*Group Sensor Trough*
Wash Hand Basins	*52*	*Manual Faucet*
Showers	*5*	
Kitchen Sinks	*14*	
Dishwashers	*14*	*Domestic*
Instant Hot Water	*14*	*Zip*
Other	*2*	*Cleaners Tub / Espresso*
TOTAL	*175 x Domestic End-Uses*	

D2: *BUILDING ID CODE* ***W42***





BUILDING ***W42*** *CHARACTERISTICS*

Net Lettable Area	*12,021 m^2*	*Average Annual Water Consumption*	*22,532 m^3*
Full Time Equivalent Occupants	*534*	*Number Of Storeys*	*21*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1989*
Hours of HVAC Operation (per week)	*65*	*Cost Recovery Method*	*Gross Lease*

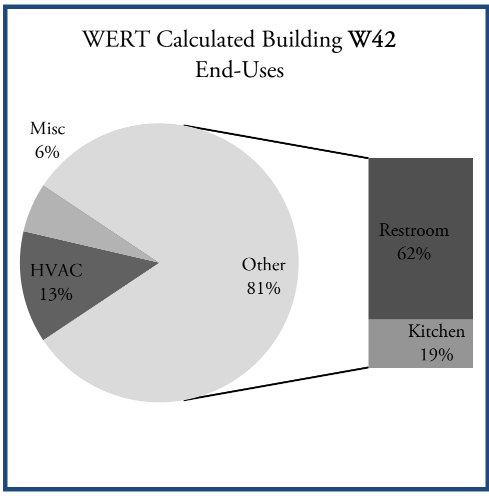
W42 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

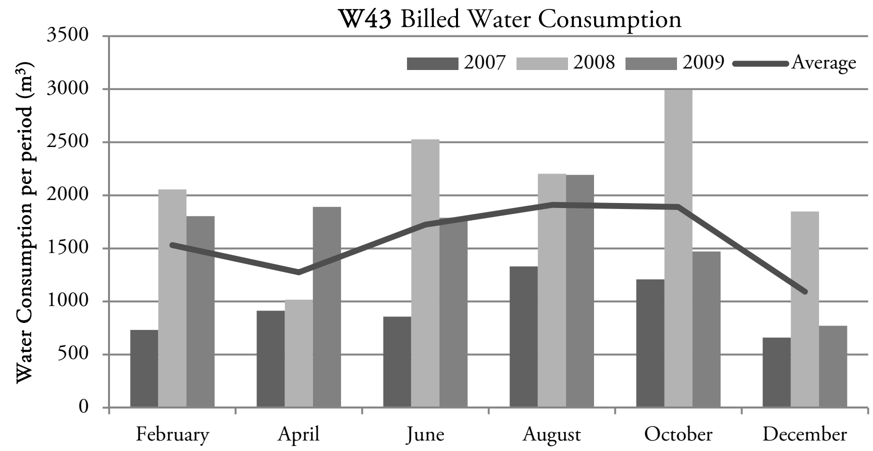
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

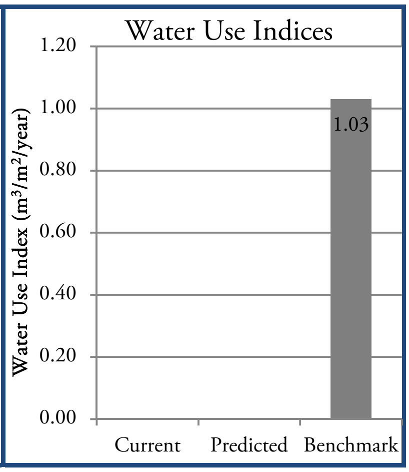


W42 *DOMESTIC END-USES DETAILS*

Toilets	*54*	*Single / Dual Flush Cistern*
Urinals	*17*	*Infrared Sensor Wall-Pod*
Wash Hand Basins	*53*	*Manual Faucet*
Showers	*-*	
Kitchen Sinks	*20*	
Dishwashers	*11*	*Domestic / Commercial*
Instant Hot Water	*19*	*Zip*
Other	*23*	*Cleaners Tub / Other / Espresso*
TOTAL	*197 x Domestic End-Uses*	

D2: *BUILDING ID CODE **W43***





*BUILDING **W43** CHARACTERISTICS*

Net Lettable Area	*- m^2*	*Average Annual Water Consumption*	*9,081 m^3*
Full Time Equivalent Occupants	*~265*	*Number Of Storeys*	*7*
Heat Rejection Method	-	*Year Built*	*1926*
Hours of HVAC Operation (per week)	-	*Cost Recovery Method*	*Gross Lease*

***W43** WATER MANAGEMENT*

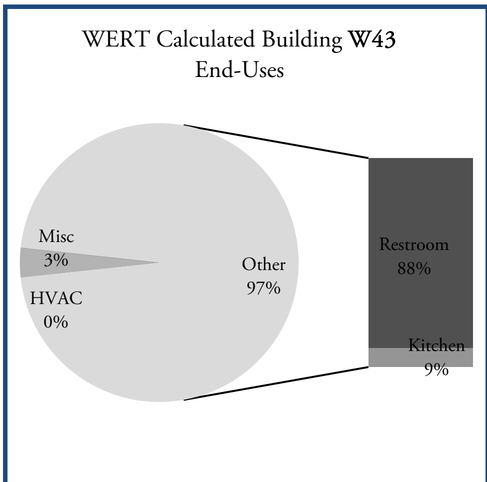
This building is managed by a facilities management company, through a body corporate. The top two floors are residential. Very little information is maintained through this method of facilities/property management.

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

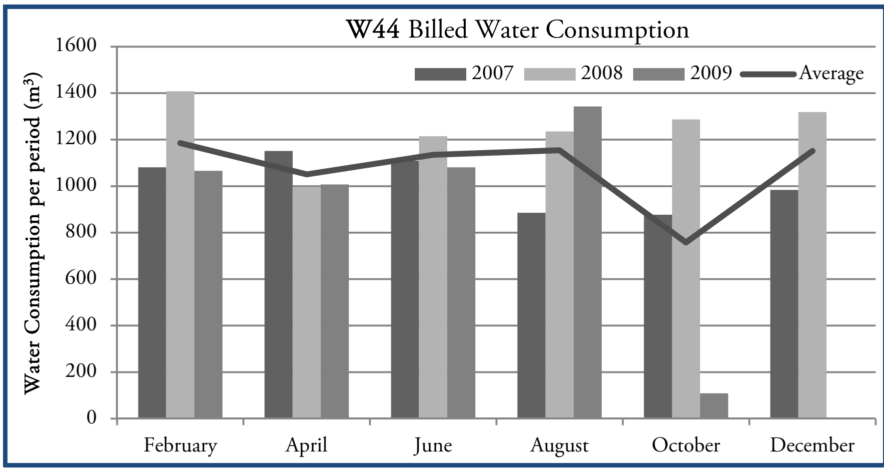
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

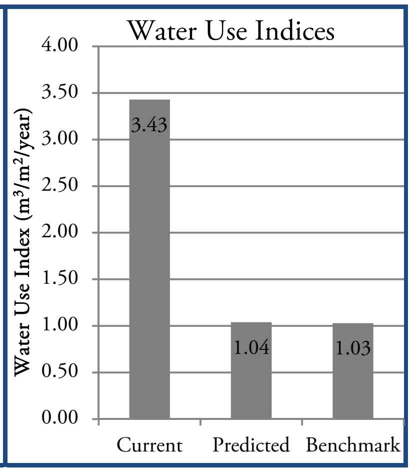


***W43** DOMESTIC END-USES DETAILS*

Toilets	*55*	*Dual Flush Cistern*
Urinals	*4*	*Cyclic Flush Trough*
Wash Hand Basins	*54*	*Manual Faucet*
Showers	*35*	
Kitchen Sinks	*47*	
Dishwashers	*45*	*Domestic / Commercial*
Instant Hot Water	*4*	*Zip*
Other	*46*	*Other / Cleaners Tub / Espresso*
TOTAL	***290 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***W44***





BUILDING ***W44*** *CHARACTERISTICS*

Net Lettable Area	*2,174 m²*	*Average Annual Water Consumption*	*6,377 m³*
Full Time Equivalent Occupants	*100*	*Number Of Storeys*	*6*
Heat Rejection Method	-	*Year Built*	*1924*
Hours of HVAC Operation (per week)	-	*Cost Recovery Method*	*Gross Lease*

W44 *WATER MANAGEMENT*

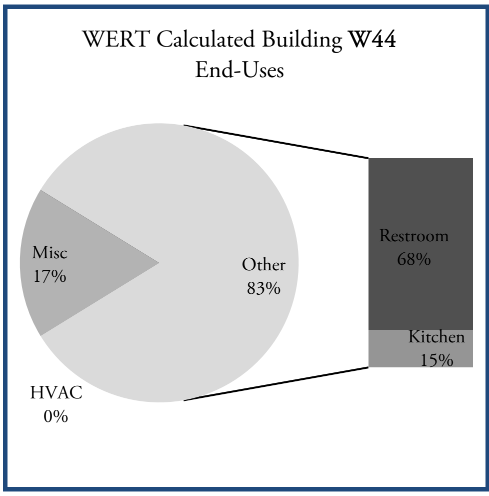
The ground floor of this building is occupied by a popular, all-hours bar/restaurant facility.

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

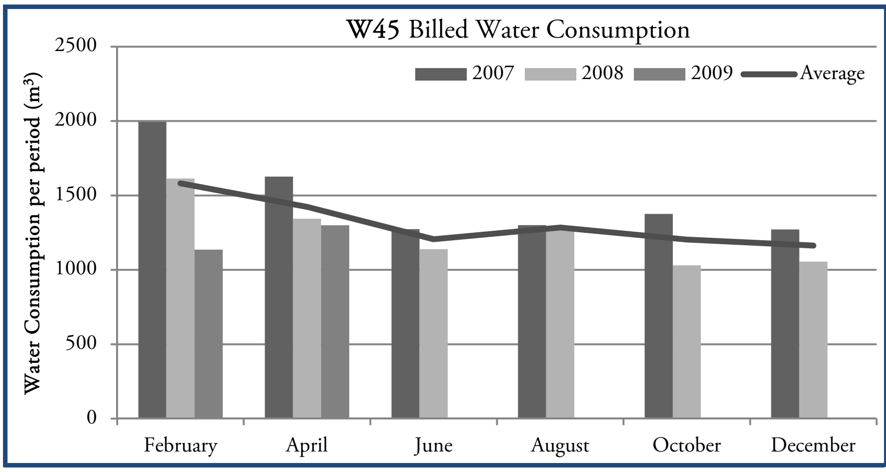
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

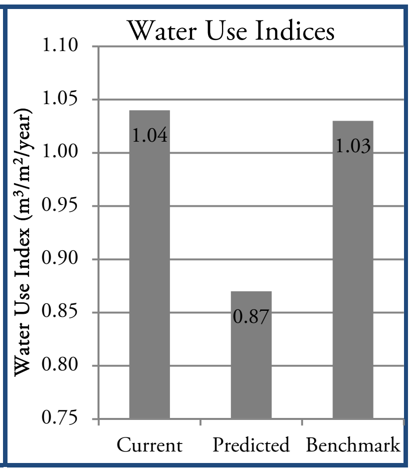


W44 *DOMESTIC END-USES DETAILS*

Toilets	*17*	*Dual Flush Cistern*
Urinals	*9*	*Cyclic Flush Wall-Pod*
Wash Hand Basins	*21*	*Manual Faucet*
Showers	*8*	
Kitchen Sinks	*6*	
Dishwashers	*5*	*Domestic*
Instant Hot Water	*1*	*Zip*
Other	*4*	*Espresso / Other*
TOTAL	***71 x Domestic End-Uses***	

D2: *BUILDING ID CODE **W45***





*BUILDING **W45** CHARACTERISTICS*

Net Lettable Area	*7,154 m²*	*Average Annual Water Consumption*	*8,614 m³*
Full Time Equivalent Occupants	*327*	*Number Of Storeys*	*14*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1982*
Hours of HVAC Operation (per week)	*50*	*Cost Recovery Method*	*Gross Lease*

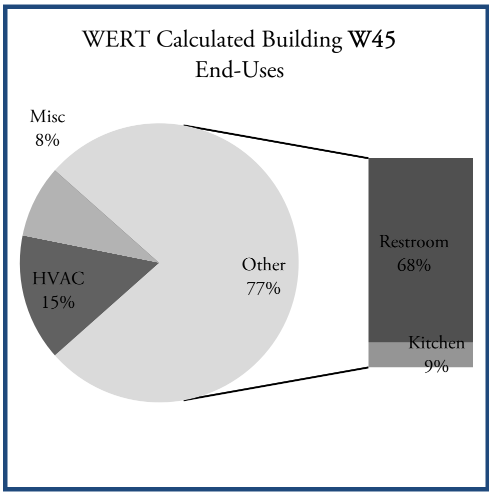
W45 *WATER MANAGEMENT*

There is currently one observed sub-meter in place. This meter is not read.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

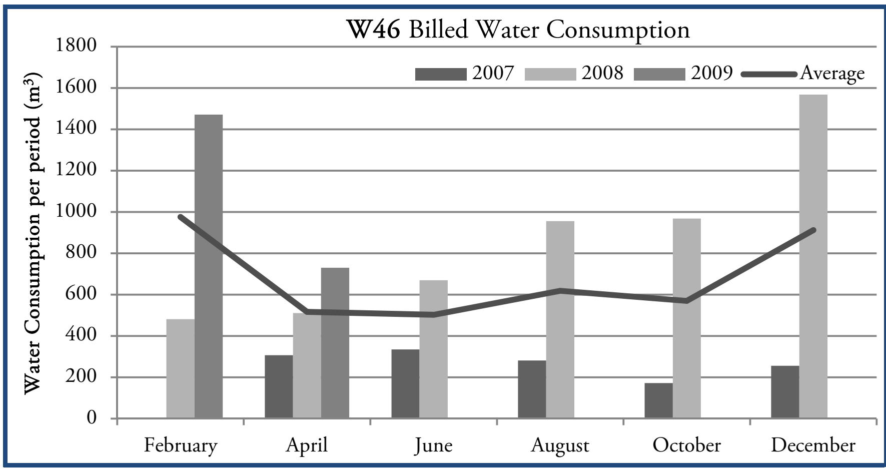
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

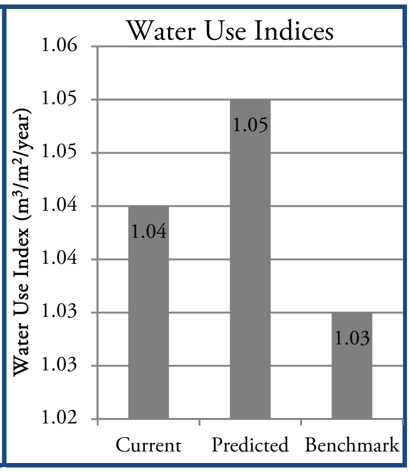


__W45__ DOMESTIC END-USES DETAILS

Toilets	*72*	*Single Flush Cistern*
Urinals	*13*	*Cyclic Flush Trough*
Wash Hand Basins	*52*	*Manual Faucet*
Showers	*6*	
Kitchen Sinks	*20*	
Dishwashers	*20*	*Domestic*
Instant Hot Water	*20*	*Zip*
Other	*46*	*Cleaners Tub / Other*
TOTAL	***249 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***W46***





BUILDING ***W46*** *CHARACTERISTICS*

Net Lettable Area	*3,154 m²*	*Average Annual Water Consumption*	*3,295 m³*
Full Time Equivalent Occupants	*180*	*Number Of Storeys*	*16*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1988*
Hours of HVAC Operation (per week)	*50*	*Cost Recovery Method*	*Gross Lease*

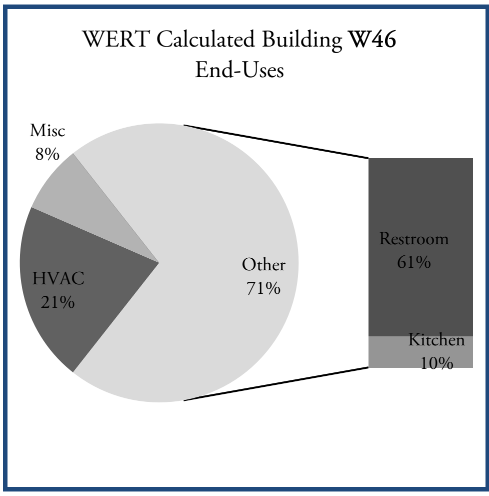
W46 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

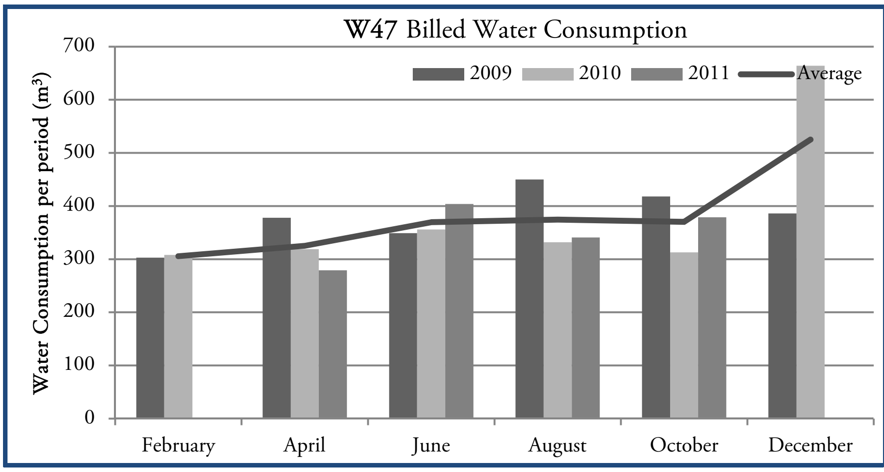
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

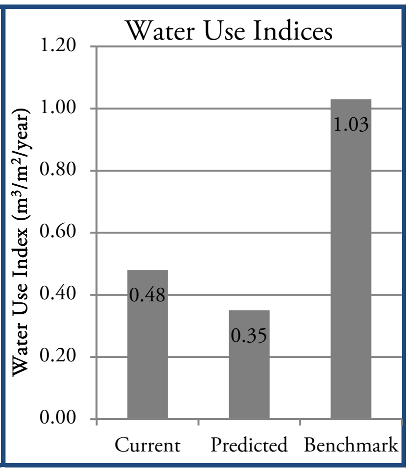


W46 *DOMESTIC END-USES DETAILS*

Toilets	*35*	*Single Flush Valve*
Urinals	*16*	*Infrared Sensor Wall-Pod*
Wash Hand Basins	*43*	*Manual Faucet*
Showers	*5*	
Kitchen Sinks	*8*	
Dishwashers	*8*	*Domestic*
Instant Hot Water	*8*	*Zip*
Other	*17*	*Cleaners Tub / Other*
TOTAL	***140 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***W47***





*BUILDING **W47** CHARACTERISTICS*

Net Lettable Area	*4,763 m²*	*Average Annual Water Consumption*	*2,436 m³*
Full Time Equivalent Occupants	*139*	*Number Of Storeys*	*14*
Heat Rejection Method	-	*Year Built*	*1967*
Hours of HVAC Operation (per week)	-	*Cost Recovery Method*	*Gross Lease*

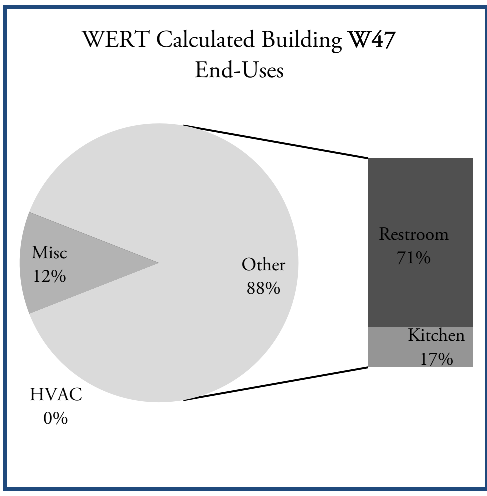
W47 *WATER MANAGEMENT*

There are currently two observed sub-meters in place. These meters are checked regularly, but not used as a cost-recovery mechanism.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

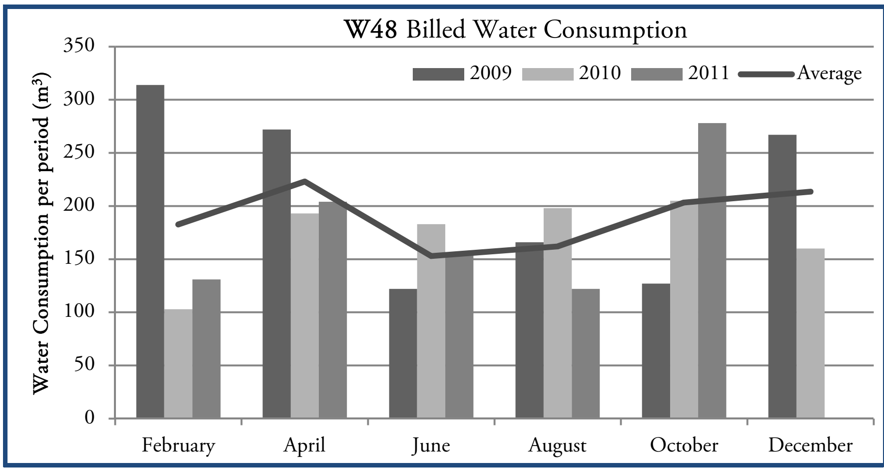
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

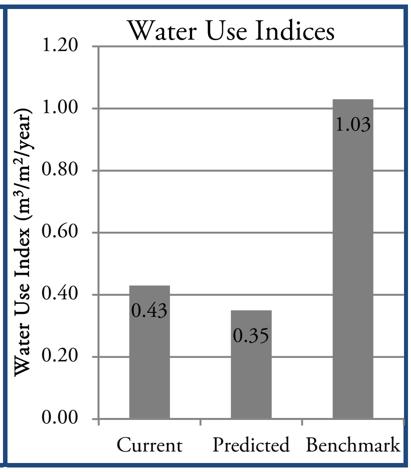


W47 *DOMESTIC END-USES DETAILS*

Toilets	*39*	*Single / Dual Flush Cistern*
Urinals	*7*	*Manual Flush Wall-Pod*
Wash Hand Basins	*32*	*Manual Faucet*
Showers	*5*	
Kitchen Sinks	*20*	
Dishwashers	*16*	*Domestic / Commercial*
Instant Hot Water	*14*	*Billi Tap*
Other	*16*	*Cleaners Tub / Espresso*
TOTAL	***149 x Domestic End-Uses***	

D2: *BUILDING ID CODE **W48***





*BUILDING **W48** CHARACTERISTICS*

Net Lettable Area	*2,442 m^2*	*Average Annual Water Consumption*	*1,827 m^3*
Full Time Equivalent Occupants	*102*	*Number Of Storeys*	*3*
Heat Rejection Method	*Air Condenser*	*Year Built*	*1976*
Hours of HVAC Operation (per week)	*52*	*Cost Recovery Method*	*Gross Lease*

