An Investigation of the Conservation Potential and Seasonality of Water Use in the Non-Domestic Sectors

AARON HODGES

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Department of Civil and Environmental Engineering
University of Auckland

ABSTRACT

The world's water resources are under increasing pressure from population growth, pollution, climate change, and water hungry societies whose consumption far exceeds the limits of local resources. Growing uncertainty has fuelled calls for water Demand Management (DM) policies, which take a holistic approach to problems such as growing urban water use per capita. DM employs end use assessments, which highlight potential water savings and target inefficient end uses. Conservation opportunities exist within seasonal water consumption patterns, where peak demand sets the requirements for water supply infrastructure. Reductions to peak demand can defer necessary investments, and hence create considerable financial savings. However, understanding of urban water demand remains underdeveloped, particularly for the Non-Domestic (ND) sectors. In New Zealand, this knowledge is especially limited. This study investigated the distribution of ND water use between its component sectors, subsectors, and end uses. This information was used to establish the timing, magnitude, and sources of peak ND water use. ND users were classified based on a two-tiered system, and then water usage in each category investigated to identify conservation opportunities and seasonal consumption patterns. Significant Seasonal Users were surveyed to establish how and when they used water, and whether these uses were efficient. This investigation concluded that water demand was greatest in the Industrial sector, followed by the Commercial and Institutional (CI) sectors. Industrial water savings are possible through retrofitting of Process end uses, such as Rinses and Sanitation. The high price elasticity of Industrial water use also suggests increasing block rates would encourage large users to improve their water efficiency and reduce wastage. Water conservation in the CI sectors is achievable through Bathroom retrofits and education campaigns to improve public attitudes towards water. ND water use peaked in February and March. Irrigation and Cooling in the CI sectors drove increased demand in February. Significant water savings for these end uses are achievable by improving uptake of Drip Irrigation and Conductivity Controllers for cooling systems. Industrial production cycles drove peak demand from Process in March. Seasonal pricing structures would encourage Industrial users to shift unessential production to off-peak periods, and hence significantly reduce water demand in March.

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"When the well's dry, we know the worth of water"

Benjamin Franklin, Poor Richard's Almanack

1.1 Preface

Water is a fundamental requirement for the growth and betterment of human society. From the birth of civilisation between the vast waters of the Euphrates and Tigris Rivers, water has supported and shaped the development of humanity (Smith and Young, 1972). Urbanisation, agriculture, and industrial processes all thrive when supported by large bodies of water (Postel, 1992), and ready access to water provides sanitation and protection from a host of common diseases (Esrey et al., 1991). There is also growing recognition of the non-health services provided by household water, such as improved education, empowerment, wellbeing, community, income, and food security (Moriarty and Butterworth, 2003). In fact, increasing water withdrawals have historically been associated with improving economic health and wellbeing (Gleick, 2003). Meanwhile, countries without adequate supplies of safe drinking water face extreme poverty, hardship, economic stagnation, disease, and poor public health.

1.2 The Water Crisis

Globally, the freshwater resources available for human extraction amount to over 45,500km^3 per year (Oki and Kanae, 2006). In contrast, total anthropogenic extraction is just 3,800km^3 per year, or less than 10% of available water. While this apparent wealth of water suggests water scarcity should not exist, there is little disputing the fact many regions face extreme hardship due to chronic water shortages (Kummu et al., 2010). This disparity stems from seasonal, annual, and regional changes to water availability, which mean over two thirds of available water is lost in flooding or rainfall over unpopulated areas (Postel, 1992). The remaining 14,000km^3 of water is then unevenly distributed around the globe, leaving some regions with an excess of supply, while many arid areas consume up to 90% of their available resources (Cosgrove and Rijsberman, 2000). In some locations, the influence of socioeconomic conditions such as urbanisation has encouraged human population growth well beyond the limits of local water supplies. As a result, societies often become impoverished by crushing water deficits.

Water scarcity is not a new phenomenon. According to Kummu et al. (2010), by 1800 AD around 5% of the global population already faced moderate water shortages (1000–1700m^3/ capita/year) as defined by the Falkenmark et al. (2007) water stress indicator. By 1960, water shortages had spread through East and South Asia, the Middle East, and Africa. Water scarcity grew exponentially on most continents from 1960 onwards, and today 2.3 billion people now experience chronic water shortages (<1000 m^3/capita/year). A number of factors have contributed to this crisis. The most intense stress to water resources comes from the global, regional, and local growth of human populations around the world. In 1927, there were two billion people on earth (Livi-Bacci, 2012). The current human population now exceeds seven billion people – more than a threefold increase since the 1920s. This exponential growth has had a massive impact on the earth's natural resources and environment (Ehrlich and Holdren, 1971, Rosa et al., 2004). The rapid expansion of the human race has been associated with increased atmospheric pollution, climate change (Rosa et al., 2004), disease transmission (Pimentel et al., 2007), absolute poverty (Birdsall, 1980), and threats to global biodiversity (McKee et al., 2003, Foley et al., 2005). However, this report is concerned with the direct relationship between population growth and water demand. On a global scale, population growth increases total water demand, placing ever-greater stress on the fixed volume of water available each year. Thus, for every extra person added to the population there is a decline in available water per capita. Moreover, Kummu et al. (2010) found that regional population growth was the greatest driver of water scarcity, with an influence around four times that of available water resources. Rapidly growing regions have experienced the harshest water shortages, because each additional person not only directly consumes water, but also increases demand from indirect uses such as agriculture and commodity production (Schutte and Pretorius, 1997). Thus, while the average individuals direct consumption is only 147 litres per day, that persons total water requirements are closer to 738 litres per day. This causes series problems in countries such as South Africa, where Schutte and Pretorius (1997) found that a predicted population increase of one million people would require an extra 638 million litres per day. This amount represented 23% of the country's current water supply. In North Africa and the Middle East infrastructure has been unable to cope with the pressure of similar population growth. As a result, 77% of North Africa and 52% of the Middle East now suffer extreme water shortages (Kummu et al., 2010).