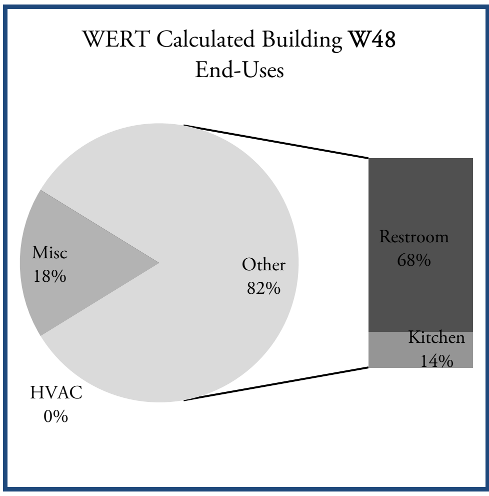
***W48** WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

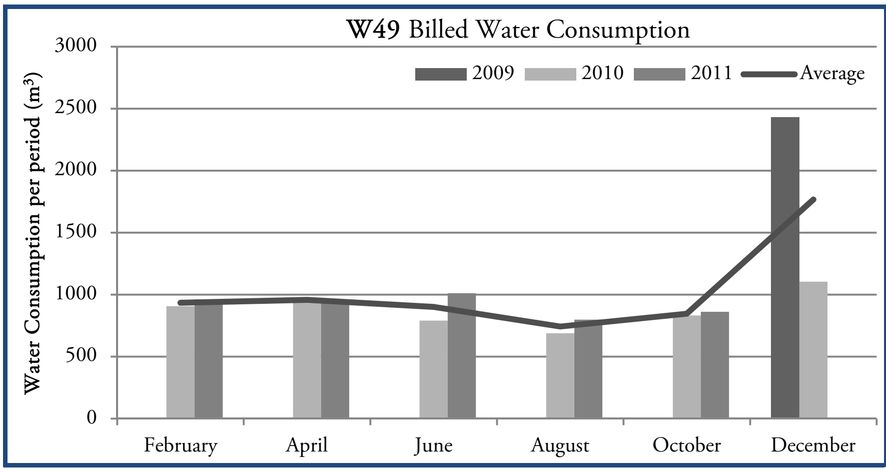
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

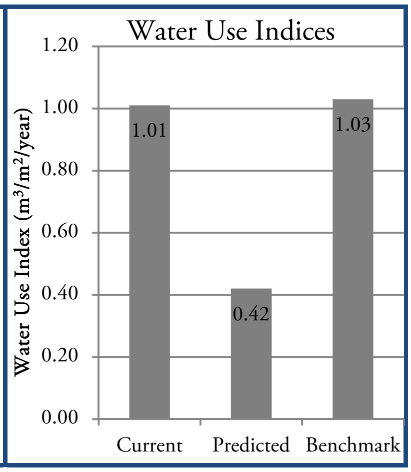


***W48** DOMESTIC END-USES DETAILS*

Toilets	*17*	*Single / Dual Flush Cistern*
Urinals	*4*	*Infrared Sensor Wall-Pod*
Wash Hand Basins	*30*	*Manual Faucet*
Showers	*2*	
Kitchen Sinks	*10*	
Dishwashers	*4*	*Domestic*
Instant Hot Water	*4*	*Zip*
Other	*4*	*Cleaners Tub*
TOTAL	***75 x Domestic End-Uses***	

D2: *BUILDING ID CODE **W49***





*BUILDING **W49** CHARACTERISTICS*

Net Lettable Area	*5,246 m²*	*Average Annual Water Consumption*	*5,281 m³*
Full Time Equivalent Occupants	*200*	*Number Of Storeys*	*5*
Heat Rejection Method	*Heat Pump*	*Year Built*	*2007*
Hours of HVAC Operation (per week)	*50*	*Cost Recovery Method*	*Net Lease*

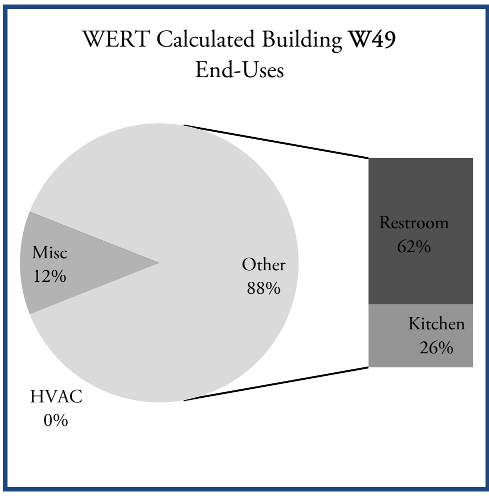
***W49** WATER MANAGEMENT*

This is a Greenstar New Zealand (GSNZ) certified building.

There are currently seven observed sub-meters in place. These are used as a cost-recovery mechanism, however the building is predominantly single tenanted.

The cost recovery method is through a Net Lease, i.e. resource consumption is charged via sub-meter readings for each tenancy.

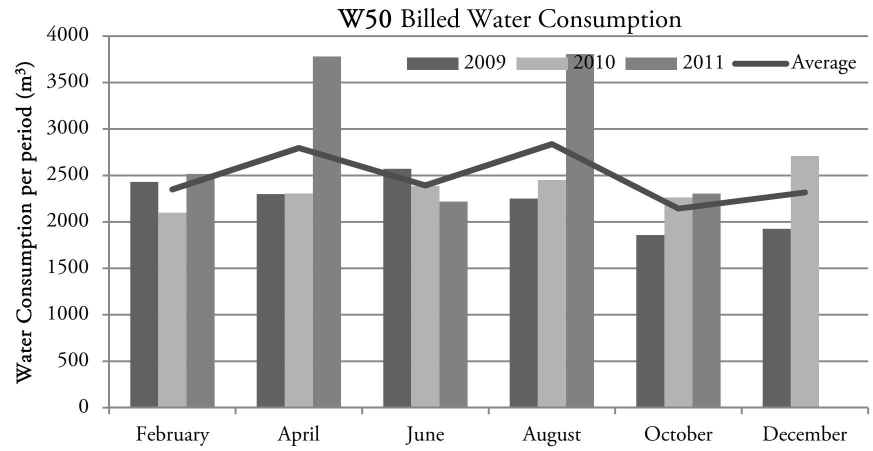
The building has a number of excellent water saving devices, yet still uses a large amount of miscellaneous water.

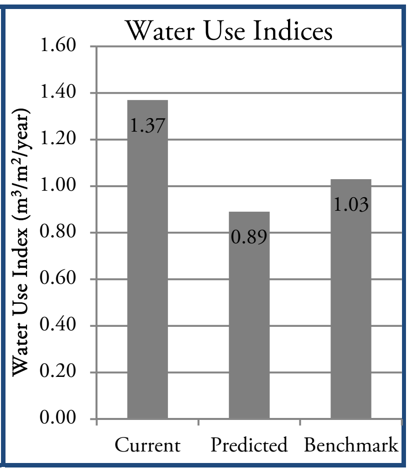


***W49** DOMESTIC END-USES DETAILS*

Toilets	*46*	*Dual Flush Cistern*
Urinals	*8*	*Waterless Wall-Pod*
Wash Hand Basins	*39*	*Manual / Infrared Sensor*
Showers	*7*	*Water Efficient*
Kitchen Sinks	*25*	
Dishwashers	*16*	*Domestic / Commercial*
Instant Hot Water	*5*	*Billi Tap*
Other	*17*	*Espresso / Other / Cleaners Tub*
TOTAL	***163 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***W50***





BUILDING ***W50*** *CHARACTERISTICS*

Net Lettable Area	*10,384 m²*	*Average Annual Water Consumption*	*14,828 m³*
Full Time Equivalent Occupants	*299*	*Number Of Storeys*	*14*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1972*
Hours of HVAC Operation (per week)	*58*	*Cost Recovery Method*	*Gross Lease*

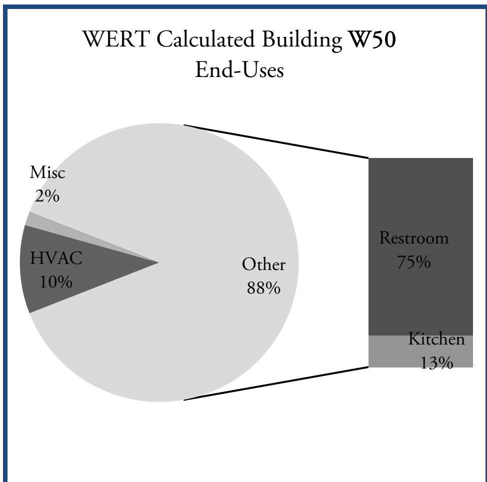
W50 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

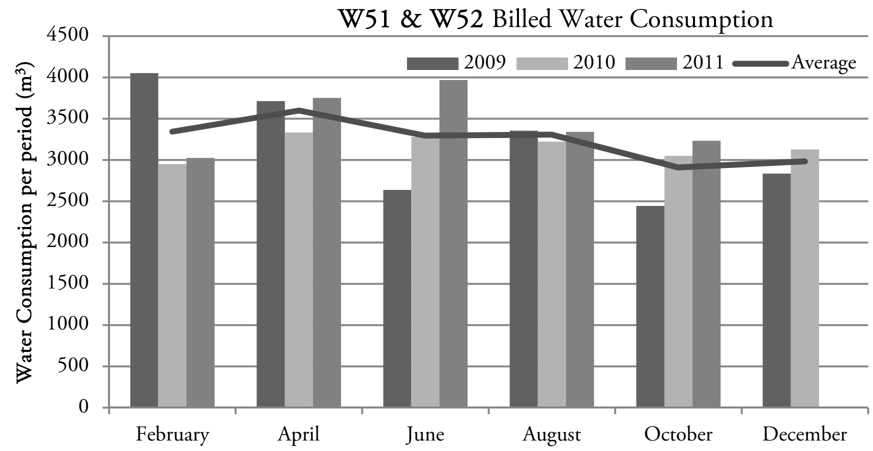
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

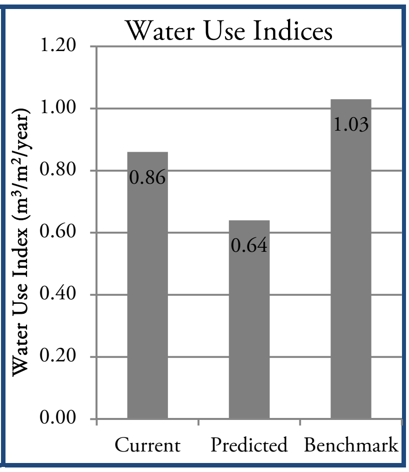


W50 *DOMESTIC END-USES DETAILS*

Toilets	*38*	*Single / Dual Flush Cistern*
Urinals	*14*	*Cyclic Flush Wall-Pod*
Wash Hand Basins	*35*	*Manual Faucet*
Showers	*7*	
Kitchen Sinks	*15*	
Dishwashers	*13*	*Domestic / Commercial*
Instant Hot Water	*12*	*Zip*
Other	*18*	*Cleaners Tub / Espresso / Other*
TOTAL	***152 x Domestic End-Uses***	

D2: *BUILDING ID CODE **W51 & W52***





*BUILDING **W51 & W52** CHARACTERISTICS*

Net Lettable Area	*22,158 m²*	*Average Annual Water Consumption*	*24,246 m³*
Full Time Equivalent Occupants	*1,213*	*Number Of Storeys*	*20*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1968*
Hours of HVAC Operation (per week)	*56*	*Cost Recovery Method*	*Gross Lease*

***W51 & W52** WATER MANAGEMENT*

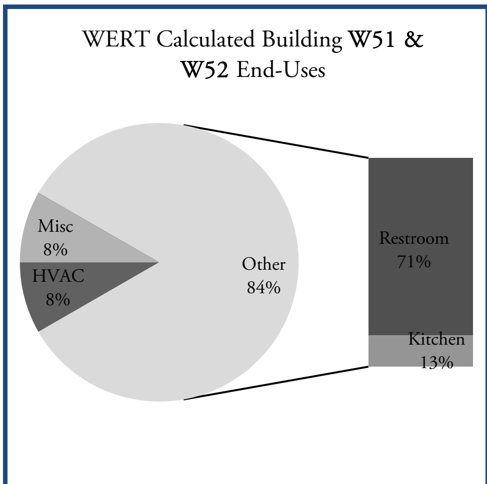
A fitness centre occupies a proportion in one of these facilities.

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

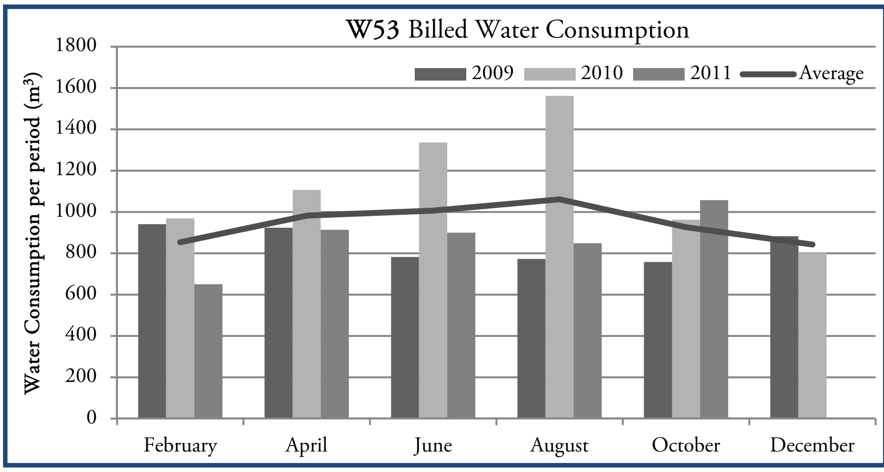
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

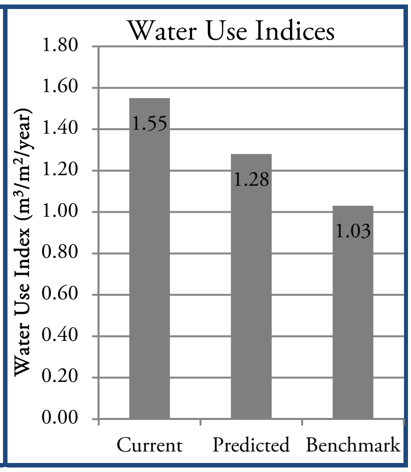


W51 & W52 DOMESTIC END-USES DETAILS

Toilets	*150*	*Combination*
Urinals	*48*	*Cyclic Flush Wall-Pod / Trough*
Wash Hand Basins	*153*	*Manual Faucet*
Showers	*29*	
Kitchen Sinks	*40*	
Dishwashers	*30*	*Domestic / Commercial*
Instant Hot Water	*34*	*Billi Tap / Zip*
Other	*42*	*Other / Cleaners Tub / Espresso*
TOTAL	***528 x Domestic End-Uses***	

D2: *BUILDING ID CODE W53*





BUILDING W53 CHARACTERISTICS

Net Lettable Area	*4,360 m^2*	*Average Annual Water Consumption*	*5,837 m^3*
Full Time Equivalent Occupants	*235*	*Number Of Storeys*	*13*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1989*
Hours of HVAC Operation (per week)	*42*	*Cost Recovery Method*	*Gross Lease*

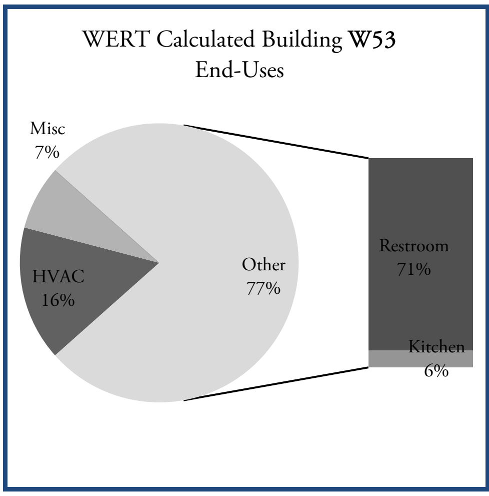
W53 WATER MANAGEMENT

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

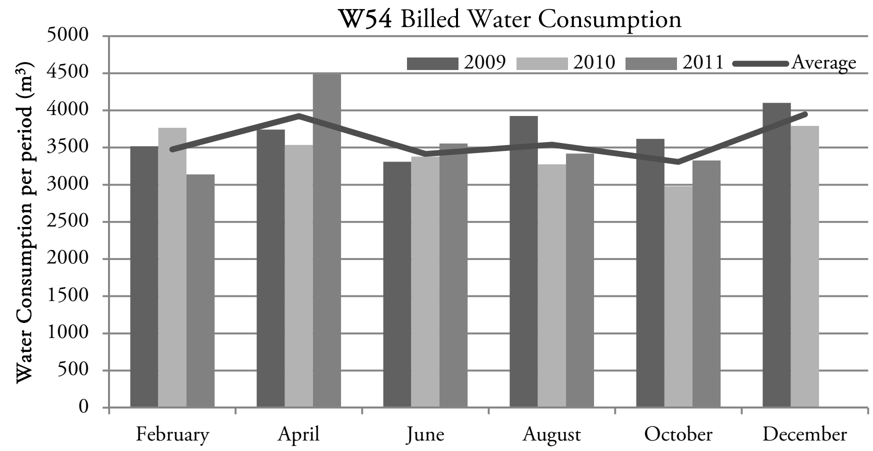
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

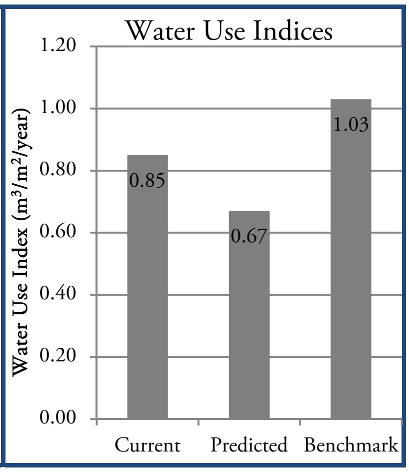


W53 DOMESTIC END-USES DETAILS

Toilets	*37*	*Single / Dual Flush Cistern*
Urinals	*10*	*Cyclic Flush Trough*
Wash Hand Basins	*42*	*Manual Faucet*
Showers	*4*	
Kitchen Sinks	*12*	
Dishwashers	*11*	*Domestic*
Instant Hot Water	*10*	*Zip*
Other	*12*	*Cleaners Tub / Other*
TOTAL	***138 x Domestic End-Uses***	

D2: *BUILDING ID CODE **W54***





*BUILDING **W54** CHARACTERISTICS*

Net Lettable Area	*24,387 m²*	*Average Annual Water Consumption*	*24,397 m³*
Full Time Equivalent Occupants	*1,200*	*Number Of Storeys*	*28*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1988*
Hours of HVAC Operation (per week)	*55*	*Cost Recovery Method*	*Gross Lease*

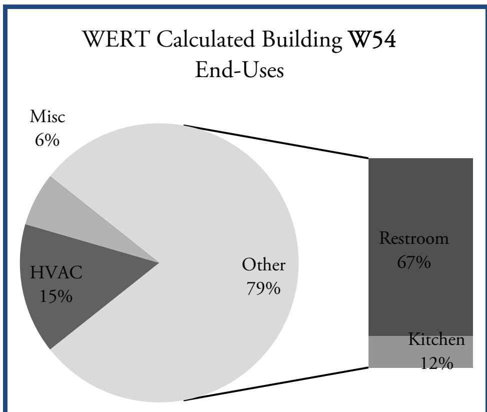
***W54** WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

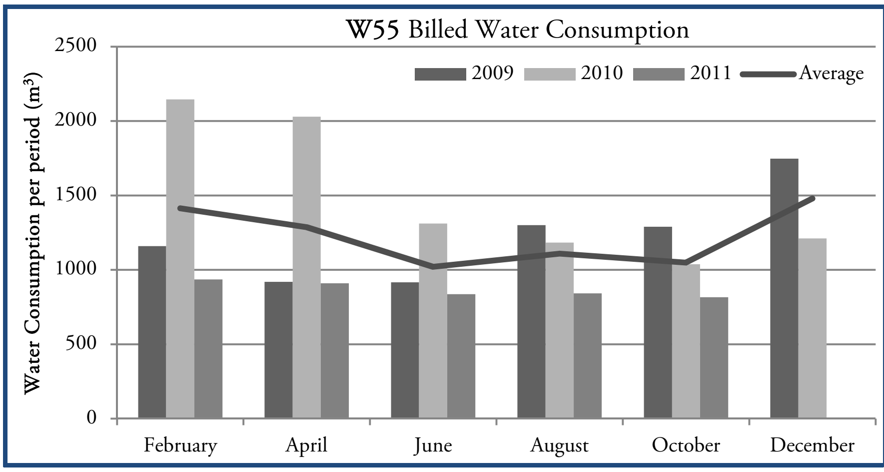
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

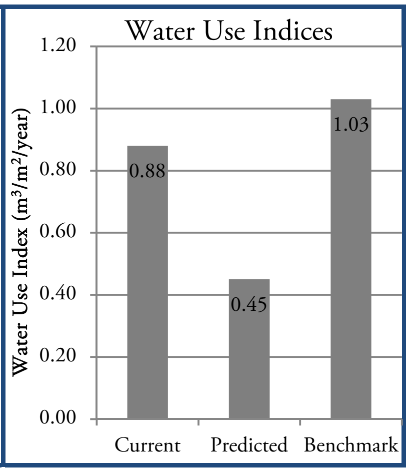


***W54** DOMESTIC END-USES DETAILS*

Toilets	*137*	*Single Flush Cistern*
Urinals	*51*	*Infrared Sensor Wall-Pod*
Wash Hand Basins	*112*	*Manual Faucet*
Showers	*32*	
Kitchen Sinks	*25*	
Dishwashers	*43*	*Domestic / Commercial*
Instant Hot Water	*21*	*Zip*
Other	*53*	*Other / Cleaners Tub / Espresso*
TOTAL	***474 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***W55***





BUILDING ***W55*** *CHARACTERISTICS*

Net Lettable Area	*10,109 m²*	*Average Annual Water Consumption*	*7,950 m³*
Full Time Equivalent Occupants	*519*	*Number Of Storeys*	*13*
Heat Rejection Method	*Air Condenser*	*Year Built*	*1976*
Hours of HVAC Operation (per week)	*52*	*Cost Recovery Method*	*Gross Lease*

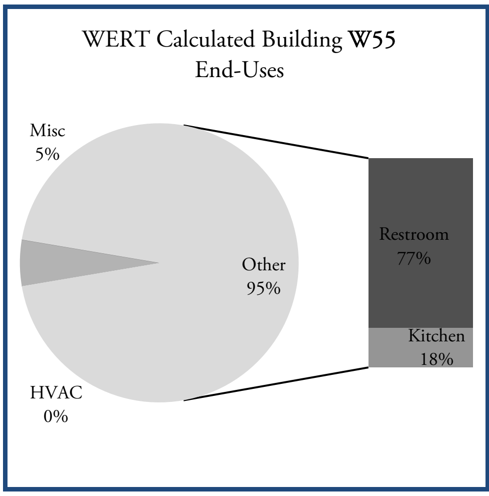
W55 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

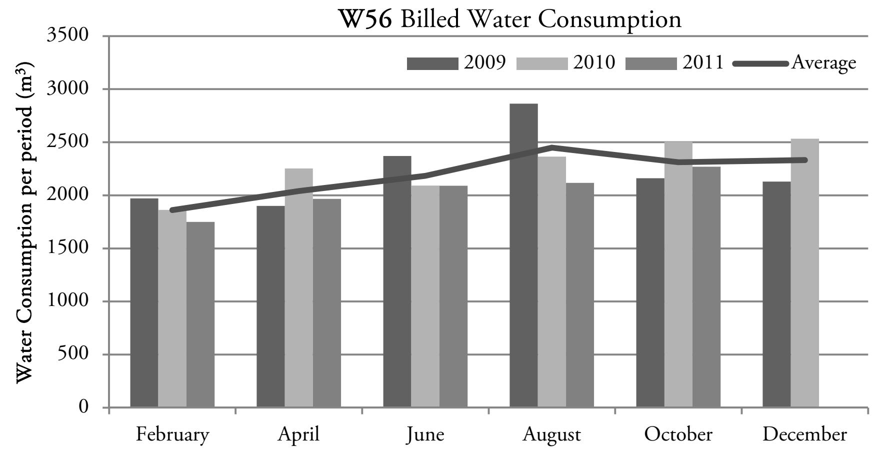
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

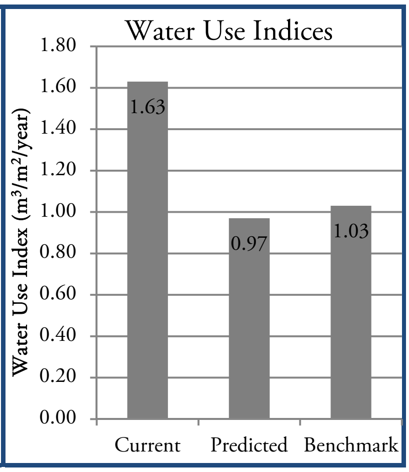


W55 *DOMESTIC END-USES DETAILS*

Toilets	*66*	*Dual / Single Flush Cistern*
Urinals	*24*	*Trap Urine Sensor Wall-Pod*
Wash Hand Basins	*58*	*Manual Faucet*
Showers	*6*	
Kitchen Sinks	*23*	
Dishwashers	*15*	*Domestic / Commercial*
Instant Hot Water	*15*	*Zip / Billi Tap*
Other	*28*	*Cleaners Tub / Other / Espresso*
TOTAL	***235 x Domestic End-Uses***	

D2: *BUILDING ID CODE **W56***





*BUILDING **W56** CHARACTERISTICS*

Net Lettable Area	*8,347 m²*	*Average Annual Water Consumption*	*10,843 m³*
Full Time Equivalent Occupants	*506*	*Number Of Storeys*	*13*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1978*
Hours of HVAC Operation (per week)	*50*	*Cost Recovery Method*	*Gross Lease*

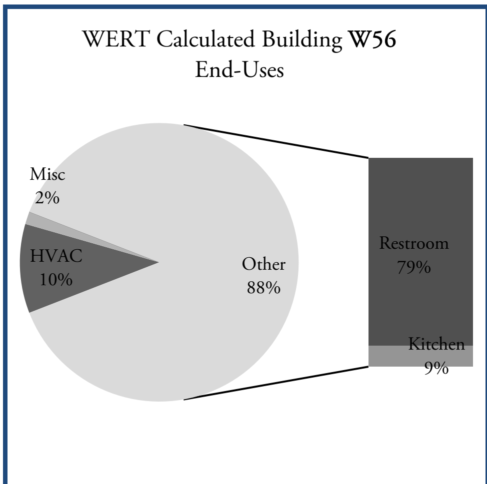
W56 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

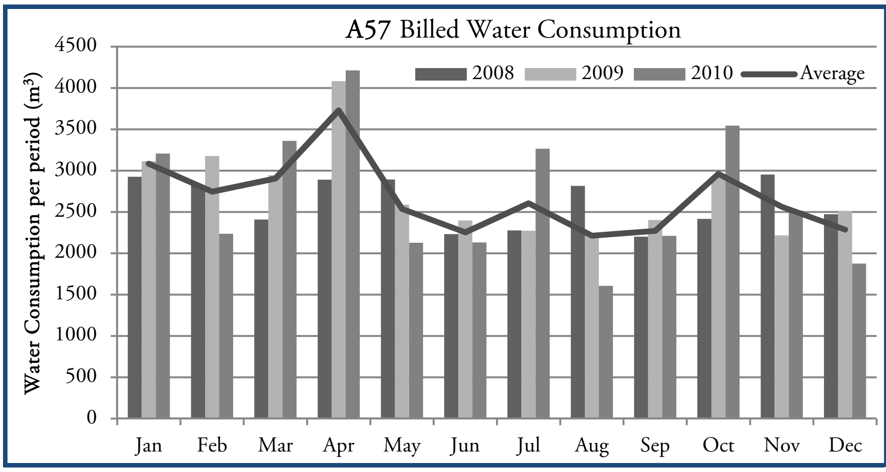
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

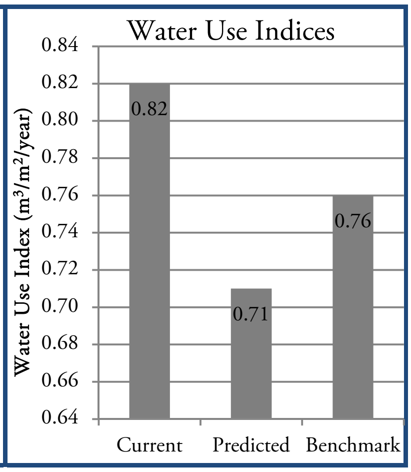


W56 *DOMESTIC END-USES DETAILS*

Toilets	*68*	*Single Flush Cistern*
Urinals	*14*	*Cyclic Trough / Waterless WP*
Wash Hand Basins	*51*	*Manual Faucet*
Showers	*10*	
Kitchen Sinks	*16*	
Dishwashers	*14*	*Domestic / Commercial*
Instant Hot Water	*13*	*Zip*
Other	*13*	*Cleaners Tub / Espresso*
TOTAL	*199 x Domestic End-Uses*	

D2: *BUILDING ID CODE **A57***





*BUILDING **A57** CHARACTERISTICS*

Net Lettable Area	*39,490 m^2*	*Average Annual Water Consumption*	*32,671 m^3*
Full Time Equivalent Occupants	*2,820*	*Number Of Storeys*	*40*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*2000*
Hours of HVAC Operation (per week)	*60*	*Cost Recovery Method*	*Gross Lease*

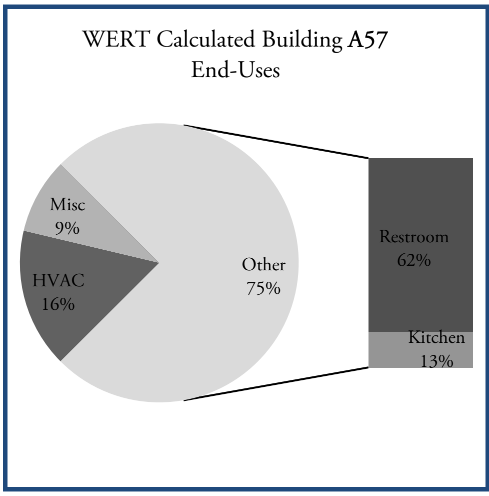
A57 WATER MANAGEMENT

There are currently two observed sub-meters in place, these are connected to the cooling tower make-up water feed.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

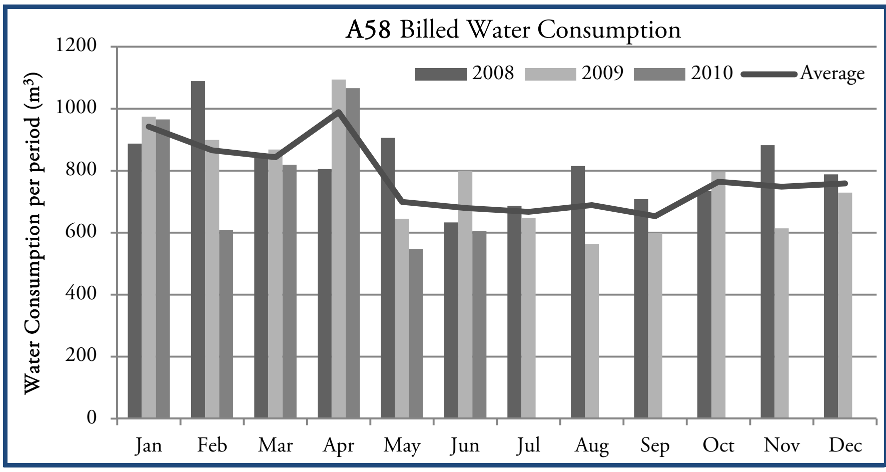
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

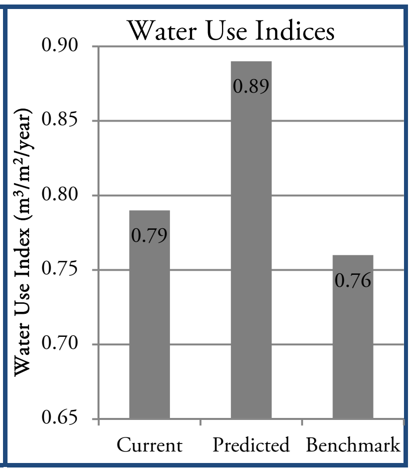


A57 DOMESTIC END-USES DETAILS

Toilets	*225*	*Dual Flush Cistern*
Urinals	*73*	*Waterless / Trap Sensor WP*
Wash Hand Basins	*215*	*Manual Faucet*
Showers	*11*	*Water Efficient*
Kitchen Sinks	*33*	
Dishwashers	*5*	*Domestic*
Instant Hot Water	*33*	*Billi Tap*
Other	*7*	*Espresso / Other*
TOTAL	***387 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***A58***





BUILDING ***A58*** *CHARACTERISTICS*

Net Lettable Area	*11,725 m²*	*Average Annual Water Consumption*	*9,227 m³*
Full Time Equivalent Occupants	*680*	*Number Of Storeys*	*20*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1984*
Hours of HVAC Operation (per week)	*60*	*Cost Recovery Method*	*Gross Lease*

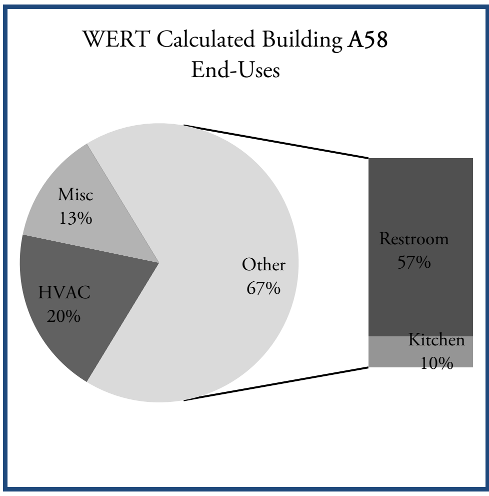
A58 *WATER MANAGEMENT*

There is currently one observed sub-meter in place, this is connected to the cooling tower make-up water feed.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

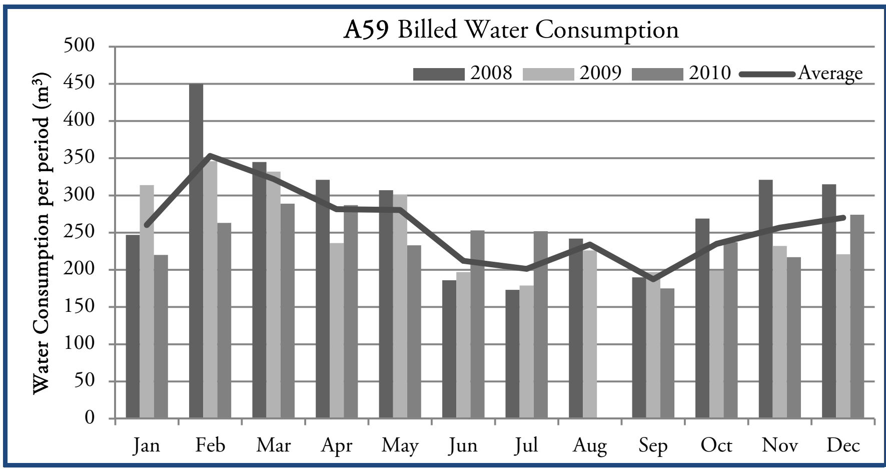
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

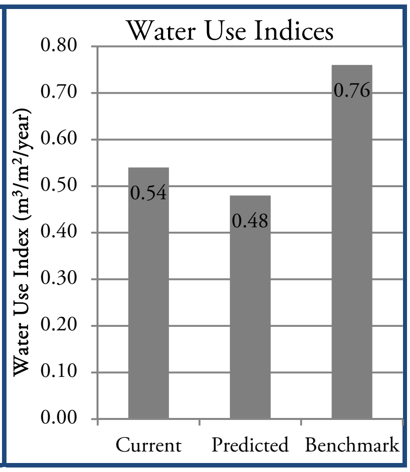


A58 *DOMESTIC END-USES DETAILS*

Toilets	*86*	*Single Flush Cistern*
Urinals	*17*	*Cyclic Flush Trough*
Wash Hand Basins	*68*	*Manual Faucet*
Showers	*-*	
Kitchen Sinks	*27*	
Dishwashers	*26*	*Domestic*
Instant Hot Water	*25*	*Zip*
Other	*1*	*Espresso*
TOTAL	***250 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***A59***





BUILDING ***A59*** *CHARACTERISTICS*

Net Lettable Area	*5,499 m^2*	*Average Annual Water Consumption*	*3,293 m^3*
Full Time Equivalent Occupants	*136*	*Number Of Storeys*	*9*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1980*
Hours of HVAC Operation (per week)	*52*	*Cost Recovery Method*	*Gross Lease*

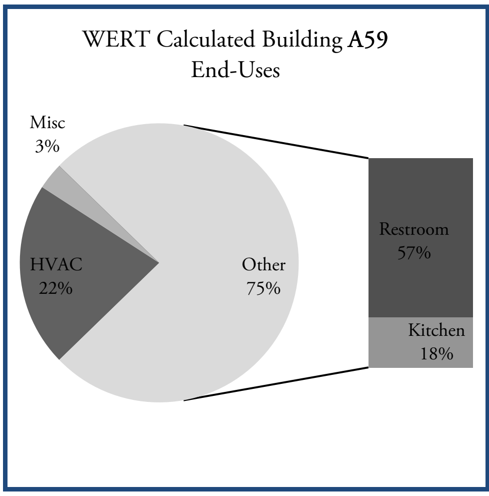
A59 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

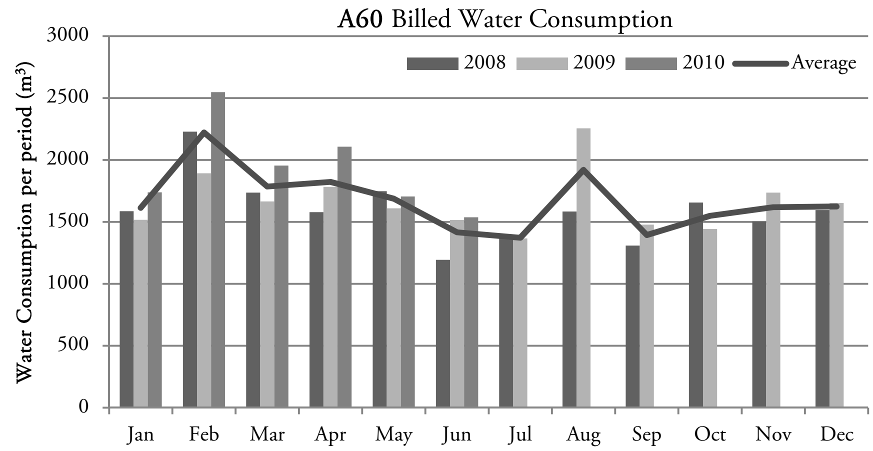
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

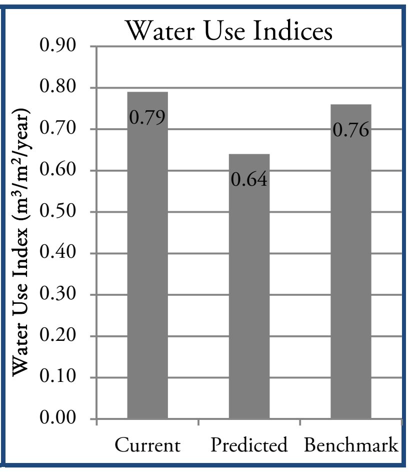


A59 *DOMESTIC END-USES DETAILS*

Toilets	*45*	*Dual Flush Cistern*
Urinals	*9*	*Waterless Wall-Pod*
Wash Hand Basins	*36*	*Self-Closing*
Showers	*-*	
Kitchen Sinks	*9*	
Dishwashers	*9*	*Domestic*
Instant Hot Water	*9*	
Other	*10*	*Cleaners Tub / Other*
TOTAL	***127 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***A60***





BUILDING ***A60*** *CHARACTERISTICS*

Net Lettable Area	*25,144 m²*	*Average Annual Water Consumption*	*19,212 m³*
Full Time Equivalent Occupants	*1,240*	*Number Of Storeys*	*25*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1980*
Hours of HVAC Operation (per week)	*60*	*Cost Recovery Method*	*Gross Lease*

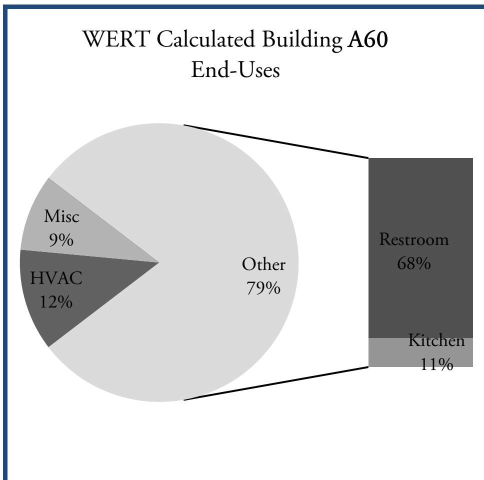
A60 *WATER MANAGEMENT*

There is currently one observed sub-meter in place, this is connected to the cooling tower make-up water feed.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

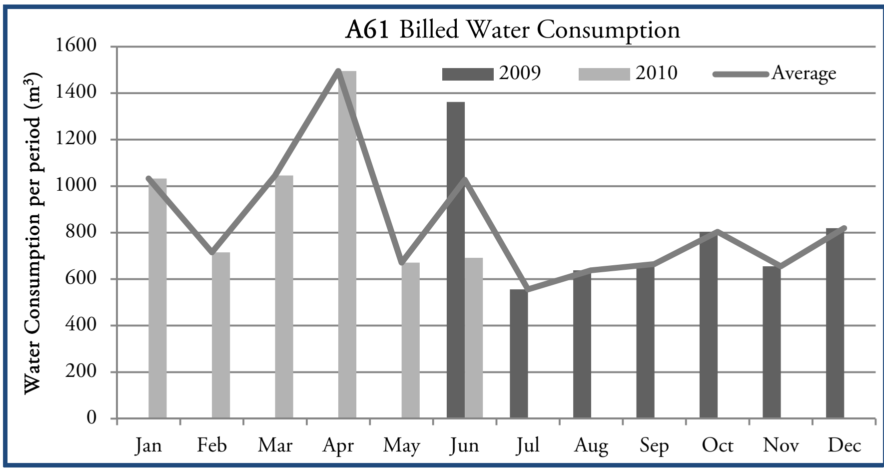
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

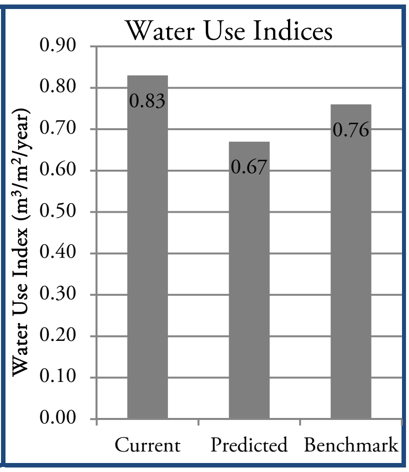


A60 *DOMESTIC END-USES DETAILS*

Toilets	*137*	*Single / Dual Flush Cistern*
Urinals	*42*	*Cyclic Flush Wall-Pod*
Wash Hand Basins	*156*	*Manual Faucet*
Showers	*29*	
Kitchen Sinks	*35*	
Dishwashers	*22*	*Domestic / Commercial*
Instant Hot Water	*21*	*Zip*
Other	*26*	*Cleaners Tub / Espresso*
TOTAL	***468 x Domestic End-Uses***	

D2: *BUILDING ID CODE **A61***





*BUILDING **A61** CHARACTERISTICS*

Net Lettable Area	*11,775 m²*	*Average Annual Water Consumption*	*9,788 m³*
Full Time Equivalent Occupants	*444*	*Number Of Storeys*	*18*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1987*
Hours of HVAC Operation (per week)	*56*	*Cost Recovery Method*	*Gross Lease*

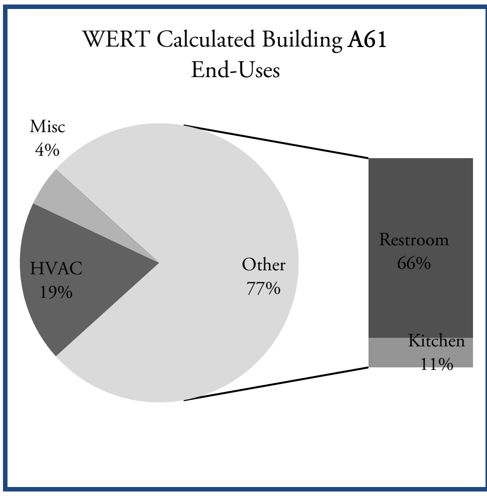
A61 WATER MANAGEMENT

There are currently three observed sub-meters in place, these are all connected to the cooling tower make-up water feed.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