Localised population growth, primarily through the mechanism of urbanisation, also threatens water security. In this review, urbanisation refers to the growth of local populations in urban settings. Urban environments have hosted most of the global population growth of the last eighty years. This, coupled with mass migration from rural areas, has increased the proportion of people living in cities from 20% to over 50% in less than 100 years (WHO, 2010). There are currently more than 3.5 billion people in urban spaces that total less than 3% of terrestrial land (UN, 2007, Grimm et al., 2008). While urbanisation generates benefits such as higher wages, increased efficiency through economies of scale, reduced land requirements for housing, and lower infrastructure costs (Bloom et al., 2008), it also raises a number of issues that must be resolved. Research has shown that the growth of cities has had a considerable influence on local climate, water and air quality, hydrology, nutrient cycles, terrestrial processes, and soil composition (RCEP, 2007). Perhaps the greatest concern is for the continued overexploitation of local resources caused by the concentration large populations into a small area of land. Urban populations have outstripped the limits of the local resources that sustain them, and so must import resources from elsewhere (Sun et al., 2008). This is certainly the case with urban water resources. While direct water demand from urban areas only accounts for 30% of global water extractions, many cities have already tapped and exploited most or all of their available freshwater (Cosgrove and Rijsberman, 2000). Moreover, most cities import massive volumes of ‘virtual’ water in the form of fruit, vegetables, meat, and other water heavy commodities. This need is indicative of water demand outstripping local supplies. Water demand in cities continues to increase with growing populations, while their local supplies dwindle and become more expensive to utilise. For this reason, many developed cities such as Melbourne, New York, and Auckland now face uncertainties about their future water security.

Climate is a key determinant of when and where water is available. Thus, there is an intrinsic link between climate variability and water security. This link occurs on multiple scales, from inter-annual variations that may compromise local water supplies, to global climate changes that permanently alter regional precipitation patterns. For instance, there is a well-documented link between the El Nino Southern Oscillation (ENSO) and rainfall in Australia. This connection is strongest in Eastern and North-Eastern Australia, where El Nino periods are generally associated with reduced rainfall and increased risks of drought (Chew et al., 1998, Kiem and Franks, 2004). When prolonged, these processes cause extended periods of drought that seriously compromise centralised water supplies. Urban areas are often forced to initiate water restrictions to maintain the integrity of their supplies. Such restrictions seriously impair the functioning of industries, businesses, and individual households (Barta et al., 2004). Meanwhile, climate change is predicted to have a significant impact on the magnitude, distribution, and timing of rainfall in different regions (Frederick and Major, 1997, Mitchell et al., 2007). Arnell (2004) predicts that climate change will dramatically increase water scarcity by reducing rainfall in arid regions such as the Mediterranean, southern Africa, and parts of America and Europe. The magnitude of these changes differs between climate models, but their direction towards scarcity is reasonably consistent. Increased potential evapotranspiration due to global warming also threatens water supplies in many regions of the United States of America (USA) (NRDC, 2010). For example, Payne et al. (2004) used climate projections from 'business as usual' emissions scenarios to forecast runoff in the Columbia River basin under a warming climate. Increased temperatures were predicted to reduce winter snow accumulation, which will decrease summer river levels and increase winter runoff. This shift in water availability would create conflict between users over the allocation of remaining water supplies. Hydropower productivity is predicted to be particularly susceptible, with significant losses in production projected by 2040 if in-stream flow targets to protect salmonids are maintained. However, Vorosmarty et al. (2000) states that demand from growing populations and per capita usage outweigh the impacts of climate change on future water security. This serves as a reminder that while climate change is problematic, ultimately the stress placed on water systems by unsustainable management practices is the issue that must be addressed.

1.3 Traditional Water Management

The sustainable provision of water in urban environments can only be achieved by moving beyond the tradition perspective of managing centralised water supplies to meet projected water demand (Gleick, 2003). This is not to say the traditional approach to water management has not served its purpose. For instance, the trebling of the population of the USA over the last century has not triggered the mass water related poverty observed in many other countries (Kummu et al., 2010). This success is largely due to the massive investments in water supply infrastructure made by the US Federal Government. Projects such as the

Colorado River Storage Project were able to add massive volumes to the nation's water stores (BoR, 1956), and hence supply the growing demands of residential, agricultural, industrial, and commercial users. However, this drive to create ever-greater stores of water, without questioning the necessity or efficiency of water uses is no longer sustainable. Traditional management strategies have dramatically altered aquatic ecosystems and caused significant environmental degradation. The global storage capacity of dams is now around three times the 2,120km^3 of water held by the worlds rivers (Shiklomanov, 1993, Tuinhof and Heederik, 2002). These dams have created a host of environmental problems, including the erosion of downstream environments (Kondolf, 1997), prevention of native fish migration (Joy and Death, 2001), spread of invasive plant species (Tal et al., 2004), falling lake and river levels (Montaigne and Essick, 2002), and have forever altered the aquatic environment. Traditional styles of management have also threatened water supplies through the return of wastewater to the environment. The WWAP (2003) estimates that globally up to 12,000km^3 of water is contaminated by wastewater, and predicts this will increase to 18,000 km^3 by 2050. Pollution already prevents up to 3.3 billion people from accessing clean water, and causes around 250 million water related infections every year. This is a compounding problem that ultimately contributes to an eminent water crisis (Donnelley, 2004). However, of equal concern is the perpetuation of an 'illusion of plenty' under the traditional management system (Postel, 1992).