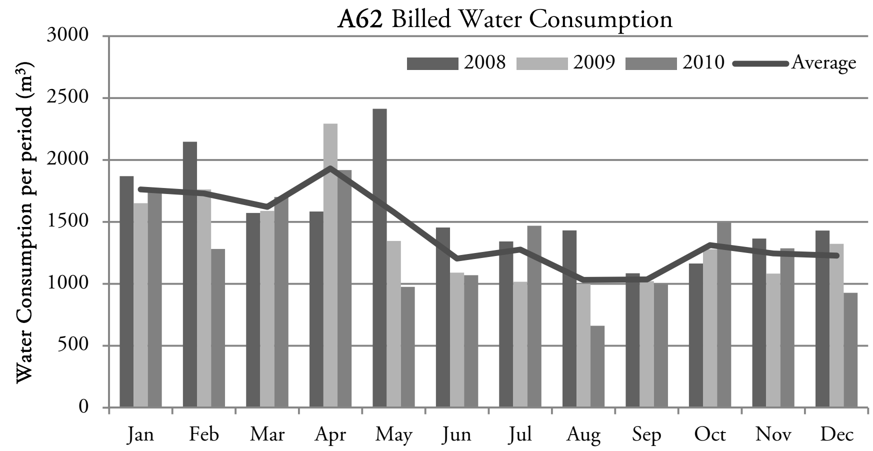
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

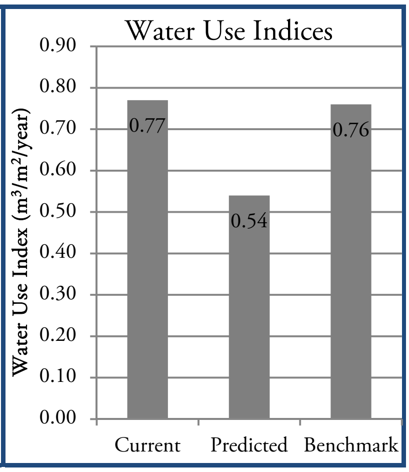


A61 DOMESTIC END-USES DETAILS

Toilets	*81*	*Combination*
Urinals	*18*	*Cyclic / Manual Wall-Pod*
Wash Hand Basins	*71*	*Manual Faucet*
Showers	*3*	
Kitchen Sinks	*26*	
Dishwashers	*23*	*Domestic / Commercial*
Instant Hot Water	*18*	*Zip / Billi Tap*
Other	*32*	*Cleaners Tub / Other / Espresso*
TOTAL	*272 x Domestic End-Uses*	

D2: *BUILDING ID CODE* ***A62***





BUILDING ***A62*** *CHARACTERISTICS*

Net Lettable Area	*20,276 m²*	*Average Annual Water Consumption*	*16,860 m³*
Full Time Equivalent Occupants	*800*	*Number Of Storeys*	*30*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*2005*
Hours of HVAC Operation (per week)	*58*	*Cost Recovery Method*	*Gross Lease*

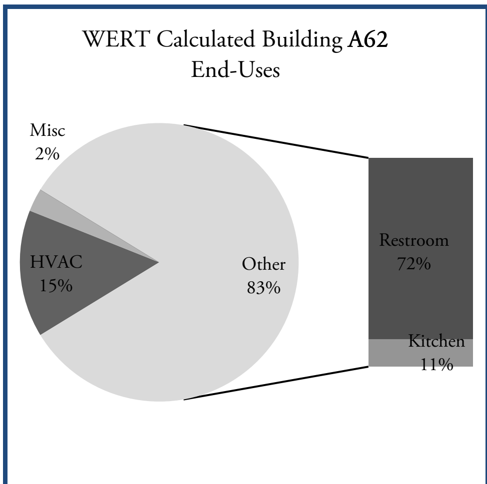
A62 WATER MANAGEMENT

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

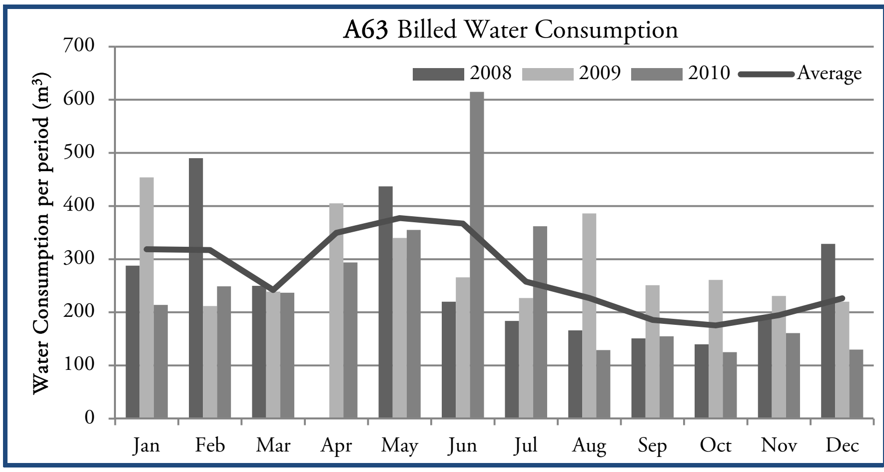
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

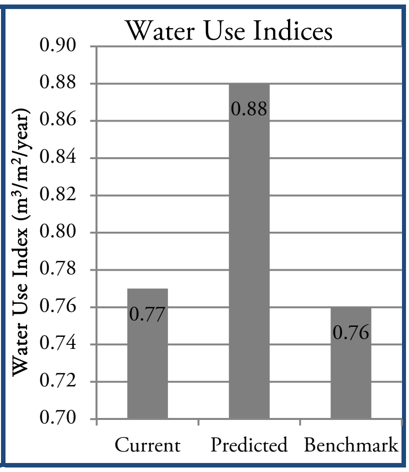


A62 DOMESTIC END-USES DETAILS

Toilets	*123*	*Single / Dual Flush Cistern*
Urinals	*30*	*Infrared Sensor Wall-Pod*
Wash Hand Basins	*95*	*Manual Faucet*
Showers	*24*	*Water Efficient*
Kitchen Sinks	*18*	
Dishwashers	*6*	*Commercial / Domestic*
Instant Hot Water	*9*	*Zip / Billi Tap*
Other	*24*	*Cleaners Tub / Espresso / Other*
TOTAL	***329 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***A63***





BUILDING ***A63*** *CHARACTERISTICS*

Net Lettable Area	*3,925 m²*	*Average Annual Water Consumption*	*4,512 m³*
Full Time Equivalent Occupants	*129*	*Number Of Storeys*	*12*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1984*
Hours of HVAC Operation (per week)	*50*	*Cost Recovery Method*	*Gross Lease*

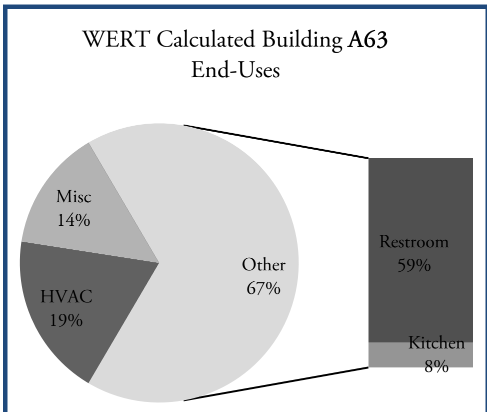
A63 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

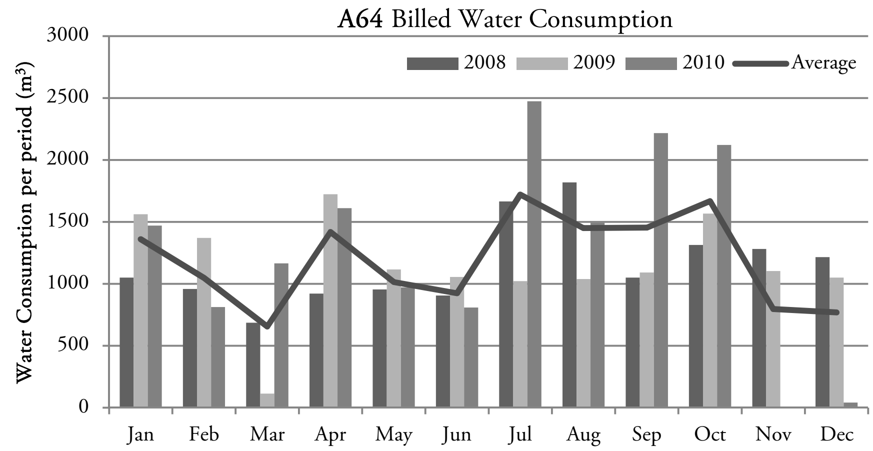
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

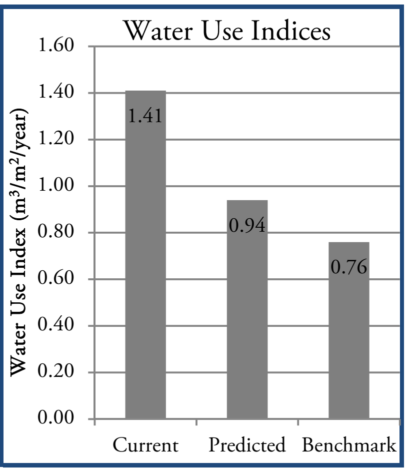


A63 *DOMESTIC END-USES DETAILS*

Toilets	*27*	*Single / Dual Flush Cistern*
Urinals	*9*	*Group Sensor Trough*
Wash Hand Basins	*18*	*Manual Faucet*
Showers	*3*	
Kitchen Sinks	*13*	
Dishwashers	*7*	*Domestic*
Instant Hot Water	*8*	*Zip*
Other	*18*	*Other / Cleaners Tub / Espresso*
TOTAL	***103 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***A64***





BUILDING ***A64*** *CHARACTERISTICS*

Net Lettable Area	*10,792 m^2*	*Average Annual Water Consumption*	*13,350 m^3*
Full Time Equivalent Occupants	*764*	*Number Of Storeys*	*11*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1957*
Hours of HVAC Operation (per week)	*50*	*Cost Recovery Method*	*Gross Lease*

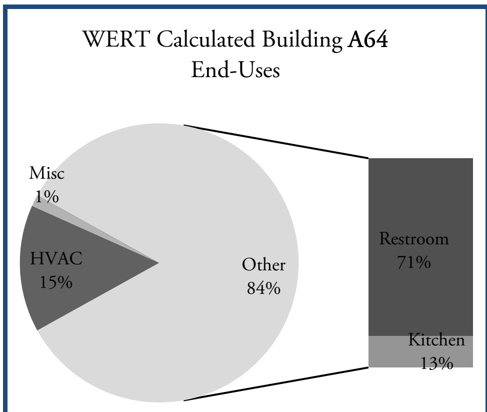
A64 *WATER MANAGEMENT*

There is currently one observed sub-meter in place, this is connected to the cooling tower make-up water feed.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

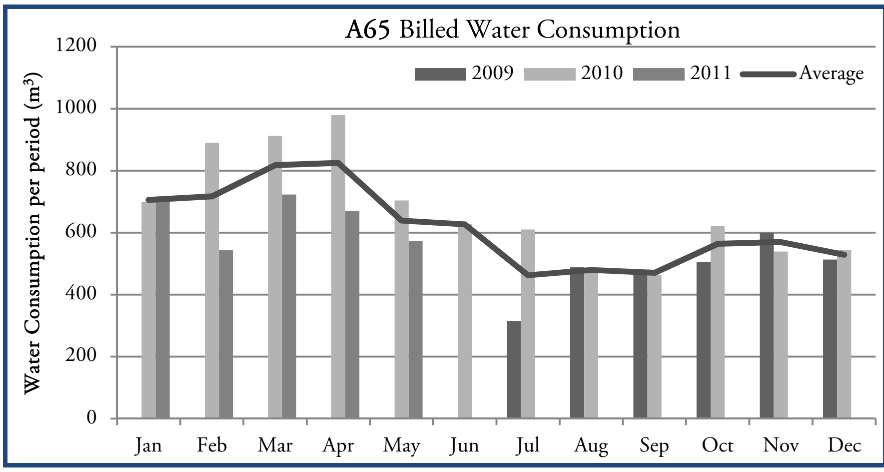
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

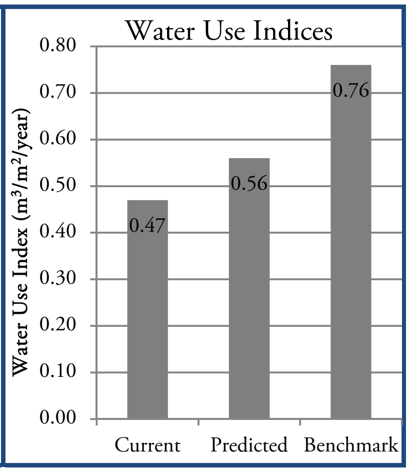


A64 *DOMESTIC END-USES DETAILS*

Toilets	*74*	*Combination*
Urinals	*23*	*Infrared Wall-Pod / Trough*
Wash Hand Basins	*82*	*Manual / Infrared Sensor*
Showers	*15*	
Kitchen Sinks	*20*	
Dishwashers	*17*	*Domestic*
Instant Hot Water	*20*	*Zip / Billi Tap*
Other	*28*	*Other / Cleaners Tub / Espresso*
TOTAL	***279 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***A65***





BUILDING ***A65*** *CHARACTERISTICS*

Net Lettable Area	*17,229 m²*	*Average Annual Water Consumption*	*8,059 m³*
Full Time Equivalent Occupants	*1,230*	*Number Of Storeys*	*8*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1989*
Hours of HVAC Operation (per week)	*65*	*Cost Recovery Method*	*Gross Lease*

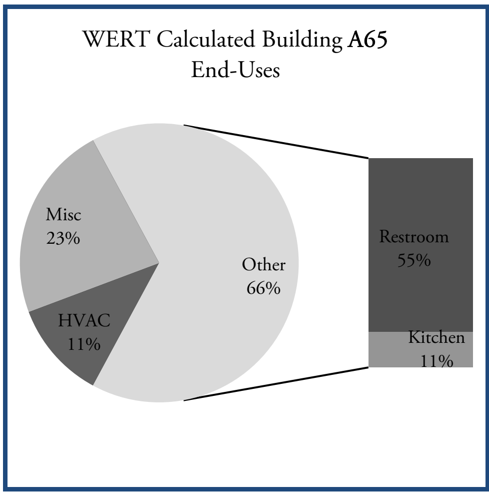
A65 *WATER MANAGEMENT*

There are currently six observed sub-meters in place. These range in monitoring irrigation, hose reels, and heating equipment.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There is a good level of water record keeping at this facility, and water management strategies are obvious on-site.

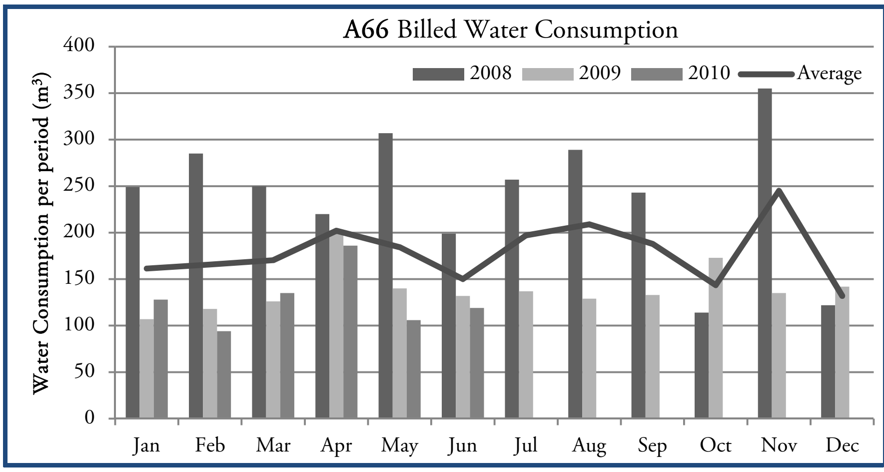
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

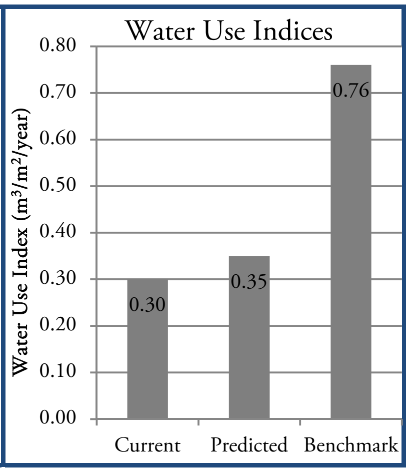


A65 *DOMESTIC END-USES DETAILS*

Toilets	*82*	*Dual / Single Flush Cistern*
Urinals	*33*	*Manual Flush Wall-Pod*
Wash Hand Basins	*78*	*Manual / Infrared Sensor*
Showers	*7*	
Kitchen Sinks	*24*	
Dishwashers	*8*	*Domestic / Commercial*
Instant Hot Water	*15*	*Zip / Billi Tap*
Other	*36*	*Cleaners Tub / Espresso / Other*
TOTAL	***283 x Domestic End-Uses***	

D2: *BUILDING ID CODE **A66***





*BUILDING **A66** CHARACTERISTICS*

Net Lettable Area	*7,505 m²*	*Average Annual Water Consumption*	*2,281 m³*
Full Time Equivalent Occupants	*375*	*Number Of Storeys*	*17*
Heat Rejection Method	*Air Condenser*	*Year Built*	*1974*
Hours of HVAC Operation (per week)	*56*	*Cost Recovery Method*	*Gross Lease*

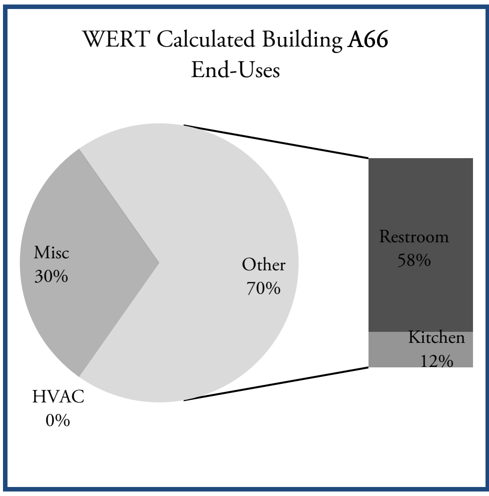
***A66** WATER MANAGEMENT*

There is currently one observed sub-meter in place. This meter is not read.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

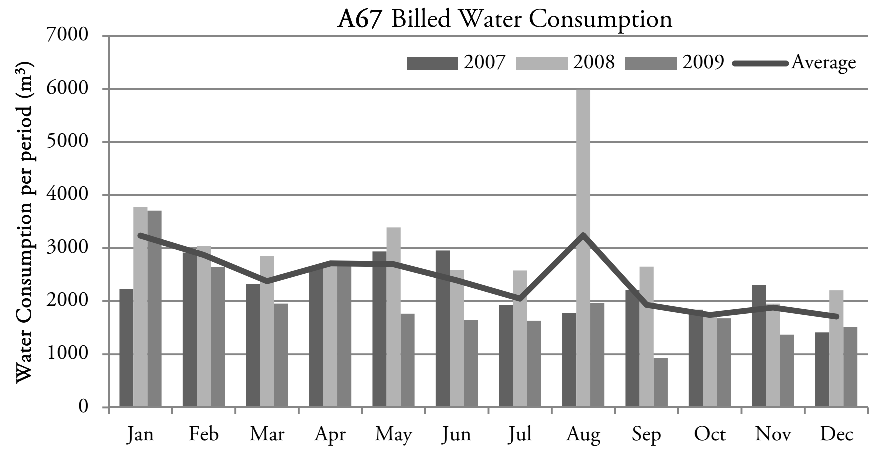
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

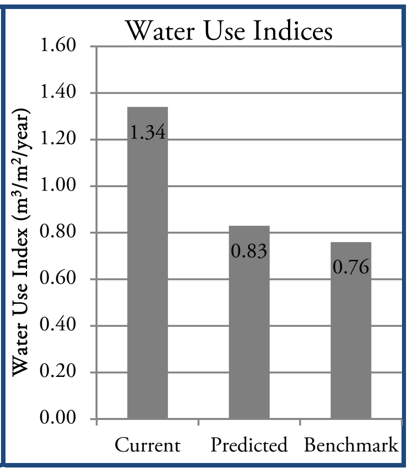


__A66__ DOMESTIC END-USES DETAILS

Toilets	*54*	*Single / Dual Flush Cistern*
Urinals	*13*	*Cyclic Flush Wall-Pod*
Wash Hand Basins	*30*	*Manual Faucet*
Showers	*-*	
Kitchen Sinks	*18*	
Dishwashers	*4*	*Domestic*
Instant Hot Water	*10*	*Billi Tap / Zip*
Other	*30*	*Cleaners Tub / Other / Espresso*
TOTAL	***159 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***A67***





*BUILDING **A67** CHARACTERISTICS*

Net Lettable Area	*17,649 m²*	*Average Annual Water Consumption*	*23,569 m³*
Full Time Equivalent Occupants	*866*	*Number Of Storeys*	*29*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1988*
Hours of HVAC Operation (per week)	*56*	*Cost Recovery Method*	*Gross Lease*

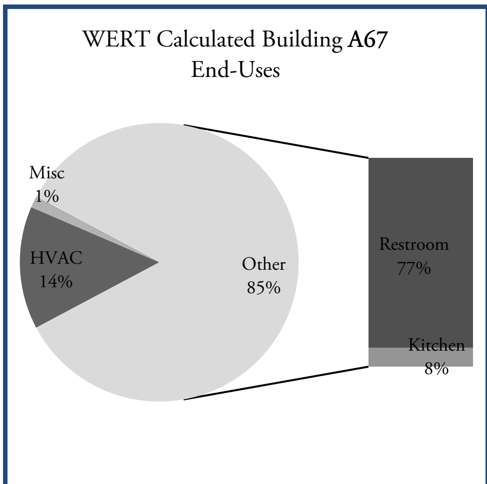
A67 *WATER MANAGEMENT*

There are currently four observed sub-meters in place. These monitor the indoor swimming pool, and cooling tower make-up water feed.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

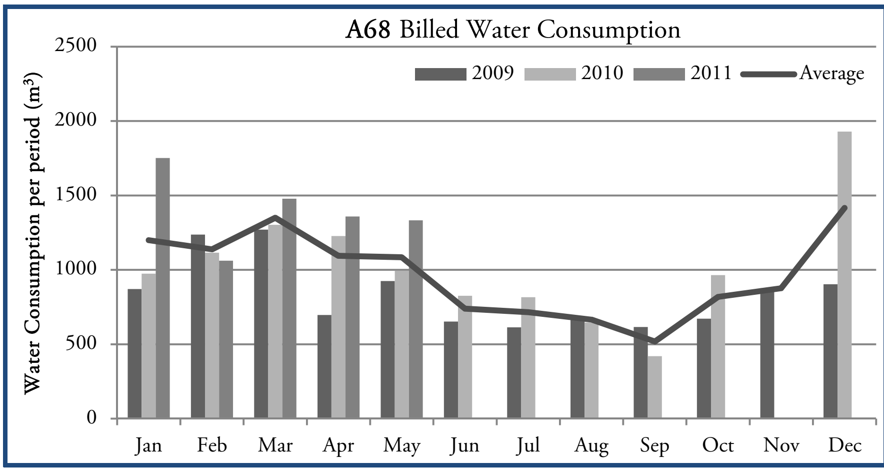
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

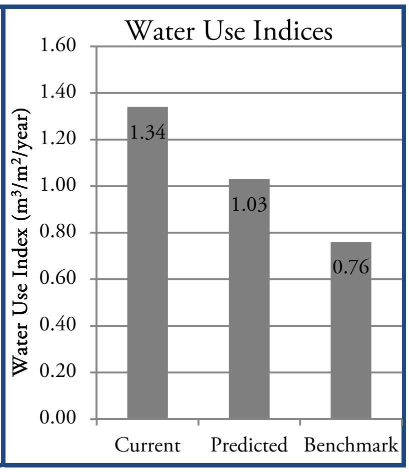


A67 DOMESTIC END-USES DETAILS

Toilets	*131*	*Single / Dual Flush Cistern*
Urinals	*41*	*Infrared Sensor Wall-Pod*
Wash Hand Basins	*150*	*Manual Faucet*
Showers	*8*	
Kitchen Sinks	*23*	
Dishwashers	*1*	*Domestic*
Instant Hot Water	*21*	*Zip / Billi Tap*
Other	*28*	*Cleaners Tub / Other*
TOTAL	***403 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***A68***





BUILDING ***A68*** *CHARACTERISTICS*

Net Lettable Area	*8,396 m²*	*Average Annual Water Consumption*	*10,617 m³*
Full Time Equivalent Occupants	*563*	*Number Of Storeys*	*23*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1966*
Hours of HVAC Operation (per week)	*50*	*Cost Recovery Method*	*Gross Lease*

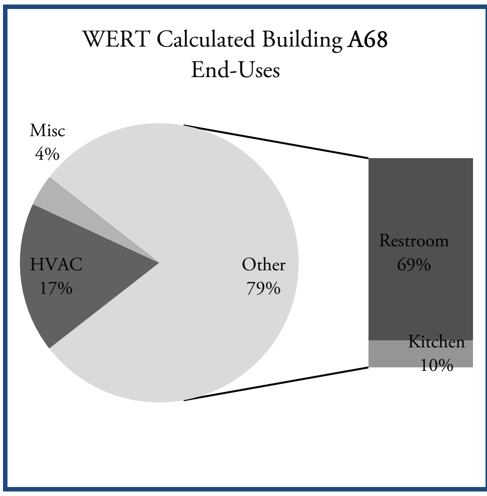
A68 *WATER MANAGEMENT*

There are currently two observed sub-meters in place. These are connected to the cooling tower make-up water feed.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

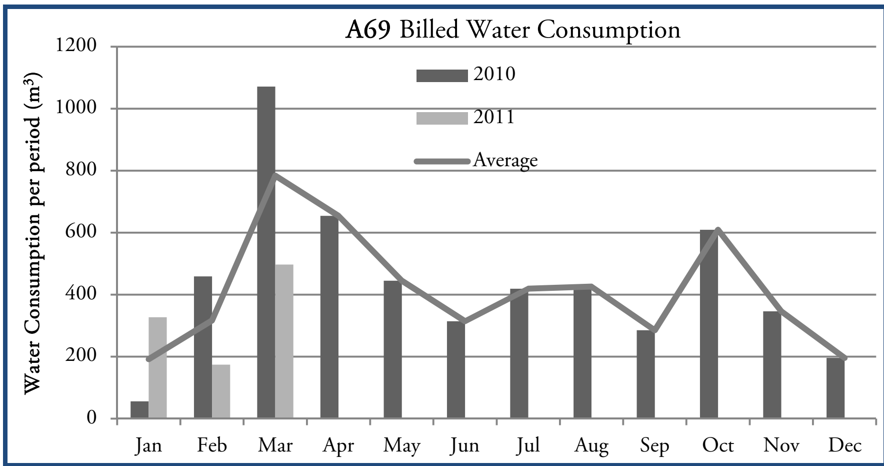
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

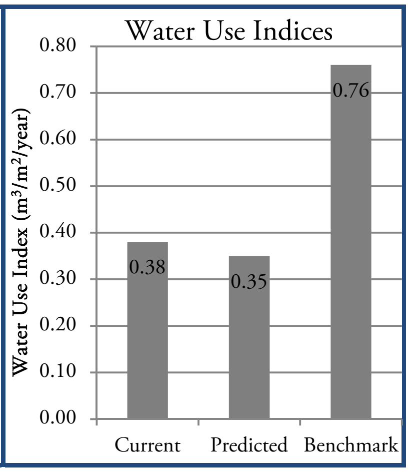


A68 *DOMESTIC END-USES DETAILS*

Toilets	*59*	*Single / Dual Flush Cistern*
Urinals	*15*	*Infrared Sensor WP / Trough*
Wash Hand Basins	*45*	*Manual Faucet*
Showers	*10*	*Water Efficient*
Kitchen Sinks	*26*	
Dishwashers	*22*	*Domestic / Commercial*
Instant Hot Water	*24*	*Zip / Billi Tap*
Other	*30*	*Other / Espresso / Cleaners Tub*
TOTAL	***231 x Domestic End-Uses***	

D2: *BUILDING ID CODE **A69***





*BUILDING **A69** CHARACTERISTICS*

Net Lettable Area	*13,935 m²*	*Average Annual Water Consumption*	*5,280 m³*
Full Time Equivalent Occupants	*500*	*Number Of Storeys*	*19*
Heat Rejection Method	*Air Condenser*	*Year Built*	*1987*
Hours of HVAC Operation (per week)	*52*	*Cost Recovery Method*	*Gross Lease*

A69 WATER MANAGEMENT

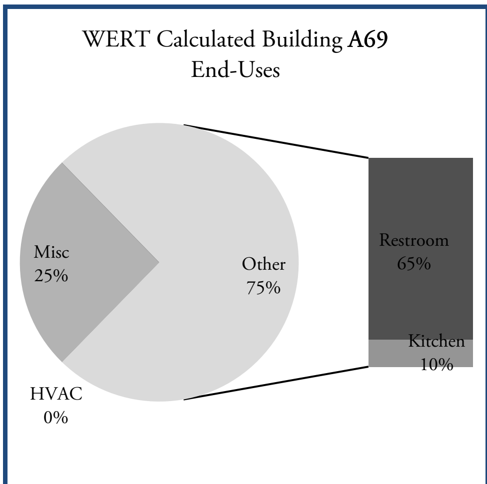
This building is currently operating as an office based institutional facility.

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

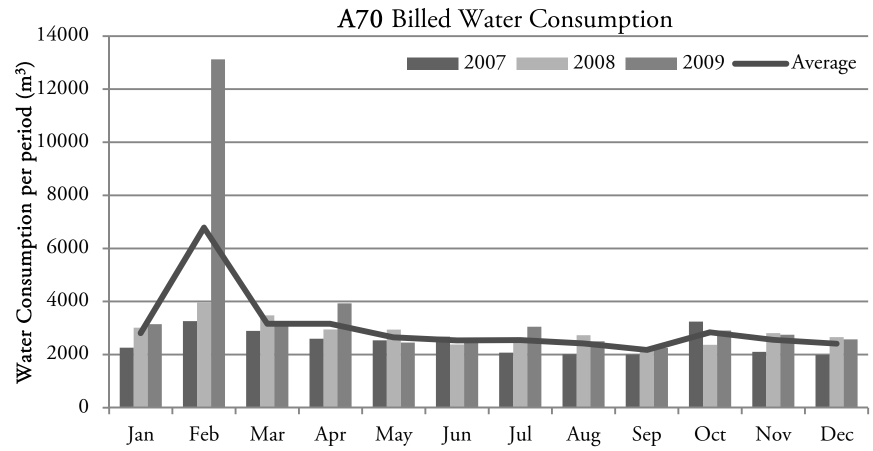
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

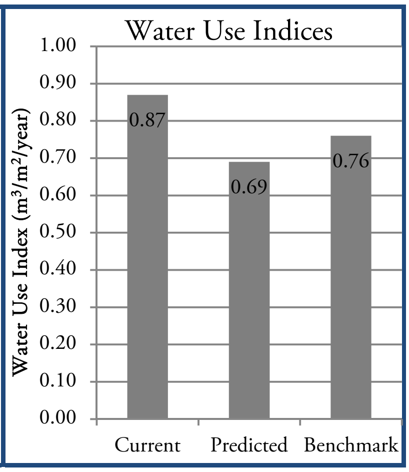


A69 DOMESTIC END-USES DETAILS

Toilets	*92*	*Combination*
Urinals	*34*	*Cyclic Flush Wall-Pod*
Wash Hand Basins	*83*	*Manual Faucet*
Showers	*2*	
Kitchen Sinks	*4*	
Dishwashers	*4*	*Domestic*
Instant Hot Water	*3*	*Zip*
Other	*26*	*Cleaners Tub / Other / Espresso*
TOTAL	***248 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***A70***





BUILDING ***A70*** *CHARACTERISTICS*

Net Lettable Area	*31,323 m²*	*Average Annual Water Consumption*	*34,072 m³*
Full Time Equivalent Occupants	*1,725*	*Number Of Storeys*	*32*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*2002*
Hours of HVAC Operation (per week)	*60*	*Cost Recovery Method*	*Gross Lease*

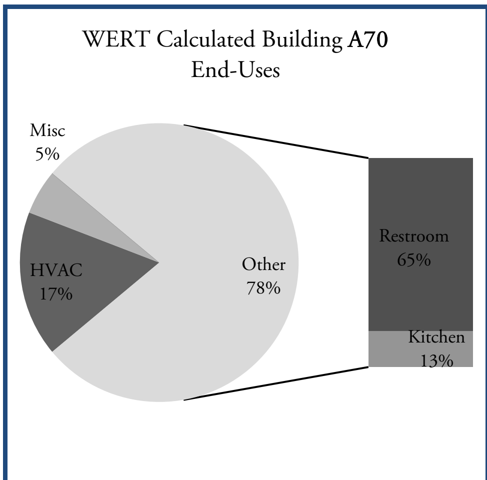
A70 *WATER MANAGEMENT*

There are currently five observed sub-meters in place. These range in monitoring irrigation, hose reels, and cooling tower make-up water feed. However, are left unread frequently.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

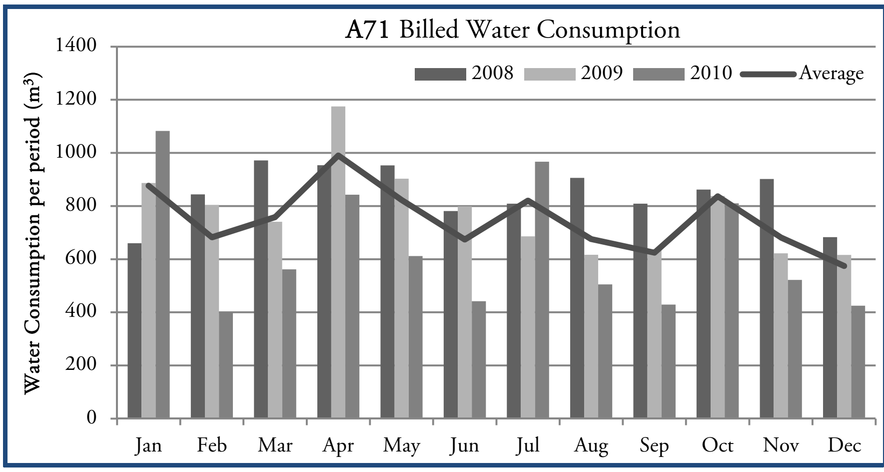
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

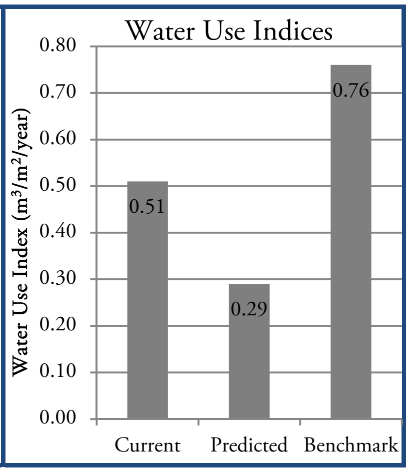


A70 *DOMESTIC END-USES DETAILS*

Toilets	*157*	*Single Flush Cistern / Valve*
Urinals	*44*	*Infrared Sensor Wall-Pod*
Wash Hand Basins	*140*	*Manual Faucet*
Showers	*22*	
Kitchen Sinks	*50*	
Dishwashers	*47*	*Domestic / Commercial*
Instant Hot Water	*44*	*Zip / Billi Tap*
Other	*34*	*Cleaners Tub / Other / Espresso*
TOTAL	***538 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***A71***





BUILDING ***A71*** *CHARACTERISTICS*

Net Lettable Area	*14,766 m²*	*Average Annual Water Consumption*	*8,504 m³*
Full Time Equivalent Occupants	*501*	*Number Of Storeys*	*15*
Heat Rejection Method	*Air Condenser*	*Year Built*	*1975*
Hours of HVAC Operation (per week)	*58*	*Cost Recovery Method*	*Gross Lease*

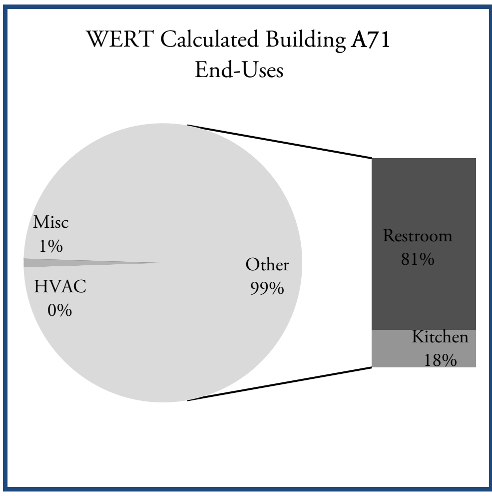
A71 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

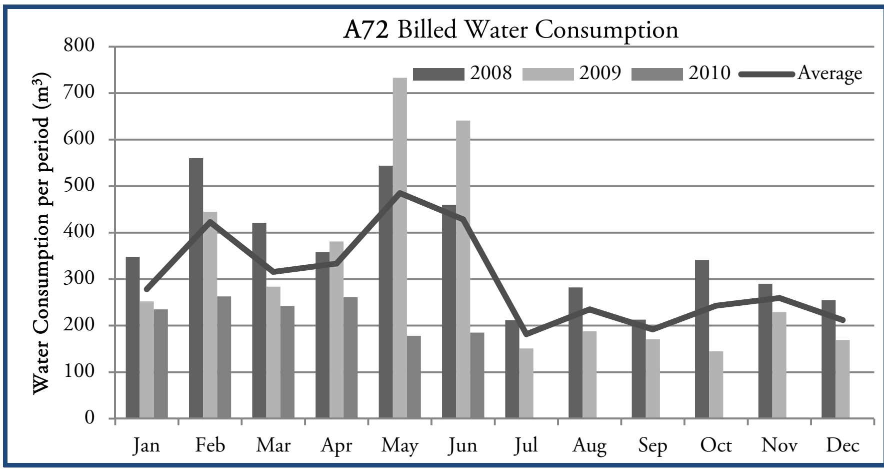
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

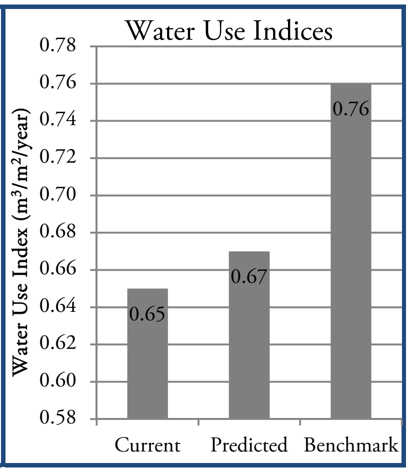


A71 *DOMESTIC END-USES DETAILS*

Toilets	*71*	*Single / Dual Flush Cistern*
Urinals	*25*	*Infrared / Waterless Wall-Pod*
Wash Hand Basins	*72*	*Manual Faucet*
Showers	*-*	
Kitchen Sinks	*10*	
Dishwashers	*12*	*Domestic / Commercial*
Instant Hot Water	*9*	*Zip*
Other	*13*	*Cleaners Tub / Espresso*
TOTAL	***212 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***A72***





BUILDING ***A72*** *CHARACTERISTICS*

Net Lettable Area	*5,797 m²*	*Average Annual Water Consumption*	*4,037 m³*
Full Time Equivalent Occupants	*335*	*Number Of Storeys*	*15*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1975*
Hours of HVAC Operation (per week)	*56*	*Cost Recovery Method*	*Gross Lease*

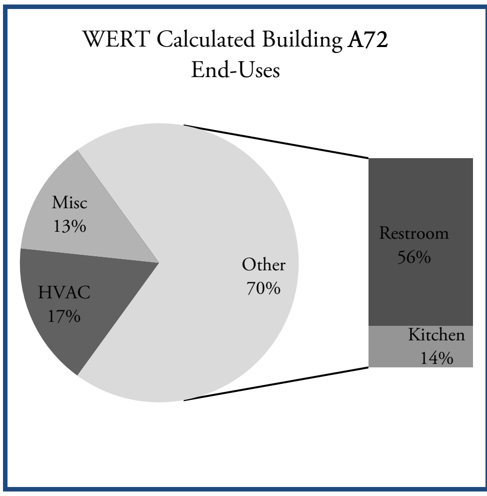
A72 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

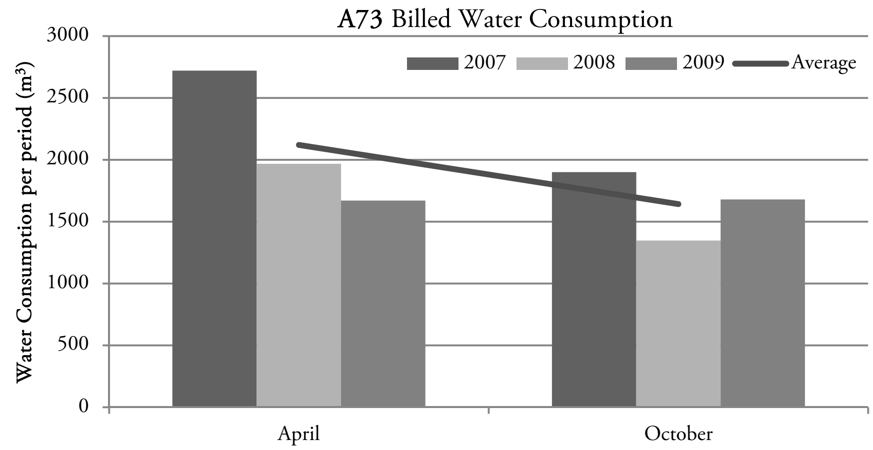
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

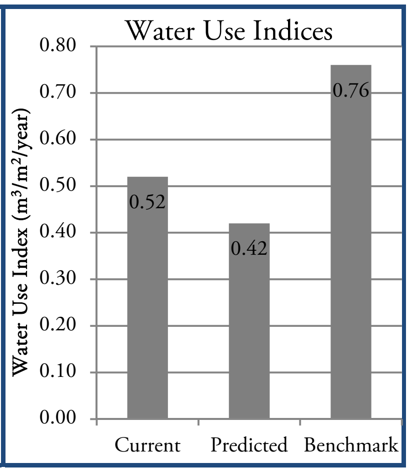


A72 *DOMESTIC END-USES DETAILS*

Toilets	*44*	*Single / Dual Flush Cistern*
Urinals	*14*	*Cyclic Flush / Infrared WP*
Wash Hand Basins	*59*	*Manual Faucet*
Showers	*2*	
Kitchen Sinks	*23*	
Dishwashers	*19*	*Domestic*
Instant Hot Water	*21*	*Zip*
Other	*17*	*Cleaners Tub / Espresso*
TOTAL	***199 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***A73***





BUILDING ***A73*** *CHARACTERISTICS*

Net Lettable Area	*6,411 m²*	*Average Annual Water Consumption*	*3,762 m³*
Full Time Equivalent Occupants	*299*	*Number Of Storeys*	*9*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1988*
Hours of HVAC Operation (per week)	*48*	*Cost Recovery Method*	*Gross Lease*

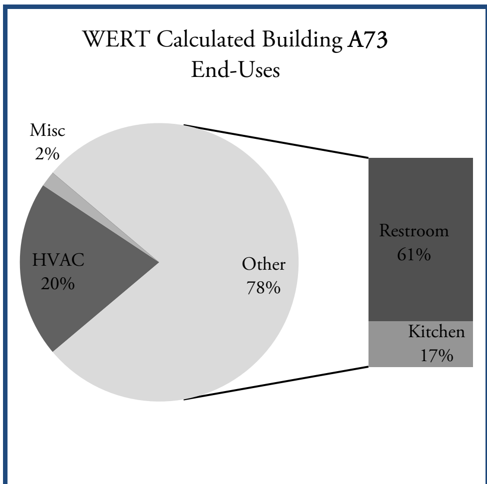
A73 *WATER MANAGEMENT*

There is currently one observed sub-meter in place. This is connected to the cooling tower make-up water feed. However, is left unread often.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

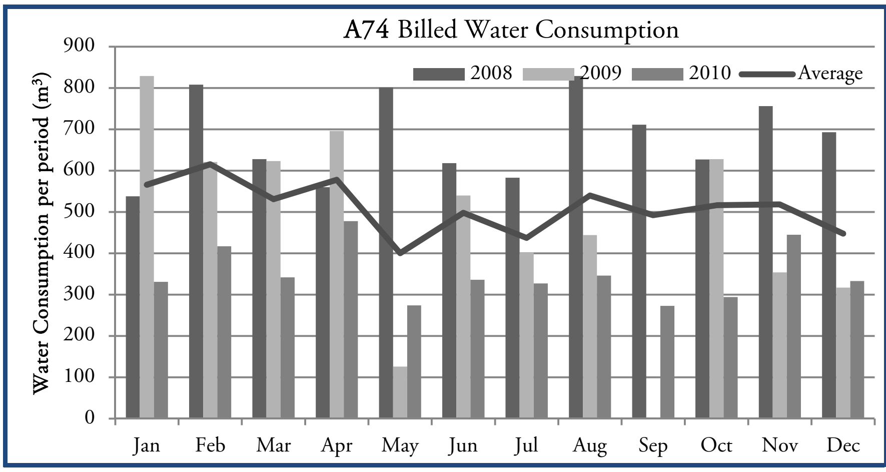
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

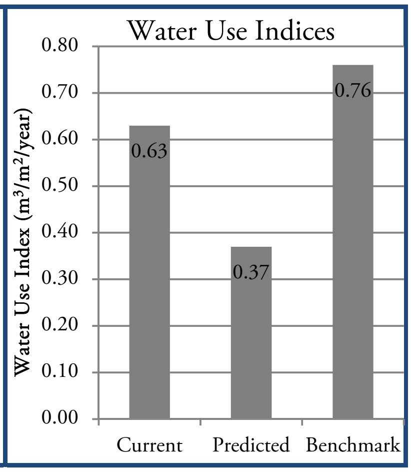


A73 *DOMESTIC END-USES DETAILS*

Toilets	*30*	*Single / Dual Flush Cistern*
Urinals	*11*	*Waterless Wall-Pod*
Wash Hand Basins	*26*	*Self-Closing*
Showers	*1*	
Kitchen Sinks	*8*	
Dishwashers	*8*	*Domestic / Commercial*
Instant Hot Water	*5*	*Billi Tap*
Other	*12*	*Cleaners Tub / Espresso / Other*
TOTAL	***101 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***A74***