The 'illusion of plenty' refers to the common delusion of urban citizens that water supplies are infinite. In many cases, water shortages are obscured by the construction of dams, river diversion, and pumping of water from distant locations; all of which act to provide a constant water supply, regardless of hydrological limits. Such systems have allowed many countries to escape the harsh realities of water scarcity, whilst simultaneously undermining the value of water. The cheap, convenient supply of water has created a perception not only of plenty, but also that water can be taken for granted. This attitude has encouraged the proliferation of water heavy devices and inefficient behaviours, such that demand has now reached unprecedented levels. This behaviour is evident when considering that global water extraction increased six fold over the last 70 years, while the human population only tripled (Donnelley, 2004). Much of this increased water consumption has occurred in developed countries. For instance, the per capita demand in the USA has reached 215m^3/capita/year, compared with nations such as China who use just 32m^3/capita/year

(AQUASTAT, 2012). Fortunately, per capita demand begun to plateau (Oki and Kanae, 2006). However, the continued growth of urban centres means water efficiency must now be improved to a point where predicted demand does not exceed the available supply. This can only be achieved by restructuring water management systems so that value is returned to water, while introducing measures that discourage water inefficient behaviours.

1.4 Water Demand Management

Over the last few decades, population growth, increasing demand per capita, water pollution, and climate uncertainties have placed considerable stress on the world's water reserves (WBI, 1999). At the same time, untapped, clean sources of water have become rare and isolated, forcing populations to utilise stores which are less accessible or of poorer quality. This has dramatically increased the price of new water infrastructure. These costs, as much as uncertain water security, have generated a major shift towards 'Demand Management' (DM) practices (Donnelley, 2004). DM is a process which examines end uses of water, and then determines whether usage can be reduced without compromising the services provided by that water (White and Howe, 1998). DM is a promising alternative to the constant expansion of existing water supplies, and has become best practice in many countries around the world (Mitchell et al., 2007). Outcomes are generally achieved by (1) reducing demand by improving water efficiency, (2) substituting potable water with water of lower quality for uses that do not require high quality water, and (3) creating new water resources (Mitchell et al., 2007). DM produces optimum results using a combination of these practices. However, improving water efficiency is generally favoured because of its low implementation cost and high volume yields (Gleick et al., 2003d). As already discussed, large inefficiencies and wasteful behaviours have been propagated under traditional management systems. Expensive drinking quality water is now used for everything from toilets, to irrigation, to industrial processes. Thus, potentially large savings can be made within the constraints of existing infrastructure. While demand reductions cannot completely substitute growing needs for new infrastructure, they can generate significant economic benefits through deferred investment opportunities (Figure 1.1). Deferred investments refer to the postponement of new infrastructure that would have been required without the savings from DM. The costs of water management are also minimised by reducing the energy and materials associated with collection, treatment and distribution of water and wastewater

(Mitchell et al., 2007). Numerous environmental and social benefits are also associated with DM. Primary environmental benefits include reduced water extraction and wastewater disposal, both of which can seriously compromise aquatic ecological communities (Cairns and Dickson, 1971, White and Howe, 1998, Walsh, 2000, Thoms and Sheldon, 2000). DM also builds resilience to drought and disaster into water systems through improved user knowledge, diversification of water sources, and increased water efficiency (ISET and PacificInstitute, 2011, Watercare, 2011).

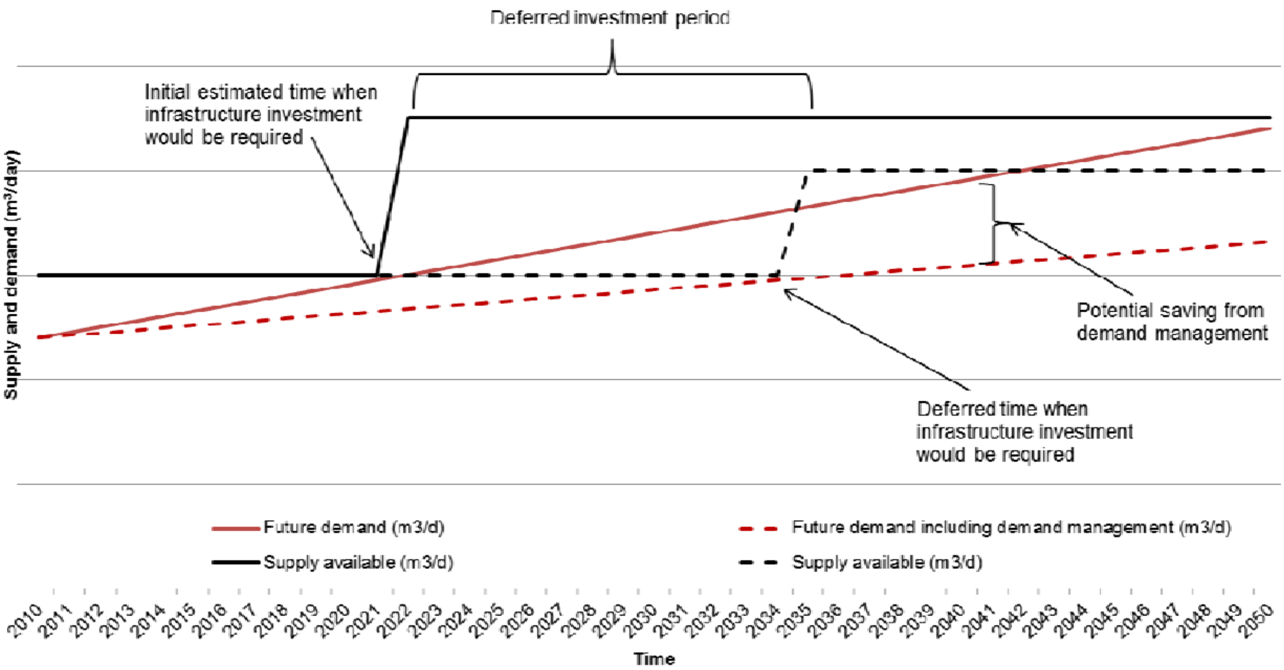


Figure 1.1 Schematic showing the effect of demand management on the timing of new infrastructure. Source: Watercare (2011).