BUILDING ***A74*** *CHARACTERISTICS*

Net Lettable Area	*6,711 m²*	*Average Annual Water Consumption*	*6,030 m³*
Full Time Equivalent Occupants	*305*	*Number Of Storeys*	*14*
Heat Rejection Method	*Air Condenser*	*Year Built*	*1981*
Hours of HVAC Operation (per week)	*54*	*Cost Recovery Method*	*Gross Lease*

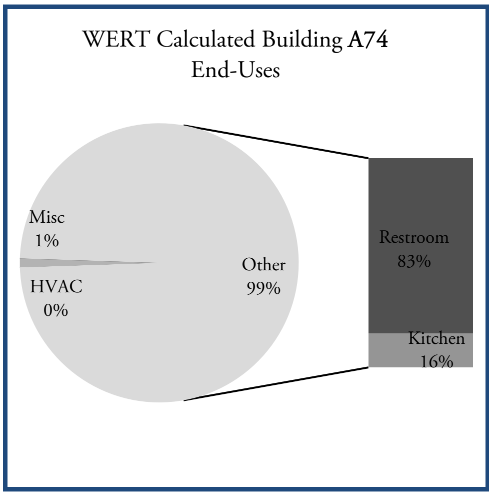
A74 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

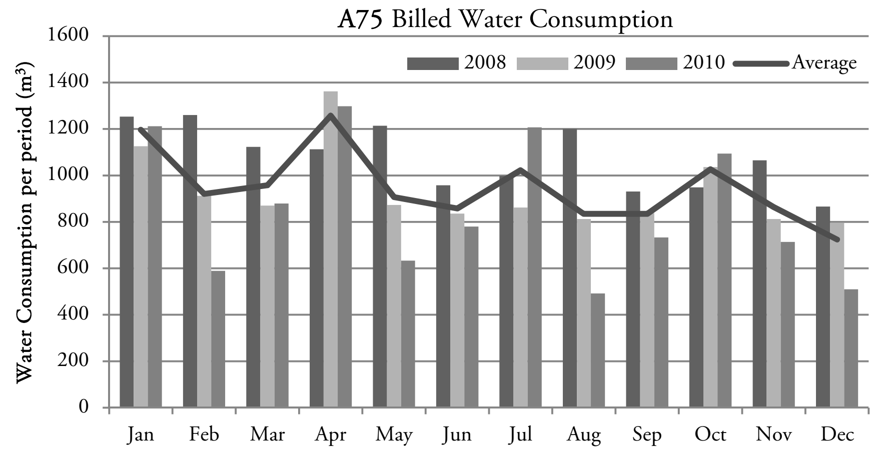
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

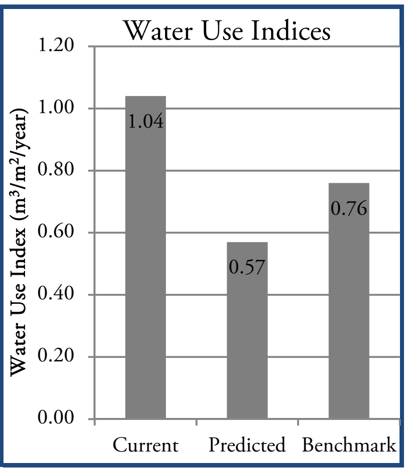


A74 *DOMESTIC END-USES DETAILS*

Toilets	*49*	*Single / Dual Flush Cistern*
Urinals	*13*	*Infrared Sensor Wall-Pod*
Wash Hand Basins	*42*	*Manual Faucet*
Showers	*5*	*Water Efficient*
Kitchen Sinks	*13*	
Dishwashers	*12*	*Domestic*
Instant Hot Water	*12*	*Zip / Billi Tap*
Other	*23*	*Other / Cleaners Tub / Espresso*
TOTAL	***171 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***A75***





BUILDING ***A75*** *CHARACTERISTICS*

Net Lettable Area	*9,777 m^2*	*Average Annual Water Consumption*	*12,336 m^3*
Full Time Equivalent Occupants	*536*	*Number Of Storeys*	*16*
Heat Rejection Method	*Air Condenser*	*Year Built*	*1989*
Hours of HVAC Operation (per week)	*56*	*Cost Recovery Method*	*Gross Lease*

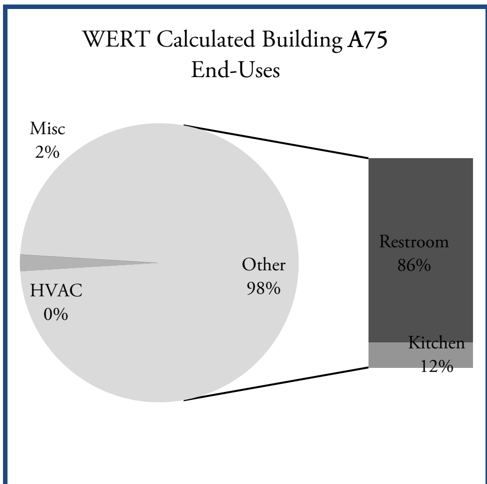
A75 *WATER MANAGEMENT*

There are currently three observed sub-meters in place. These are for the ground floor tenants, which are then charged based on those readings.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no other water efficiency or water management strategies or targets in place.

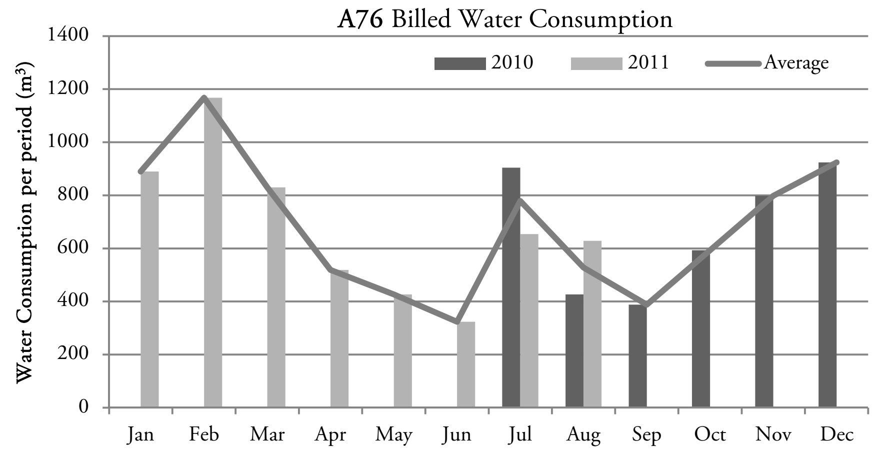
There are no incentives for end-users to reduce their consumption. There is no method of informing end-users of their consumption, other than those ground floor tenants.

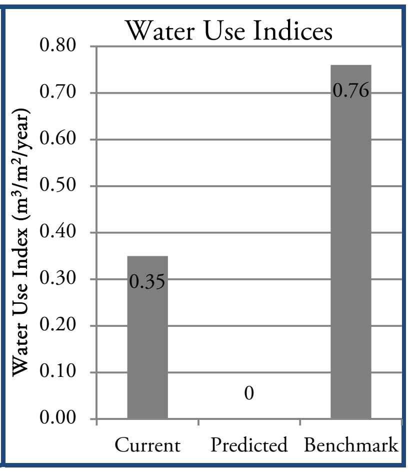


A75 *DOMESTIC END-USES DETAILS*

Toilets	*62*	*Single / Dual Flush Cistern*
Urinals	*15*	*Cyclic Flush Wall-Pod*
Wash Hand Basins	*36*	*Manual Faucet*
Showers	*10*	
Kitchen Sinks	*22*	
Dishwashers	*16*	*Domestic / Commercial*
Instant Hot Water	*14*	*Zip*
Other	*15*	*Cleaners Tub / Espresso*
TOTAL	***190 x Domestic End-Uses***	

D2: *BUILDING ID CODE **A76***





*BUILDING **A76** CHARACTERISTICS*

Net Lettable Area	*23,000 m²*	*Average Annual Water Consumption*	*8,050 m³*
Full Time Equivalent Occupants	-	*Number Of Storeys*	*24*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*2009*
Hours of HVAC Operation (per week)	-	*Cost Recovery Method*	*Gross Lease*

***A76** WATER MANAGEMENT*

This is a Greenstar New Zealand (GSNZ) certified building.

There are currently a large number of sub-meters in place. These are monitoring both internal and external use, from both mains water supply and harvested rainwater.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee. However, the extensive number of water meters are connected to the BMS, and record at intervals of <10 minutes.

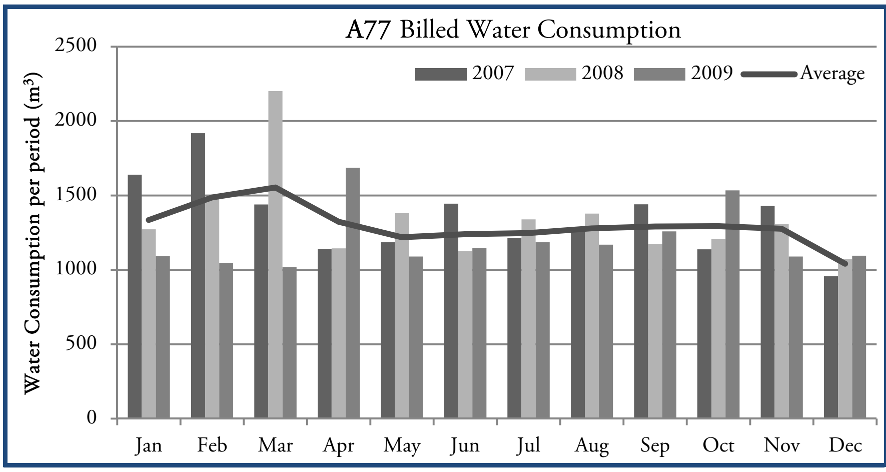
The appliances and number of occupants for this building were not given and/or recorded.

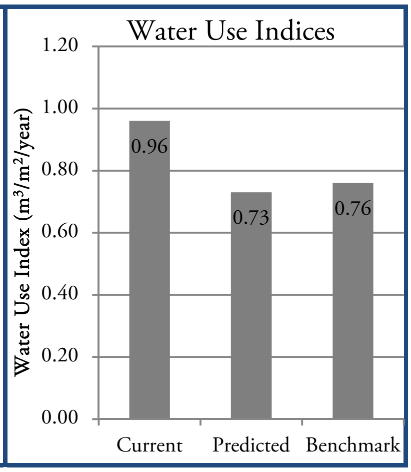
WERT Calculated Building **A76** End-Uses

__A76__ DOMESTIC END-USES DETAILS

Toilets		
Urinals		
Wash Hand Basins		
Showers		
Kitchen Sinks		
Dishwashers		
Instant Hot Water		
Other		
TOTAL	***x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***A77***





BUILDING ***A77*** *CHARACTERISTICS*

Net Lettable Area	*15,025 m²*	*Average Annual Water Consumption*	*16,479 m³*
Full Time Equivalent Occupants	*464*	*Number Of Storeys*	*24*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1981*
Hours of HVAC Operation (per week)	*56*	*Cost Recovery Method*	*Gross Lease*

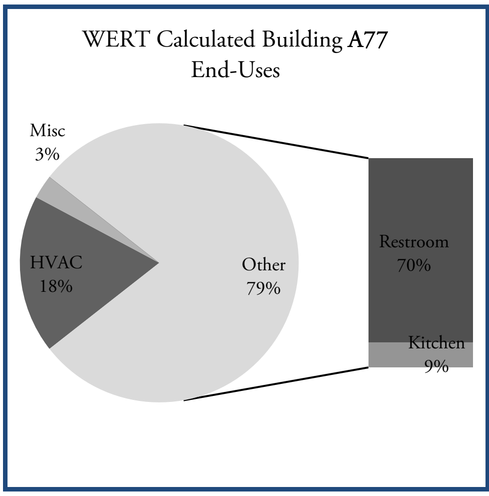
A77 WATER MANAGEMENT

There is currently one observed sub-meter in place. This is connected to the cooling tower make-up water feed.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

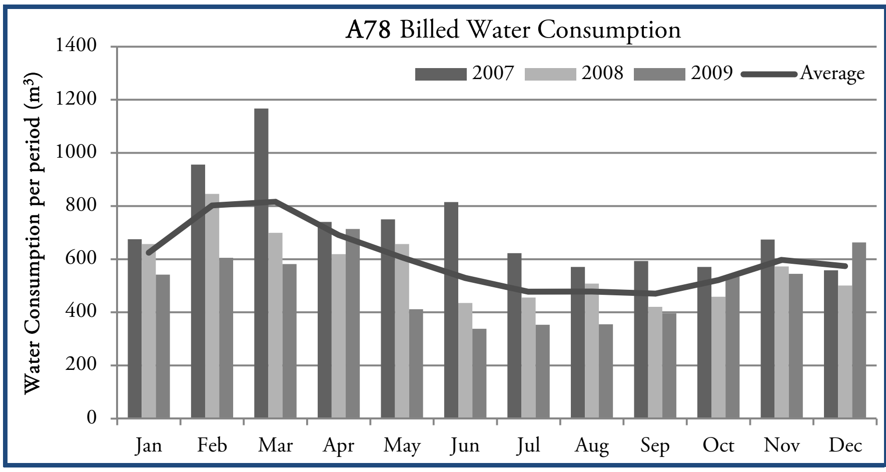
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

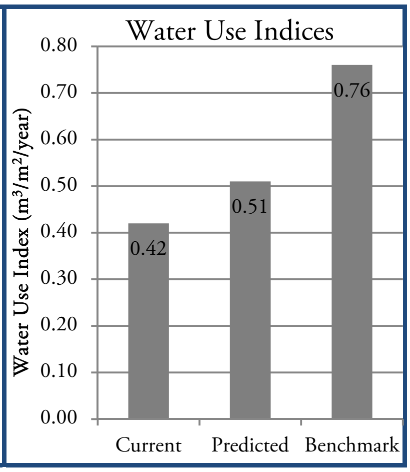


A77 DOMESTIC END-USES DETAILS

Toilets	*90*	*Single / Dual Flush Cistern*
Urinals	*42*	*Cyclic Flush Wall-Pod*
Wash Hand Basins	*91*	*Manual Faucet*
Showers	*-*	
Kitchen Sinks	*33*	
Dishwashers	*30*	*Domestic / Commercial*
Instant Hot Water	*25*	*Zip / Billi Tap*
Other	*33*	*Cleaners Tub / Other / Espresso*
TOTAL	***344 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***A78***





BUILDING ***A78*** *CHARACTERISTICS*

Net Lettable Area	*14,348 m^2*	*Average Annual Water Consumption*	*10,193 m^3*
Full Time Equivalent Occupants	*580*	*Number Of Storeys*	*20*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1989*
Hours of HVAC Operation (per week)	*54*	*Cost Recovery Method*	*Gross Lease*

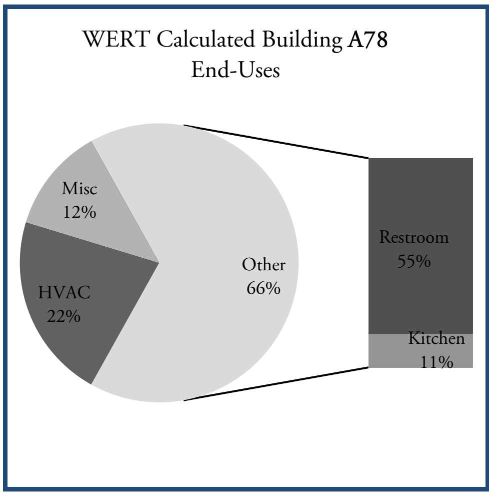
A78 *WATER MANAGEMENT*

There is currently one observed sub-meter in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

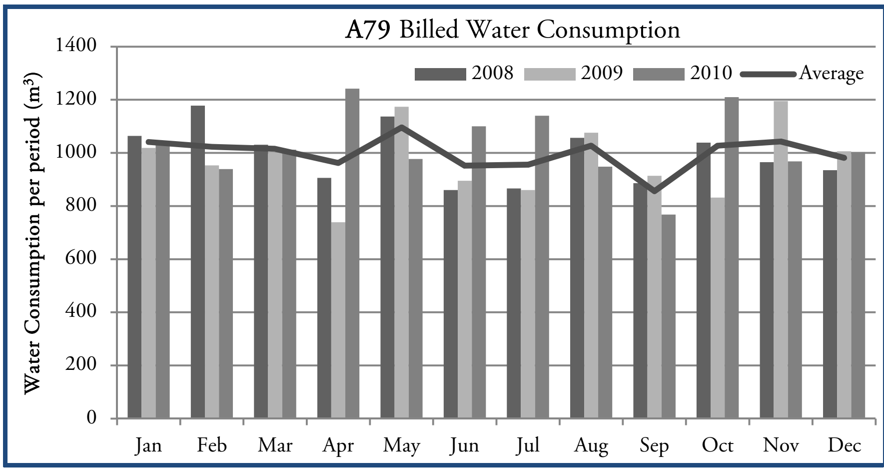
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

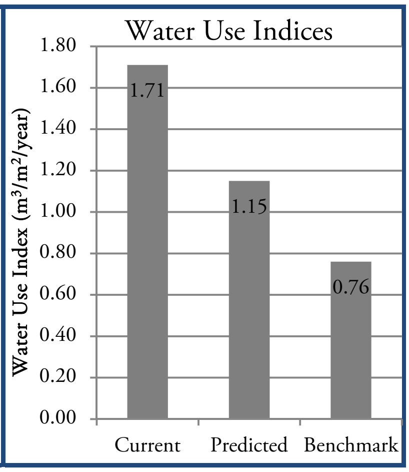


A78 *DOMESTIC END-USES DETAILS*

Toilets	*87*	*Single Flush Cistern*
Urinals	*29*	*Cyclic Flush Wall-Pod*
Wash Hand Basins	*91*	*Manual Faucet*
Showers	*3*	
Kitchen Sinks	*18*	
Dishwashers	*2*	*Domestic*
Instant Hot Water	*16*	*Zip*
Other	*1*	*Cleaners Tub*
TOTAL	***247 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***A79***





BUILDING ***A79*** *CHARACTERISTICS*

Net Lettable Area	*7,239 m²*	*Average Annual Water Consumption*	*12,348 m³*
Full Time Equivalent Occupants	*325*	*Number Of Storeys*	*15*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1988*
Hours of HVAC Operation (per week)	*55*	*Cost Recovery Method*	*Gross Lease*

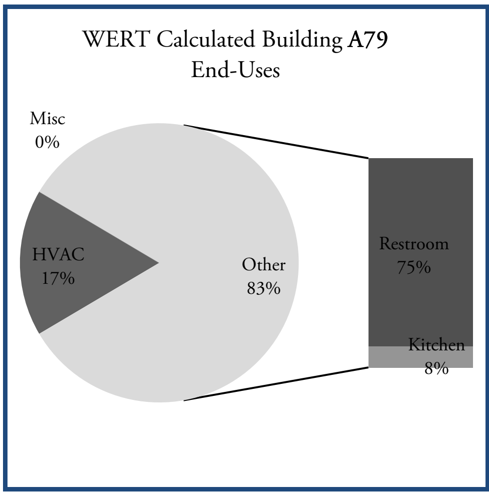
A79 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

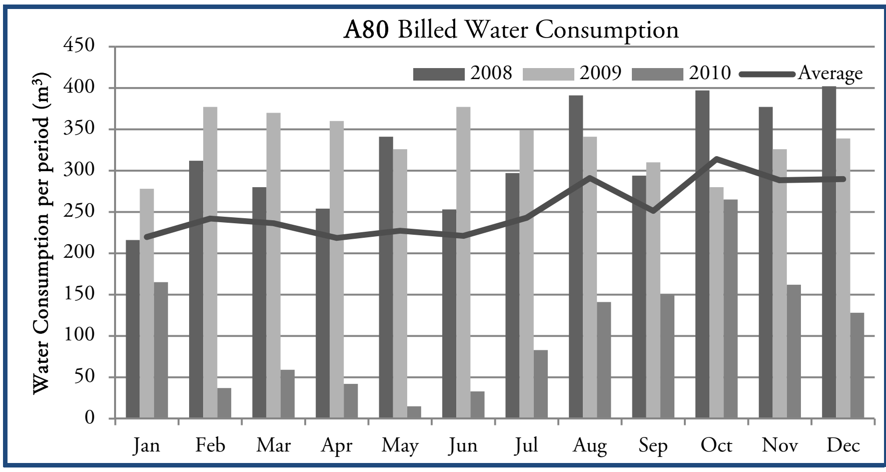
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

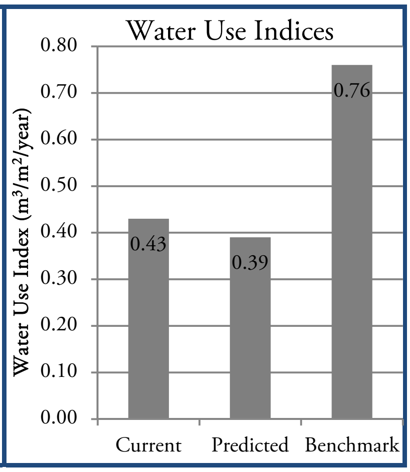


A79 *DOMESTIC END-USES DETAILS*

Toilets	*51*	*Single / Dual Flush Cistern*
Urinals	*24*	*Cyclic Flush Wall-Pod*
Wash Hand Basins	*52*	*Manual Faucet*
Showers	*3*	
Kitchen Sinks	*12*	
Dishwashers	*12*	*Domestic / Commercial*
Instant Hot Water	*11*	*Zip*
Other	*25*	*Cleaners Tub / Other / Espresso*
TOTAL	***190 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***A80***





BUILDING ***A80*** *CHARACTERISTICS*

Net Lettable Area	*8,030 m²*	*Average Annual Water Consumption*	*4,033 m³*
Full Time Equivalent Occupants	*350*	*Number Of Storeys*	*9*
Heat Rejection Method	*Air Condenser*	*Year Built*	*1999*
Hours of HVAC Operation (per week)	*50*	*Cost Recovery Method*	*Gross Lease*

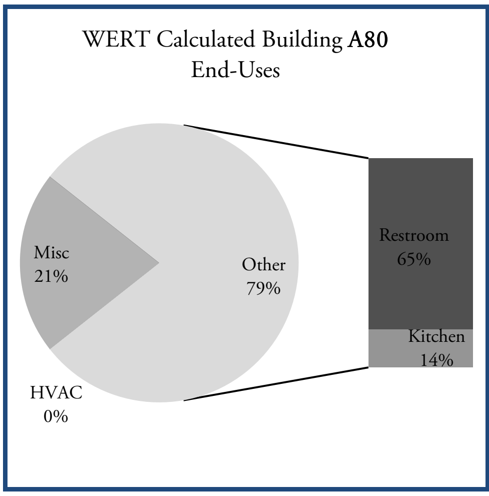
A80 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

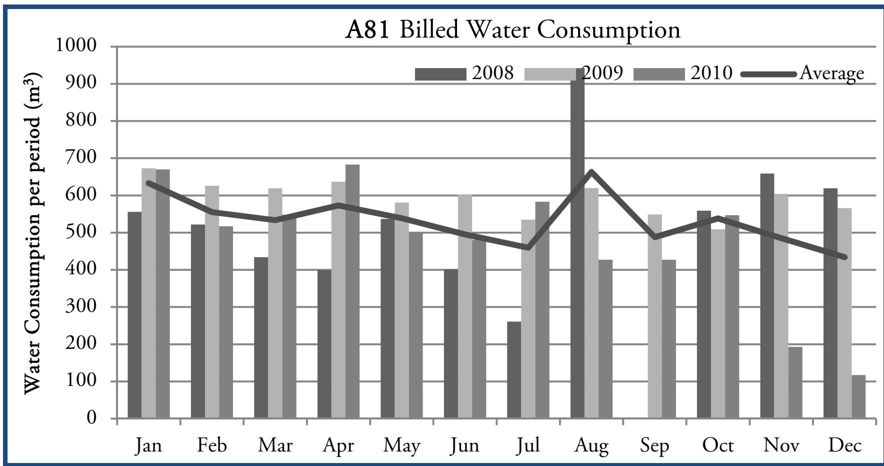
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

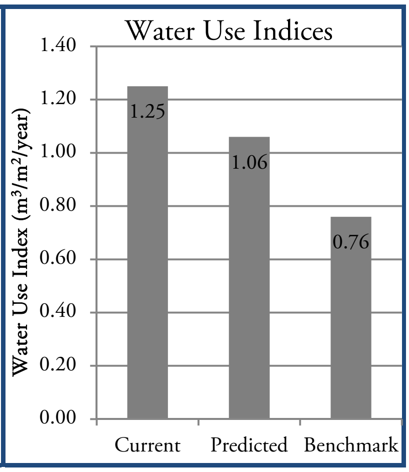


A80 *DOMESTIC END-USES DETAILS*

Toilets	*50*	*Dual / Single Flush Cistern*
Urinals	*21*	*Cyclic Flush Wall-Pod*
Wash Hand Basins	*47*	*Manual Faucet*
Showers	*3*	
Kitchen Sinks	*18*	
Dishwashers	*10*	*Domestic / Commercial*
Instant Hot Water	*8*	*Zip / Billi Tap*
Other	*16*	*Cleaners Tub / Other / Espesso*
TOTAL	*173 x Domestic End-Uses*	

D2: *BUILDING ID CODE* ***A81***





BUILDING ***A81*** *CHARACTERISTICS*

Net Lettable Area	*4,551 m²*	*Average Annual Water Consumption*	*5,841 m³*
Full Time Equivalent Occupants	*125*	*Number Of Storeys*	*8*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*2005*
Hours of HVAC Operation (per week)	*52*	*Cost Recovery Method*	*Gross Lease*

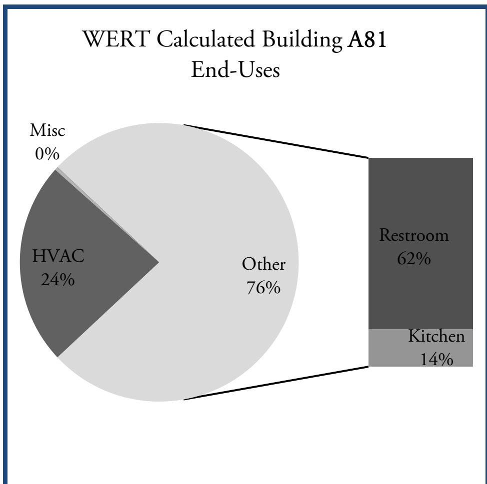
A81 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

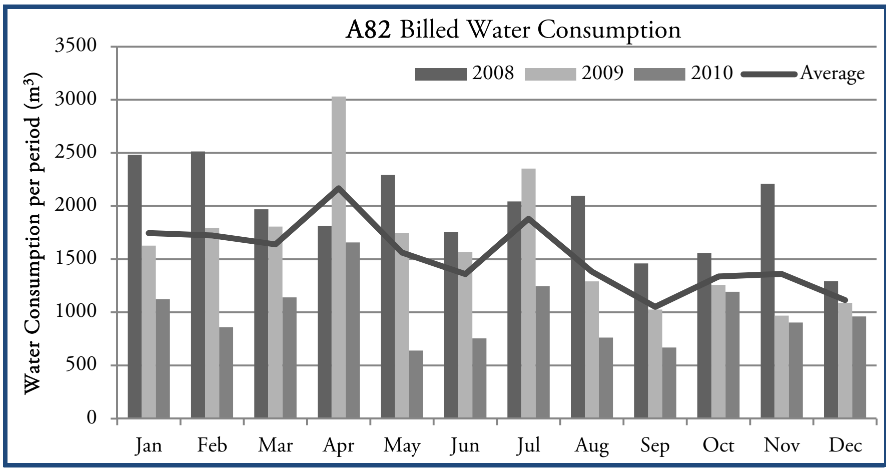
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

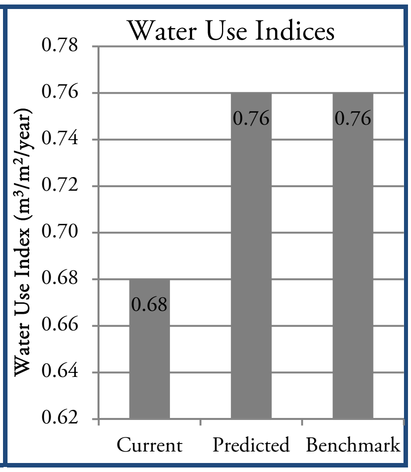


A81 *DOMESTIC END-USES DETAILS*

Toilets	*28*	*Dual Flush Cistern*
Urinals	*14*	*Waterless Wall-Pod*
Wash Hand Basins	*28*	*Self-Closing*
Showers	*7*	*Water Efficient*
Kitchen Sinks	*9*	
Dishwashers	*8*	*Domestic / Commercial*
Instant Hot Water	*7*	*Billi Tap*
Other	*14*	*Cleaners Tub / Espresso / Other*
TOTAL	*115 x Domestic End-Uses*	

D2: *BUILDING ID CODE **A82***





*BUILDING **A82** CHARACTERISTICS*

Net Lettable Area	*17,466 m²*	*Average Annual Water Consumption*	*14,622 m³*
Full Time Equivalent Occupants	*1,483*	*Number Of Storeys*	*19*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1978*
Hours of HVAC Operation (per week)	*52*	*Cost Recovery Method*	*Gross Lease*

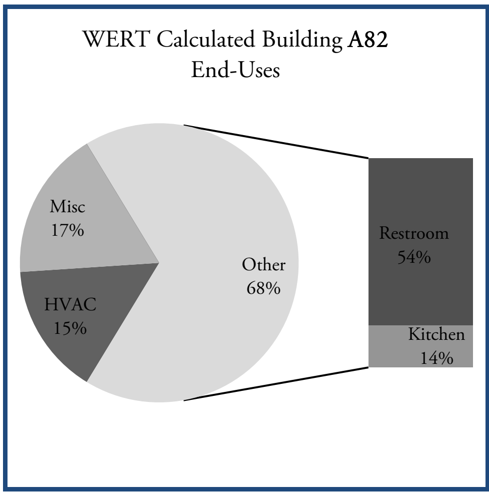
***A82** WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

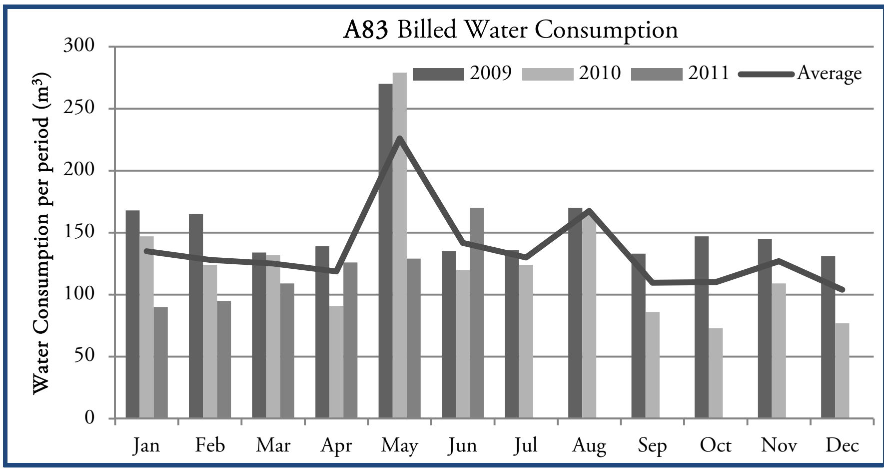
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

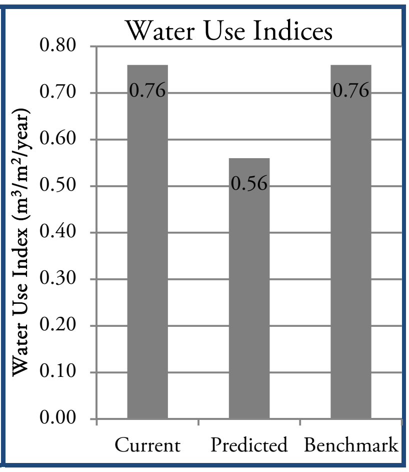


***A82** DOMESTIC END-USES DETAILS*

Toilets	*108*	*Single / Dual Flush Cistern*
Urinals	*43*	*Infrared / Cyclic Wall-Pod*
Wash Hand Basins	*89*	*Manual Faucet*
Showers	*6*	
Kitchen Sinks	*39*	
Dishwashers	*20*	*Domestic / Commercial*
Instant Hot Water	*18*	*Zip*
Other	*1*	*Espresso*
TOTAL	***324 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***A83***





BUILDING ***A83*** *CHARACTERISTICS*

Net Lettable Area	*2,002 m²*	*Average Annual Water Consumption*	*1,380 m³*
Full Time Equivalent Occupants	*135*	*Number Of Storeys*	*4*
Heat Rejection Method	*Shared w A72*	*Year Built*	*1987*
Hours of HVAC Operation (per week)	*-*	*Cost Recovery Method*	*Gross Lease*

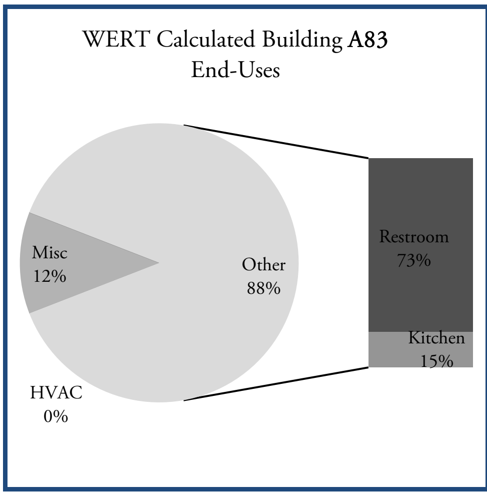
A83 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

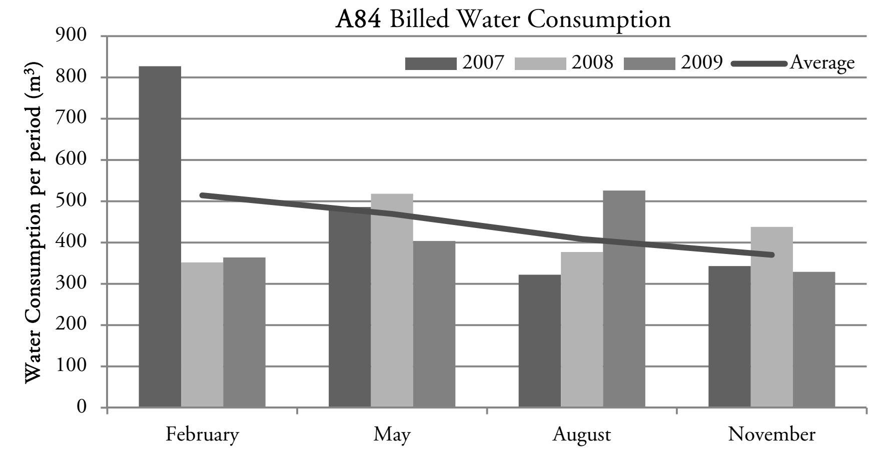
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

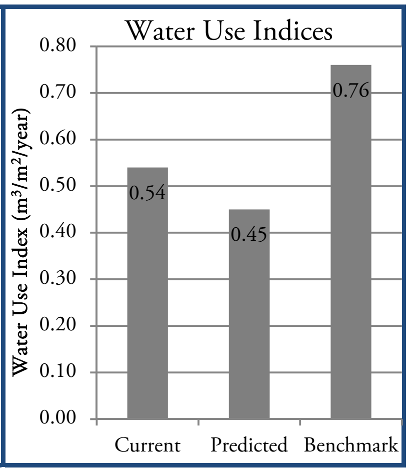


A83 *DOMESTIC END-USES DETAILS*

Toilets	*21*	*Single Flush Cistern*
Urinals	*8*	*Cyclic Flush Wall-Pod*
Wash Hand Basins	*21*	*Manual Faucet*
Showers	*-*	
Kitchen Sinks	*4*	
Dishwashers	*-*	
Instant Hot Water	*4*	*Zip*
Other	*8*	*Cleaners Tub / Other*
TOTAL	***66 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***A84***





BUILDING ***A84*** *CHARACTERISTICS*

Net Lettable Area	*3,027 m²*	*Average Annual Water Consumption*	*1,762 m³*
Full Time Equivalent Occupants	*130*	*Number Of Storeys*	*4*
Heat Rejection Method	*Air Condenser*	*Year Built*	*1981*
Hours of HVAC Operation (per week)	*66*	*Cost Recovery Method*	*Gross Lease*

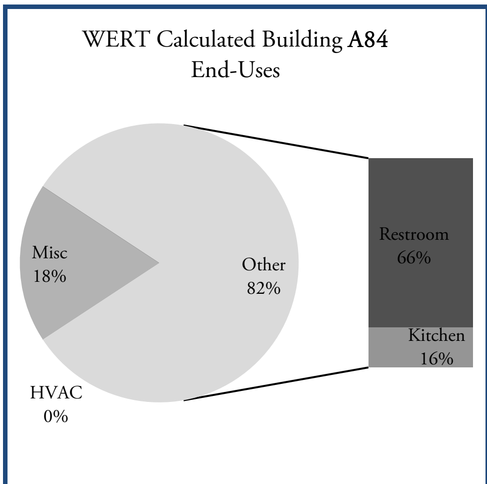
A84 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

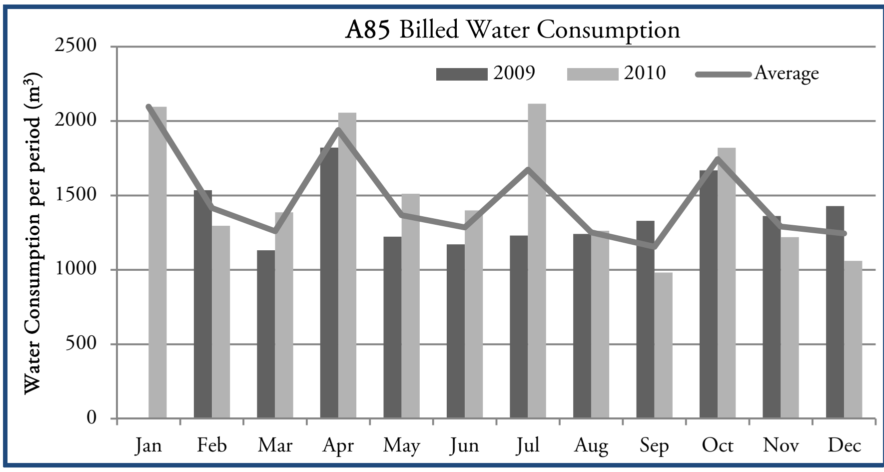
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

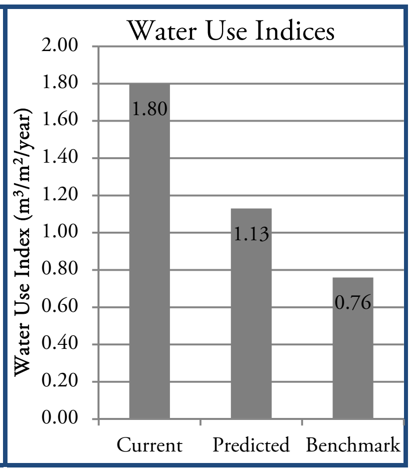


A84 *DOMESTIC END-USES DETAILS*

Toilets	*18*	*Dual Flush Cistern*
Urinals	*8*	*Cyclic Flush Wall-Pod*
Wash Hand Basins	*16*	*Self-Closing*
Showers	*-*	
Kitchen Sinks	*6*	
Dishwashers	*5*	*Domestic / Commercial*
Instant Hot Water	*4*	*Zip*
Other	*6*	*Cleaners Tub / Espresso / Other*
TOTAL	*63 x Domestic End-Uses*	

D2: *BUILDING ID CODE* ***A85***





BUILDING ***A85*** *CHARACTERISTICS*

Net Lettable Area	*10,129 m²*	*Average Annual Water Consumption*	*16,674 m³*
Full Time Equivalent Occupants	*511*	*Number Of Storeys*	*15*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1987*
Hours of HVAC Operation (per week)	*52*	*Cost Recovery Method*	*Gross Lease*

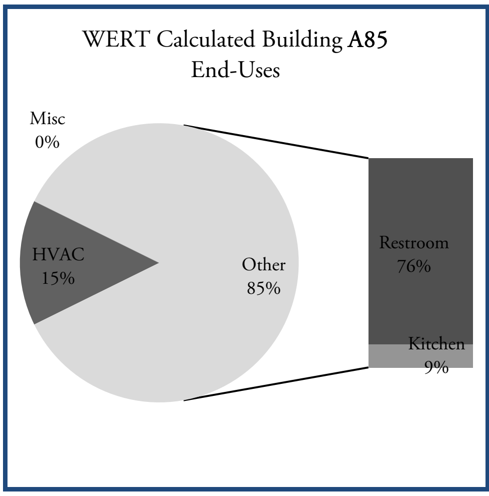
A85 *WATER MANAGEMENT*

There is currently one observed sub-meter in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

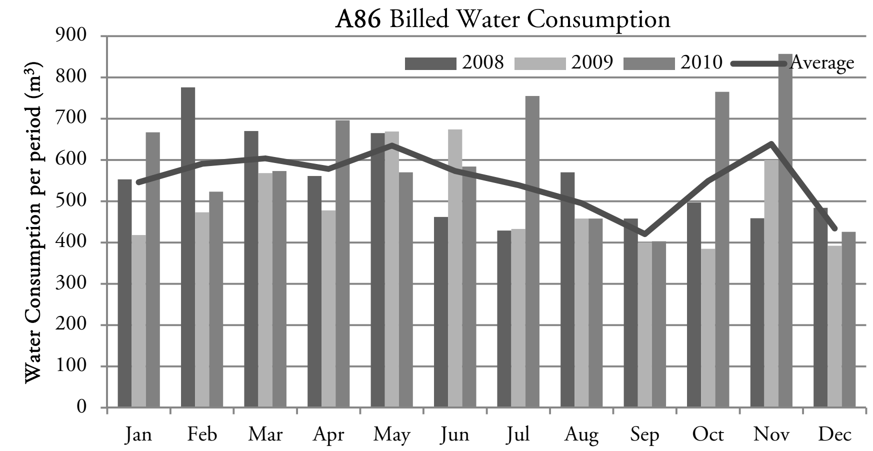
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

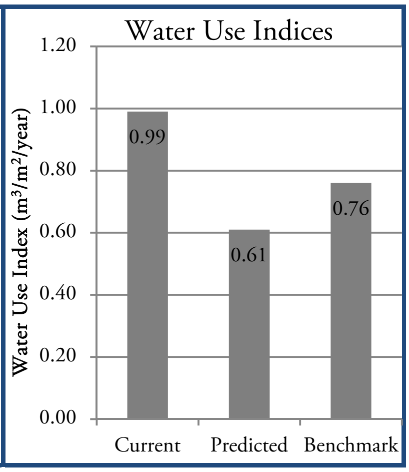


A85 *DOMESTIC END-USES DETAILS*

Toilets	*64*	*Single Flush Cistern*
Urinals	*24*	*Trap Sensor Wall-Pod*
Wash Hand Basins	*51*	*Manual Faucet*
Showers	*3*	
Kitchen Sinks	*14*	
Dishwashers	*10*	*Domestic*
Instant Hot Water	*11*	*Zip / Billi Tap*
Other	*16*	*Other / Cleaners Tub / Espresso*
TOTAL	*193 x Domestic End-Uses*	

D2: *BUILDING ID CODE* ***A86***





BUILDING ***A86*** *CHARACTERISTICS*

Net Lettable Area	*7,369 m²*	*Average Annual Water Consumption*	*6,652 m³*
Full Time Equivalent Occupants	*285*	*Number Of Storeys*	*7*
Heat Rejection Method	*Air Condenser*	*Year Built*	*2000*
Hours of HVAC Operation (per week)	*48*	*Cost Recovery Method*	*Gross Lease*

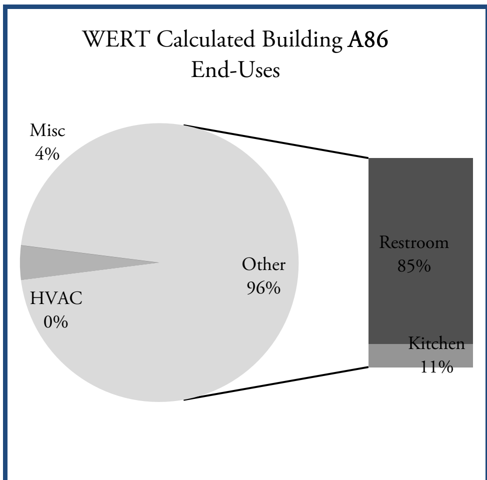
A86 *WATER MANAGEMENT*

There is currently one observed sub-meter in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