DM requires more than simple snapshot modelling. Traditional water demand modelling typically used historical correlations between per capita usage and variables such as income, population, and price. This form of prediction has consistently overestimated future water needs, and traps managers within the presumption of constant per capita demand (White et al., 2003). In contrast, the first step of DM is the bottom-up construction of forecasts based on detailed analysis of end uses of water (Mitchell et al., 2007). These forecasts also account for predicted changes in variables such as stocks of water efficient appliances, which can significantly affect projected water use. This form of analysis requires sound local knowledge about the types of users and services needed in a given region. The next step to DM is to examine end uses of water and determine whether less or lower quality water can be used to achieve the same quality of service. These findings are then used to develop options to meet the identified service demands, while using less water. The third step to DM is to compare these options using a least cost assessment (Mitchell et al., 2007). Least cost assessments are based off the premise that a kilolitre of water saved is equivalent to an additional kilolitre of water supplied (Fane et al., 2004). Thus, least cost assessments incorporate and evaluate the full swathe of costs and benefits, rather than make narrow comparisons between utility costs (Fane and White, 2003). For instance, avoided or deferred costs of water treatment and transport would be incorporated into a DM option that reduces per capita consumption, which may offset the initial costs of the program. Policies are then selected based on which engenders the lowest overall costs while using the least water to maintain water related services (Howe and White, 1999).

In general, DM uses three strategies to manage water resources: (1) volumetric pricing with universal metering, (2) communication through water conservation/education campaigns, and (3) regulation to encourage water efficiency and/or discourage wastage (White et al., 2003). 'User pay' systems have been widely recognised as being fundamental for improving water efficiency by reducing nonessential and wasteful consumption (Howe, 1982, Nieswiadomy, 1992, Olmstead and Stavins, 2007). User pay systems employ water meters to track water use, and then apply fees based on volumetric consumption. The response of users to these charges is referred to as 'price elasticity,' which describes the direction and magnitude of changes to water use in response to a 1% change in the price of water. For instance, Olmstead and Stavins (2007) found that a 10% increase in price reduces residential water consumption by an average of 3% to 4%, which is a price elasticity of -0.3 to -0.4. In contrast, subsidies that devalue water encourage wasteful behaviour and undercut the benefits of water efficient appliances that would otherwise be economically viable. Moreover, inappropriate pricing can compromise the value and long term effectiveness of alternative conservation strategies. In the 1970s, Tucsoni launched a public water conservation campaign that invoked their residents civic responsibility to reduce their consumption (Nieswiadomy, 1992). This created a significant short term decline in per capita consumption. However, water charges remained low, and within a few years demand returned to previous levels (Martin et al., 1984). In contrast, a price elasticity of -0.5 in Brisbane translates into average savings of 580L per household for an increase of 8 cents per kilolitre of water (Hoffmann et al., 2006).These savings would have offset increased per capita consumption in Brisbane between 1998 and 2003, and conserved up to 789,000 kilolitres (kL) every year.

Communication through education and conservation campaigns has also been used to some effect to improve urban water efficiency. These campaigns attempt to reduce consumer demand by altering behaviours and raising awareness of water supply issues (Barta et al., 2004). This can involve leaflets attached to water bills advertising water saving initiatives, informing consumers about the true cost to deliver water services, providing information about environmental degradation associated with water supply, and school education campaigns (White and Fane, 2001). These strategies can create significant water savings when properly implemented (Nieswiadomy, 1992). However, Syme et al. (2000) found that while information campaigns could produce short term water savings of between 10% and 25%, the benefits of long term actions are relatively unknown. They suggest more research is required to establish the impact of information campaigns and identify areas needing improvement. The third option to improve water efficiency is to use government legislation to encourage the uptake of water efficient behaviours and devices and discourage wasteful practices. This can range from prohibitions on particular end uses (i.e. Car washes), to subsidising the installation of water efficient appliances. For instance, some locations in Australia have banned the use of outdoor hoses and sprinklers except between the hours of 10am to 4pm (SW, 2012). Water savings can also be achieved through retrofit programs that encourage uptake of water efficient devices. However, retrofitting is costly, because old appliances and fittings must be replaced with costly water efficient alternatives. Incentives such as increased water charges or government subsidies are generally necessary to initiate widespread uptake in older housing stock (White and Fane, 2001). Alternatively, costs can be minimised by creating mandatory water efficiency ratings for new buildings (Mitchell et al., 2007). The Building Sustainability Index ($BASIX_2$) in New South Wales operates under the premise that the excess costs associated with retrofitting can be avoided by requiring new residential buildings to meet a set of sustainability requirements. As such, the only additional expenditure incurred is the difference in cost between the water efficient and the traditional fittings that would otherwise have been installed. This strategy is expected to create huge water savings for Sydney, where an additional 500,000 houses are expected in the next 25 years (DIPNR, 2004).

1.5 Water Efficiency and End Use Assessments

As mentioned in the previous section, effective DM forecasts future water demand based on a comprehensive assessment of the end uses and water efficiency of the current population. End use assessments are important because they disaggregate demand into services, and thus build on the DM perspective of water as a provision of services, rather than a commodity. This detailed knowledge gives managers insight into where and how water is being used. Moreover, end use assessments highlight where significant water savings can be made by improving the efficiency of particular end uses. At the coarsest level, 'end use' can refer to the distribution of water use between groups of 'Residential' and 'Non-Domestic' users (Mitchell et al., 2007). As resolution increases, end use analysis examines the distribution of water use between sectors (i.e. Commercial, Institutional, and Industrial) and then subsectors. The more typical definition of 'end use' refers to the allocation of water between various water services (i.e. Bathrooms, Kitchen, Irrigation) (White et al., 2004). This definition of 'end use' is adapted in this report, with higher levels of aggregation being referred to by name (i.e. Sector, subsector). Academic research to date has tended to focus on residential water consumption, since this usually accounts for the greatest portion of demand in urban areas (Reynaud, 2003). As a result, there is a now great deal of literature regarding residential water use (Howe, 1982, Nieswiadomy, 1992, Espey et al., 1997, Arbues et al., 2003, Worthington and Hoffmann, 2006, BRANZ, 2010). The consensus among these studies is that toilets, washing machines, and showers account for the majority of residential water demand (BRANZ, 2010). This knowledge has proved valuable in terms of identifying inefficiencies, and subsequent reductions to water demand. For example, in Sydney the replacement of single flush toilets with dual-flush models was initiated in the 1980s. This has encouraged a steady uptake of dual flush toilets, and now amounts to savings of over 24,000 ML per annum (White and Fane, 2001). Analysis of residential end uses continues to identify potential savings in cities around the world (Nieswiadomy, 1992, Arbues et al., 2003, BRANZ, 2010).

'Non-Domestic' (ND) includes users who fall within the Commercial (i.e. Restaurants, hotels), Institutional (i.e. Sports fields, schools), or Industrial (i.e. Manufacturers) sectors (Quirijns et al., 2012). ND water demand has not been studied to the same degree as the residential sector (Renzetti, 1992, Dziegielewski et al., 2000, Reynaud, 2003). Research of ND consumption has typically not been prioritised because: (1) ND water demand is much smaller than residential demand, (2) ND users exhibit diurnal and seasonal patterns distinctly different from other users (Quirijns et al., 2012), and (3) the ND sectors are more heterogeneous than the residential sector, making them more difficult to study (Morales et al., 2009). However, this has left a significant gap in contemporary understanding of urban water systems. This is somewhat concerning, considering the ND sectors account for between 25% and 40% of total urban consumption (Hanemann, 1997, Maddaus et al., 2000, WaterSense, 2009, Watercare, 2011). This proportion is likely to increase in the future, especially considering over the last two decades Industrial water demand grew faster than any other sector (Biswas, 1997, Meinzen-Dick and Appasamy, 2002). As such, there is a growing recognition for the need to develop greater understanding of ND water consumption.

A basic understanding of ND water use has already been developed by the few studies that address the subject. Williams and Suh (1986) were some of the first researchers to examine Industrial and Commercial water use as discrete urban sectors. By disaggregating urban water into Residential, Commercial, and Industrial sectors, their study was able to identify distinct price elasticities of -0.485, -0.360, and -0.735, respectively. Schneider and Whitlatch (1991) expanded on these findings by deriving price elasticities for residential (-0.262), industrial (-0.438), commercial (-0.918), school (-0.956), and government (-0.781) user categories. These findings are remarkably different from the previous study. Subsequent studies have supported the findings of Williams and Suh (1986) that price elasticity is high in the Industrial sector and low in the Commercial/Institutional sectors (Renzetti, 1992, Dziegielewski et al., 2000, Dupont and Renzetti, 2001). Other studies have examined the distribution of ND water use between the primary sectors and individual subsectors. This type of analysis serves to inform managers about the types of users in an area, how much water they consume, and whether any are appropriate water conservation targets. These studies have found that the distribution of water use between the Commercial, Institutional, and Industrial sectors varies substantially between regions. For instance, studies have found the proportion of ND water use consumed by the Commercial sector to range from 38% (USA, Watersense., 2009) to 79% (Southern California, Hanemann., 1997). Likewise, Institutional water use generally consumes between 30% and 40%, and Industrial water use 14% to 38% of ND water (Maddaus et al., 2000, WaterSense, 2009, Watercare, 2011). These differences reflect regional changes in variables such as climate, government policies, available resources, and population characteristics, which alter the prominence of different categories in each city (Dziegielewski et al., 2000). Changes to study designs and classification systems between regions also has a significant impact on the distribution of water between sectors (Morales et al., 2011). For example, most of the studies above assessed urban demand for mains water, with only Watersense (2009) including 'self-supplied' water in its breakdown. As a result, the Industrial sector, which self-supplies most of its water (Solley et al., 1998), made up a much larger proportion of ND demand in Watersense (2009). These regional differences emphasise the importance of local knowledge, which allows managers to tailor programs to exploit the specific inefficiencies in a given region.