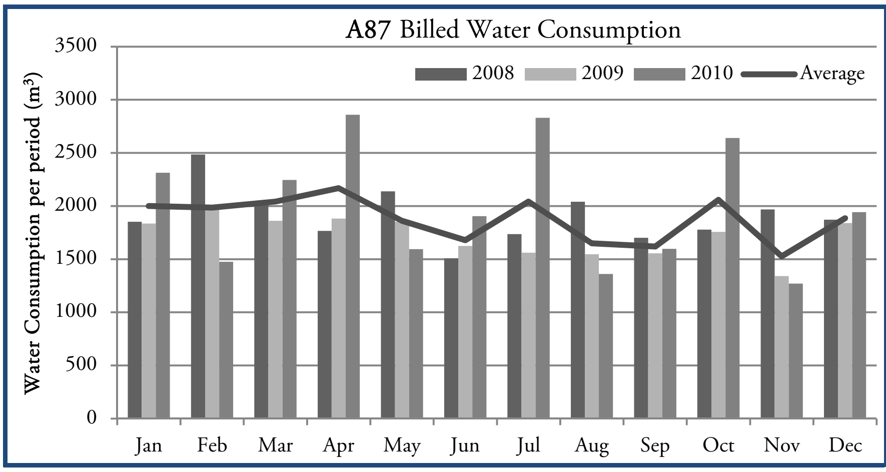
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

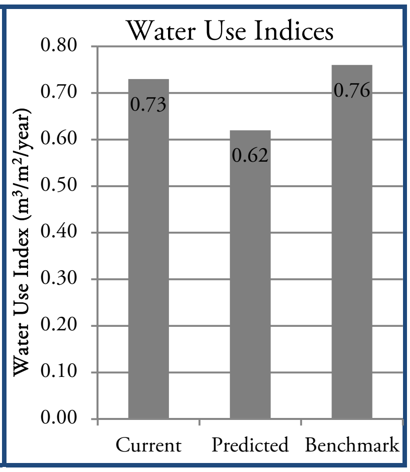


A86 *DOMESTIC END-USES DETAILS*

Toilets	*38*	*Dual Flush Cistern*
Urinals	*18*	*Cyclic Flush Wall-Pod*
Wash Hand Basins	*41*	*Manual Faucet*
Showers	*3*	
Kitchen Sinks	*12*	
Dishwashers	*12*	*Domestic / Commercial*
Instant Hot Water	*8*	*Zip / Billi Tap*
Other	*13*	*Cleaners Tub / Espresso / Other*
TOTAL	***145 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***A87***





BUILDING ***A87*** *CHARACTERISTICS*

Net Lettable Area	*32,793 m²*	*Average Annual Water Consumption*	*22,373 m³*
Full Time Equivalent Occupants	*1,850*	*Number Of Storeys*	*42*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1992*
Hours of HVAC Operation (per week)	*58*	*Cost Recovery Method*	*Gross Lease*

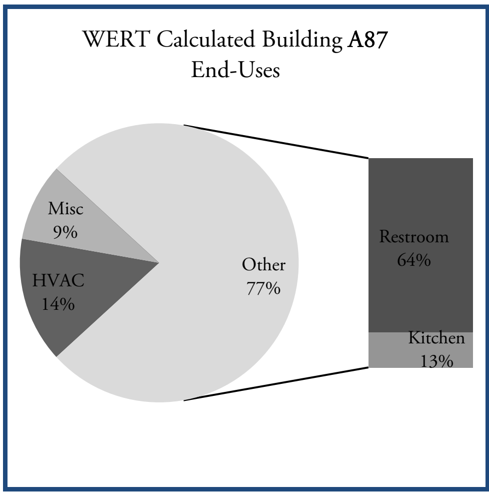
A87 *WATER MANAGEMENT*

There is currently one observed sub-meter in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

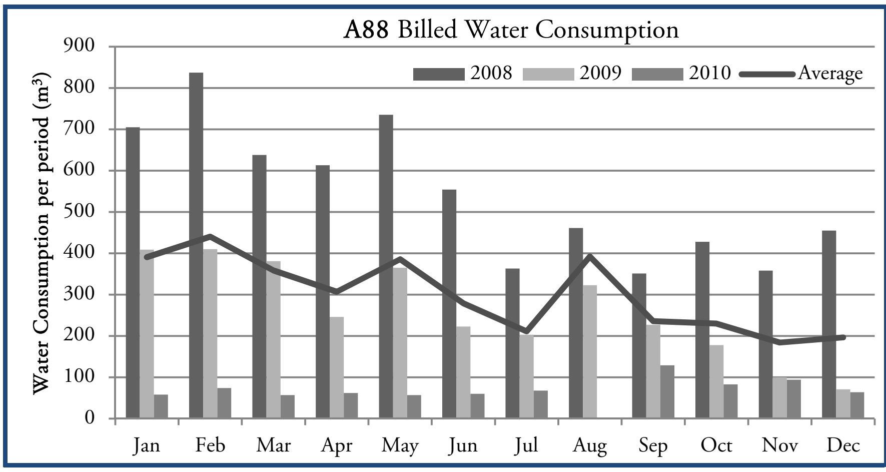
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

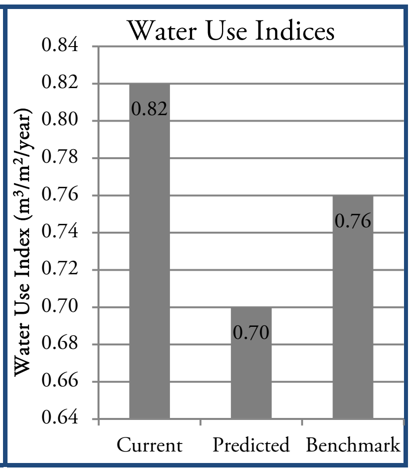


A87 *DOMESTIC END-USES DETAILS*

Toilets	*199*	*Single / Dual Flush Cistern*
Urinals	*69*	*Manual Flush Wall-Pod*
Wash Hand Basins	*214*	*Manual Faucet*
Showers	*10*	
Kitchen Sinks	*38*	
Dishwashers	*34*	*Domestic / Commercial*
Instant Hot Water	*33*	*Zip / Billi Tap*
Other	*102*	*Other / Espresso / Cleaners Tub*
TOTAL	***699 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***A88***





*BUILDING **A88** CHARACTERISTICS*

Net Lettable Area	*5,043 m²*	*Average Annual Water Consumption*	*4,156 m³*
Full Time Equivalent Occupants	*180*	*Number Of Storeys*	*6*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1981*
Hours of HVAC Operation (per week)	*58*	*Cost Recovery Method*	*Gross Lease*

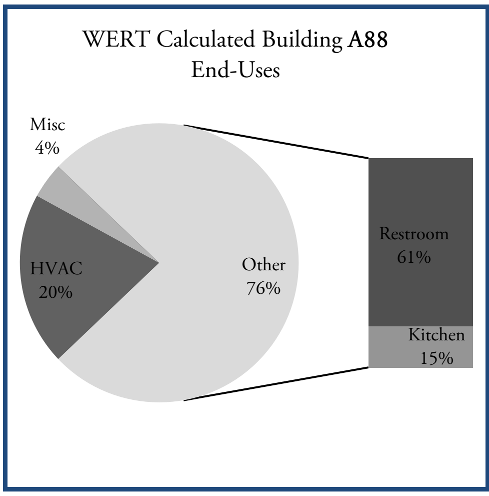
A88 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

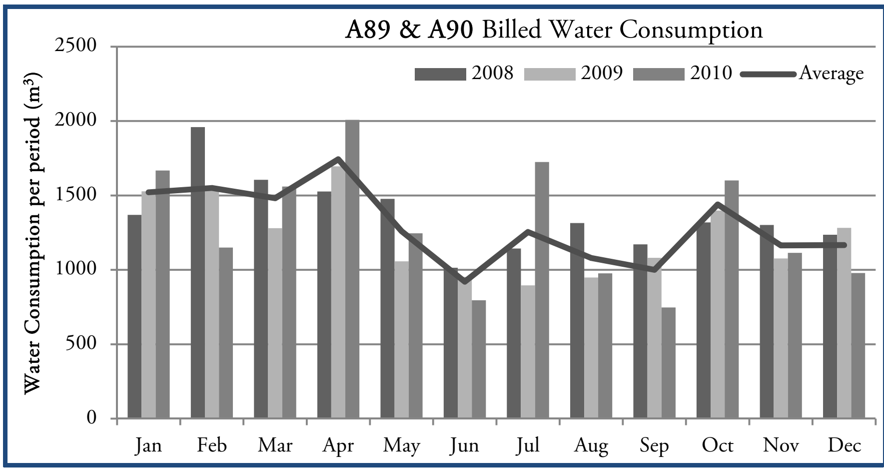
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

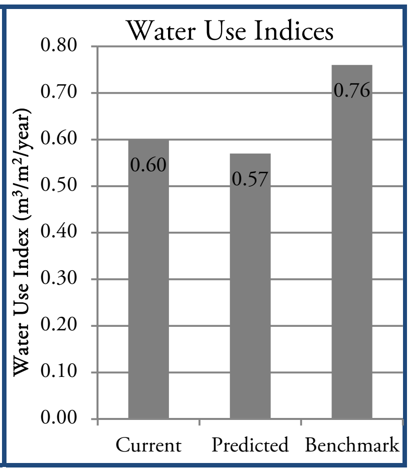


A88 DOMESTIC END-USES DETAILS

Toilets	*17*	*Dual Flush Cistern*
Urinals	*6*	*Waterless Wall-Pod*
Wash Hand Basins	*14*	*Self-Closing*
Showers	*2*	*Water Efficient*
Kitchen Sinks	*12*	
Dishwashers	*6*	*Domestic / Commercial*
Instant Hot Water	*5*	*Billi Tap*
Other	*5*	*Cleaners Tub / Espresso*
TOTAL	***67 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***A89 & A90***





BUILDING ***A89 & A90*** *CHARACTERISTICS*

Net Lettable Area	*26,141 m²*	*Average Annual Water Consumption*	*15,598 m³*
Full Time Equivalent Occupants	*1,800*	*Number Of Storeys*	*40*
Heat Rejection Method	*Cooling Tower*	*Year Built*	*1990*
Hours of HVAC Operation (per week)	*70*	*Cost Recovery Method*	*Gross Lease*

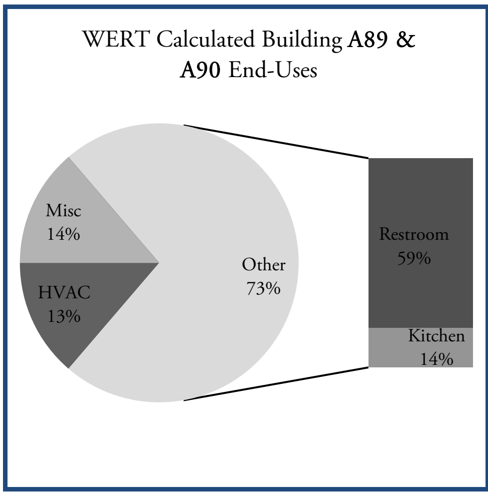
A89 & A90 *WATER MANAGEMENT*

There is currently one observed sub-meter in place, this is connected to the cooling tower make-up feed.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

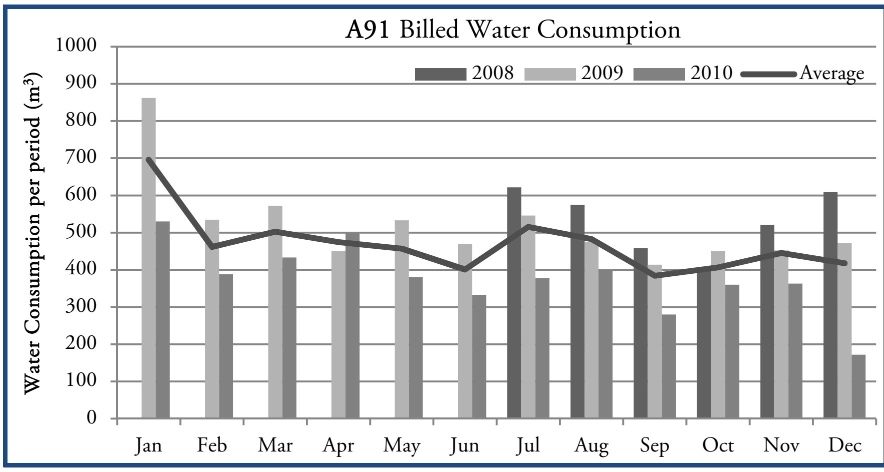
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

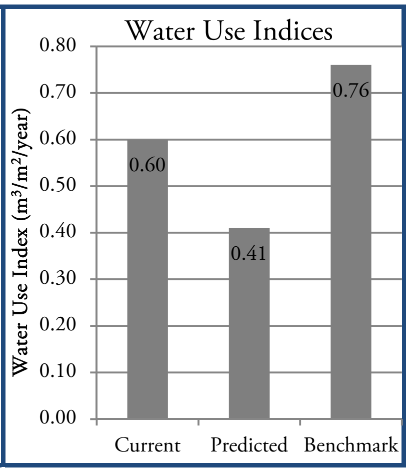


A89 & A90 *DOMESTIC END-USES DETAILS*

Toilets	*177*	*Single / Dual Flush Valve*
Urinals	*78*	*Infrared Sensor Wall-Pod*
Wash Hand Basins	*171*	*Manual Faucet*
Showers	*20*	*Water Efficient*
Kitchen Sinks	*54*	
Dishwashers	*45*	*Domestic / Commercial*
Instant Hot Water	*46*	*Zip*
Other	*43*	*Cleaners Tub / Espresso / Other*
TOTAL	***364 x Domestic End-Uses***	

D2: *BUILDING ID CODE **A91***





*BUILDING **A91** CHARACTERISTICS*

Net Lettable Area	*8,912 m²*	*Average Annual Water Consumption*	*5,373 m³*
Full Time Equivalent Occupants	*280*	*Number Of Storeys*	*10*
Heat Rejection Method	*Air Condenser*	*Year Built*	*1987*
Hours of HVAC Operation (per week)	*70*	*Cost Recovery Method*	*Gross Lease*

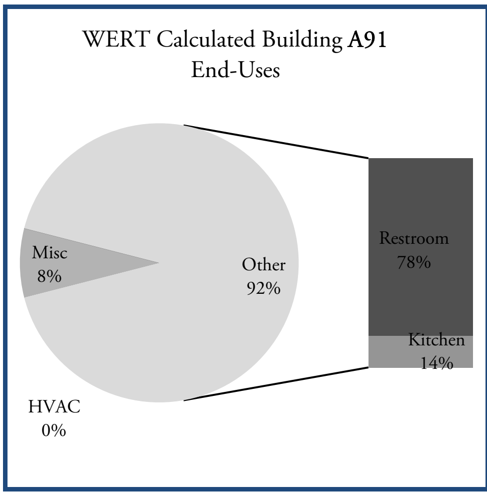
A91 WATER MANAGEMENT

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

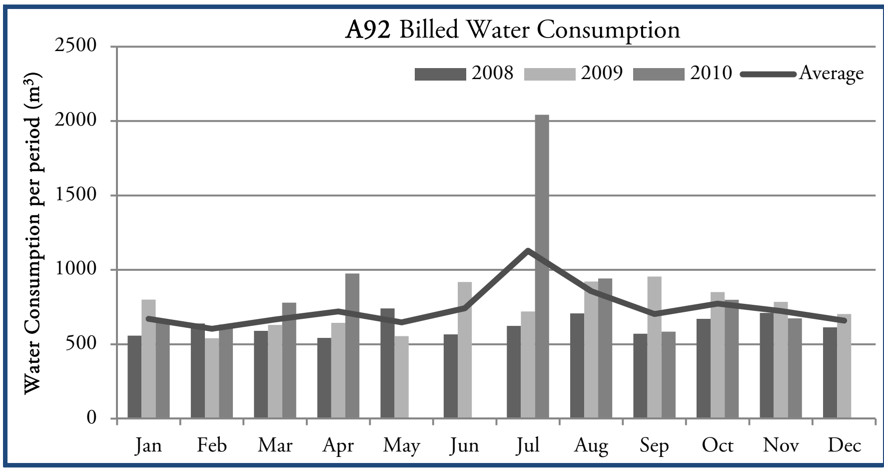
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

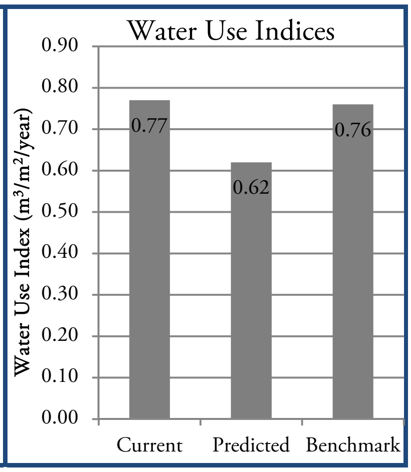


A91 DOMESTIC END-USES DETAILS

Toilets	*46*	*Single Flush Cistern*
Urinals	*17*	*Infrared Sensor Wall-Pod*
Wash Hand Basins	*44*	*Manual Faucet*
Showers	*8*	
Kitchen Sinks	*9*	
Dishwashers	*9*	*Domestic*
Instant Hot Water	*9*	*Zip*
Other	*9*	*Cleaners Tub*
TOTAL	***151 x Domestic End-Uses***	

D2: *BUILDING ID CODE* ***A92***





*BUILDING **A92** CHARACTERISTICS*

Net Lettable Area	*10,545 m²*	*Average Annual Water Consumption*	*7,985 m³*
Full Time Equivalent Occupants	*~300*	*Number Of Storeys*	*15*
Heat Rejection Method	*Air Condenser*	*Year Built*	*1990*
Hours of HVAC Operation (per week)	*56*	*Cost Recovery Method*	*Gross Lease*

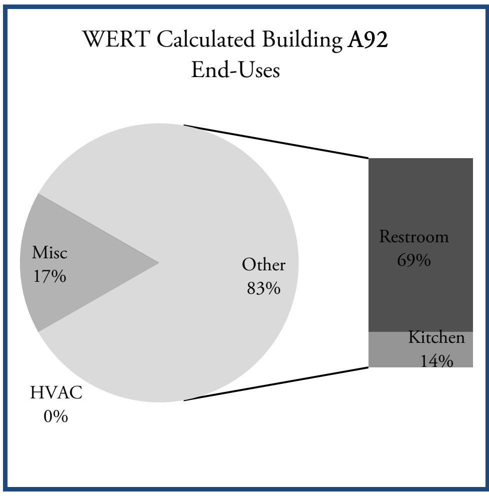
A92 *WATER MANAGEMENT*

There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

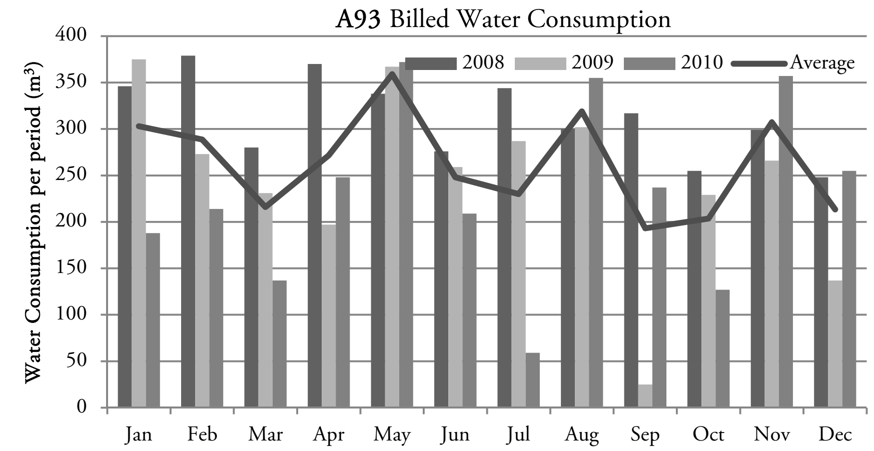
There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

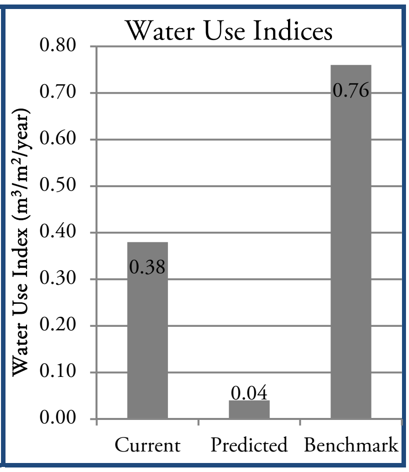


A92 DOMESTIC END-USES DETAILS

Toilets	*83*	*Single / Dual Flush Cistern*
Urinals	*22*	*Cyclic Flush Wall-Pod*
Wash Hand Basins	*63*	*Manual Faucet*
Showers	*7*	
Kitchen Sinks	*16*	
Dishwashers	*19*	*Domestic / Commercial*
Instant Hot Water	*13*	*Zip*
Other	*13*	*Cleaners Tub*
TOTAL	*236 x Domestic End-Uses*	

D2: *BUILDING ID CODE* ***A93***





BUILDING ***A93*** *CHARACTERISTICS*

Net Lettable Area	*8,349 m²*	*Average Annual Water Consumption*	*3,247 m³*
Full Time Equivalent Occupants	*13*	*Number Of Storeys*	*5*
Heat Rejection Method	*Air Condenser*	*Year Built*	*~1980*
Hours of HVAC Operation (per week)	*70*	*Cost Recovery Method*	*Gross Lease*

A93 *WATER MANAGEMENT*

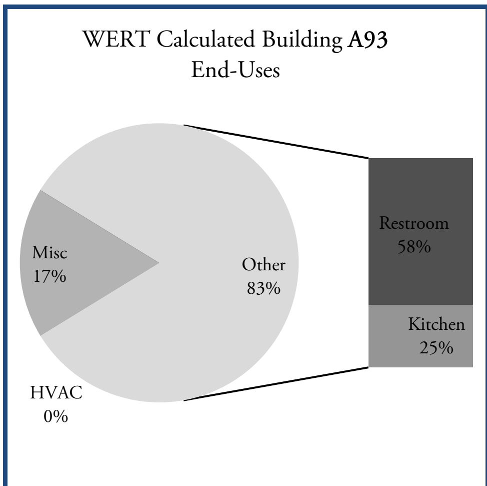
There are currently no sub-meters in place.

The cost recovery method is through a Gross Lease, i.e. is incorporated into rental fee.

There are no water efficiency or water management strategies or targets in place.

There are no incentives whatsoever for end-users to reduce their consumption. There is no method of informing end-users of their consumption.

This building is mainly occupied by information technology personnel, and houses a rather large server. Not a typical office building.



A93 *DOMESTIC END-USES DETAILS*

Toilets	*48*	*Dual Flush Cistern*
Urinals	*16*	*Trap Sensor Wall-Pod*
Wash Hand Basins	*28*	*Self-Closing*
Showers	*4*	*Water Efficient*
Kitchen Sinks	*6*	
Dishwashers	*6*	*Domestic*
Instant Hot Water	*6*	*Billi Tap*
Other	*4*	*Cleaners Tub*
TOTAL	***118 x Domestic End-Uses***	

APPENDIX E: WERT

Compact Disc of the Water Efficiency Rating Tool (WERT)

If this compact disc is missing, please contact the author for viewing:
bintlee@myvuw.ac.nz
leelbi@hotmail.com