Water use within each of the ND sectors tends to be consistently dominated by a small number of subsectors, with regional differences playing a lesser role. Dziegielewski et al. (2000) provides a useful breakdown of the distribution of Commercial and Institutional (CI) water use into individual subsectors (Table 1.1). Office Buildings consistently accounted for about 10% of CI demand. Overall, Hospitality (including Motels and Hotels) and Warehousing consumed the greatest proportion of CI water, but this influence varied quite dramatically between cities; 5-35% for Hospitality and 0-31% for Warehousing. The influence of Irrigation was also patchy, ranging from 0.3% to 22% of CI water use. Findings were similar for the Institutional subsectors, with Utilities/Infrastructure, Healthcare, and Education accounting for a large proportion of total CI demand, with their influence varying considerably between regions (Table 1.1). Studies elsewhere generally agree with the overall dominance of these subsectors, but again there is considerable variation between regions (DNRW, 2006, Watersense, 2009). Deviations between the Industrial subsectors are even greater, with distributions rarely being comparable between studies. For example, Reynaud (2003) found that the Food, Beverages, and Alcohol industries accounted for 85% of Industrial demand in France, while Morales et al. (2009) found Mineral Processing and Warehousing/Distribution consumed 93% of Industrial water in Hillsborough County, Florida. These findings underline the significance of both regional variations to industries and incompatible classification schemes between studies.

Table 1.1 Distribution of Commercial (top) and Institutional Water use by subsector in cities in the USA. Source: The US Environmental Protection Agency (1997) and Dziegielewki et al. (2000).

Commercial Users	Austin TX	Buffalo NY	Burbank CA	EB-MUD CA	Glendale CA	Miami FL	Orlando FL	Portland OR	San Diego CA	Santa Monica CA	St. Paul MN	Santa Rosa CA	Weighted Average
Reporting Year	**1992**	**1995**	**1995**	**1994**	**1995**	**1995**	**1995**	**1995**	**1995**	**1995**	**1994-95**	**1994**	**1992-95**
Hospitality[*]	13.26	20.94	11.75	7.94	13.45	17.53	34.86	5.45	34.28	38.55	15.96	28.12	14.80
Warehousing	1.79	10.83		30.77	0.45	6.73	30.94	2.78	0.03		16.87	0.25	12.40
Offices[†]	13.97	15.81	11.37	7.09	12.78	12.29	9.7	5.69	7.59		13.03	15.4	9.20
Irrigation[‡]	2.18	5.13		21.94	5.12		0.8	1.57	4.25	10.32	3.12	0.3	6.15
Miscellaneous commercial[§]						31.05	0.45		0.06		0.46		5.72
Sales[**]	6.82	18.15	9.36	3.91	3.54	8.29	2.32	2.99	7.23	6.59	11.97	7.54	5.48
Services[††]	5.64	0.22	0.59	2.61	4.97		0.45	0.75	13.07		0.21	0.43	2.36
Laundries		3.41	3.52	2.53		2.89	2.13	1.10		3.91		5.88	1.73
Vehicle dealers and services	0.90	3.39	0.24	0.59	4.17	0.95	2.11	0.50	2.63	0.57	3.37	4.83	1.15
Meeting and recreation[‡‡]	0.96		2.48	2.13	9.59	0.26	0.53	0.01	2.17	3.14	4.98	0.44	1.11
Communication and research	0.11	0.06	27.84	0.15	7.77		1.04		2.97	1.43	0	0.26	0.72
Landscape[§§]	0.05	2.26	1.01	0.42			0.15	1.63				0.3	0.58
Transportation and fuels		1.15		1.40	0.58		0.74	0			0.61	1.12	0.43
Car wash		2.15	1.17	0.38	0.40		0.20		0.77	2.54	1.24	1.23	0.28
Passenger terminals	0.45	1.17	2.31		0.05		0.01	0.30	0.22	0.33	0.16		0.20
Share of Reported CI Use	46.13	84.67	76.64	81.86	62.87	79.99	86.43	22.77	75.27	67.38	71.98	66.9	62.28

Institutional users	Austin TX	Buffalo NY	Burbank CA	EB-MUD CA	Glendale CA	Miami FL	Orlando FL	Portland OR	San Diego CA	Santa Monica CA	St. Paul MN	Santa Rosa CA	Weighted Average
	1992	**1995**	**1995**	**1994**	**1995**	**1995**	**1995**	**1995**	**1995**	**1995**	**1994-95**	**1994**	**1992-95**
Utilities and infrastructure[*]	32.34	0.67	0.77	1.88	8.49		5.59	73.04	0.98		0.06	2.86	22.76
Health care[†]	5.83	12.03	16.73	5.62	18.21	11.5	4.8	3.5	10.94	20.43	17.18	16.36	7.32
Education[‡]	11.14	0.97	10.19	8.30	7.16	7.33	1.55	0.27	11.41	11.96	8.55	11.06	5.88
Church	1.43	0.31	0.67		2.70	1.18	0.70	0.42	1.19	0.21	1.49	2.79	0.73
Non-profit service and org.[§]		1.42		2.34	0.59		0.76		0.20		0.78	0.50	0.66
Military	2.42						0.02					0.33	0.27
Share of reported CI use[**]	53.16	15.4	28.36	18.14	37.15	20.01	13.42	77.23	24.72	32.6	28.06	33.9	37.61

Table 1.2 shows the allocation of water to general end uses within some of the major CI subsectors. The water consumption of each end use has been determined from surveys and water audits conducted by researchers attempting to identify potential water savings within each subsector. The complexity of ND water consumption is evidenced by the variations in end uses between subsectors. Restroom was the only end use that consumed a relatively constant proportion of water, accounting for at least 20% in all but the Laundromat subsector. In the Laundromat subsector, water provided the subsectors primary service (Dziegielewski et al., 2000), meaning 85% of demand was concentrated in the Laundry end use. In addition to Restrooms, Cooling/Heating and Landscaping accounted for a large proportion of water demand in the Office Building subsector (Table 1.2). Water demand was distributed evenly between end uses in the Hotel subsector, with each consuming between 10-15% and Restrooms using 30-51% of demand. In the Hospital category, Cooling/Heating accounted for a large proportion of demand, as did 'Other' end uses such as X-ray processing and sanitation. Kitchens consumed around 50% of water in the Restaurant subsector, while in Schools Landscaping was the most significant end use after Restrooms. End uses within the Industrial sector are highly user specific, varying even between individuals in the same subsector (Liaw et al., 2006). As such, researchers have struggled establish a quantitative estimation of water demand from specific Industrial end uses. There is consensus that 'Process' accounts for most of Industrial water use (Gleick et al., 2003d). However, this broad term incorporates a number of uses. The significance of each use varies between subsectors. For instance, Sanitation and Transport are significant end uses for Food Processing (Schultz, 1999), while Rinses and Cooling are significant for Manufacturing (Gleick et al., 2003c).

Table 1.2 The Distribution of End Uses of Water in some of the significant CI subsectors according to Watersense (2009) and Gleick et al. (2003b).

Subsector	Study	Cooling & Heat	Kitchen	Landscaping	Restroom	Laundry	Other
Office Building	(Gleick et al., 2003b)	23%	3%	38%	26%	--	10%
	(WaterSense, 2009)	28%	13%	22%	37%	--	--
Hotel	(Gleick et al., 2003b)	10%	10%	10%	51%	14%	5%
	(WaterSense, 2009)	11%	14%	16%	30%	16%	13%
Hospital	(Gleick et al., 2003b)	27%	8%	16%	25%	2%	--
	(WaterSense, 2009)	20%	7%	7%	35%	9%	22%
Laundromat	(Gleick et al., 2003b)	5%	--	--	5%	85%	--
	(WaterSense, 2009)	6%	--	--	4%	86%	4%
Restaurant	(Gleick et al., 2003b)	2%	46%	6%	34%	--	12%
	(WaterSense, 2009)	1%	52%	4%	31%	--	8%
School	(Gleick et al., 2003b)	--	2%	72%	20%	--	6%
	(WaterSense, 2009)	11%	7%	28%	45%	3%	6%

A cities potential for water savings is dependent on the distribution of water among sectors, subsectors, end uses, and current stocks of water efficient devices. For instance, opportunities for conservation in a city with a large Industrial sector would differ markedly from one dominated by Commercial water use. The prominence of individual categories is dependent on a broad range of variables, and can vary markedly between regions. Thus, local water end use assessments are necessary to provide managers with information about the services water provides in a given area. These end use assessments can also provide information about whether water services could be performed using less water. For instance, EPA (1997) conducted a study to disaggregate water use the CI sectors and asses water audits from major cities across the USA. The study identified average water savings ranging from 15% (Laundries, Accommodation) to 30% (Irrigation, Offices, Healthcare) across a range of categories, with potential varying markedly between cities. Expected savings in terms of volume were generally greatest for the Office Building subsector. In Austin, Texas, the subsector offered over 2.3 million kL per year of savings. In the same region, Education, Sales and Services, and Healthcare offered savings of 1.4 million kL, 1.1 million kL, and 0.85 million kL per annum, respectively. Notably, the study concluded that subsectors with the greatest water demand also had the greatest capacity for water conservation in terms of volume (EPA, 1997). End use assessments have also identified considerable potential for water savings in the Industrial subsectors (Gleick et al., 2003d). For instance, Gleick et al. (2003c) estimated potential savings of 27% for Meat Processing, 39% for Dairy Production, 15% for Beverage Processing, 39% for Textile, and 35% for the Fabricated Metals subsector. However, these estimates rely heavily on water audits of a relatively small sample of buildings, and vary considerably depending on regional differences to industry standards, penetration of water efficient devices, and population dynamics. Overall, these studies demonstrate the vast opportunities provided by robust end use assessments of urban water consumption.

1.6 Seasonal Water Demand

Urban water use typically follows a seasonal pattern, in which demand peaks over summer and reaches minimum/base levels in the winter (Dziegielewski et al., 2000). This raises a number of issues. First, the timing of peak water demand coincides with summer, a period when supplies are already strained by low rainfall and high evapotranspiration.

Seasonal water use patterns also reduce the relative efficiency of water reuse systems, particularly in terms of the energy consumed (Sala-Garrido et al., 2012). Moreover, seasonal variations have a significant impact on water infrastructure requirements, since periods of peak demand set the minimum capacity of pipes and storage systems (Watercare, 2011). As such, a decrease in peak consumption levels would reduce stress on water infrastructure, even if average demand does not change (Quirijns et al., 2010). This suggests DM programs that reduce peak demand could significantly improve system efficiency, and hence create deferred investment opportunities for minimum costs. However, to identify these opportunities managers need a comprehensive understanding of the underlying drivers of seasonality. End use assessments offer an ideal method of unravelling the complex systems driving peak water consumption. In the residential sector, end use assessments have already been used to establish sources of seasonality. Seasonal changes to residential water demand are highly correlated with climate, with higher temperatures and decreased rainfall resulting in elevated levels of demand, and vice versa (Billings and Agthe, 1998, Balling and Gober, 2007). This relationship has been attributed to outdoor water uses such as Landscaping, Recreation, and Irrigation, which are most likely to be influenced by climate. Research has also shown that residential price elasticity varies according to season. Most noticeably, price elasticity appears to be greatest during summer peak consumption, while winter demand is fairly price inelastic (Howe, 1982, Maidment and Miaou, 1986). This suggests that summer peaks in residential water use reflect an increase in discretionary usage, which consumers quickly discontinue in response to higher water prices (Worthington and Hoffmann, 2006).

Researchers are still developing an understanding of seasonality within the ND sectors, although there is a general agreement that peak ND water use coincides with peak residential demand (Moeltner and Stoddard, 2004). Some studies have examined seasonality as a percentage of average water demand in the ND sectors and subsectors. For instance, Dziegielewski et al. (2000) ranks CI subsectors by seasonality in the descending order of Irrigation (87.2%), Schools (57.7%), Office Buildings (33.4%), Hotels/Motels (28.6%), Food Stores (19.4%), Restaurants (16.1%), Car Wash (14.2%), Hospitals (13.4%), and Laundromats (10.0%). Morales et al. (2009) also calculates percentage seasonality for the full range of ND subsectors, although using a calculation that is not comparable to Dziegielewski et al. (2000). However, these assessments do not investigate the timing of peak water demand, or the influence of particular subsectors on the overall pattern of ND consumption.

Moeltner and Stoddard (2004) briefly assessed of the timing and magnitude of peak demand in the Wholesale, Eat/Drink, Banks, Amusement/Recreation, Auto Repair, and School subsectors. Water consumption patterns were reasonably consistent between subsectors, with peak demand occurring over summer. However, the magnitude of peak demand differed considerably between subsectors. Banks and Schools demonstrated the largest peak demand relative to background demand, followed by Wholesale and Amusement/Recreation. The seasonal pattern was weakest in the Auto Repair/Service and Eat/Drink subsectors. Sources of seasonality within these subsectors can be deduced from existing end use assessments. For instance, Dziegielewski et al. (2000) reported that end uses such as Irrigation/Landscaping, Outdoor water use and Cooling demonstrate a positive association with temperature and a negative relationship to rainfall. Since temperature peaks and rainfall troughs over summer, this creates optimum conditions for peak demand from these end uses. According to Gleick et al. (2003a) and Watersense (2009), Cooling accounts for more than 10% of water use in Office Buildings, Hospitals, and Hotels. This explains the seasonal pattern observed for Banks (Moeltner and Stoddard, 2004), and suggests a similar pattern might be expected for Hospitals and Hotels. Landscaping was also a significant end use in the School and Amusement/Recreation subsectors, which may explain their peak demand over summer (Moeltner and Stoddard, 2004). Business and production cycles are also likely to influence seasonality. For example, in the Southern Hemisphere summer coincides with the Christmas and New Year's holiday periods. As such, the number of users in subsectors such as Schools and Office Buildings are expected to decline, reducing demand from uses such as Restrooms and Kitchens. Whether this offsets elevated demand from Irrigation and Cooling is yet to be established. Industrial production cycles are also likely to create seasonal water consumption patterns in the Industrial subsectors. Beaulieu and Miron (1990) found that Industrial production in Australia dropped to an annual low in December and January, corresponding with the summer holiday period, before production peaked in February. These fluctuations are likely to influence demand in water intensive subsectors such as Food Processing. These studies emphasise the need for greater analysis of ND water use, particularly surrounding the underlying sources of peak water demand.

2 STUDY AREA

The Auckland region extends from the Kaipara Harbour in the north, to the Bombay Hills in the south, covering almost 5000 square kilometres of land (AC, 2011a). The region supports over 1.5 million people – roughly 33% of the population of New Zealand. This number is expected to grow by between seven hundred thousand, to one million people over the next thirty years (AC, 2011a). Auckland has a subtropical climate, receiving on average 1250mm of precipitation in a year. The region has experienced a number of water shortages, the most recent being caused by a hydrological drought in 1994. However, climate change is expected to increase the length and frequency of drought in Auckland, which could seriously affect the region's water supplies (AC, 2011b). The current population consumes roughly 140 million kilolitres (kL) of treated water in a year (Watercare, 2011). This water comes from eleven dams, twenty six springs/bores, and four rivers, and is then pumped through over 9,000 km of pipes. Approximately 80% of this volume is returned as wastewater along 7,000km of sewer pipes to the nineteen wastewater treatment plants in the region. However, on a per capita basis, Auckland's water consumption is relatively efficient compared to its neighbours. For instance, domestic water use per capita in Auckland is currently 175 litres per person per day (lpd) (Table 2.1). This was the lowest rate for the New Zealand cities reported by Watercare Services (2011). Brisbane was the only city with a lower residential rate of use.

Table 2.1 Gross and Domestic water use in cities in New Zealand, Australia, and the United Kingdom (Office of the Auditor General). Source: Watercare (2011).

Local Authority	Household water meters	Average drinking water consumption (litres per person per day)	
		Domestic	Gross
South Taranaki District Council	No	408 (excluding farms)	888 (including farms)
Kapiti Coast District Council	No	440 – 763 depending on the supply	
Nelson City Council	Yes	180	500
Christchurch City Council	Yes	Not available	435
Opotiki District Council	Yes	Not available	300
Tauranga City Council	Yes	198	270
Auckland region	**Yes**	**175**	**275***
** The 2025 target is to achieve 255 l/p/d*			
International comparative data			
Sydney**	Yes	~215	310
Perth**	Yes	~290	-
Brisbane**	Yes	~150	-
UK (average)	Yes	~125-170	-

***Based on the WSAA 2009-10 performance report*

Auckland's low per capita demand is the product of over three decades of progress towards sustainable management of water. A number of conservation strategies have been implemented to encourage water efficient behaviours and the uptake of water efficient devices. Foremost among these strategies was the introduction of universal volumetric charging in 1990, which saw a drop in per capita demand of about 100 lpd over the next four years (Figure 2.1). This was followed by a large hydrological drought in 1994, at which point water conservation adverts and water restrictions reduced per capita water demand by another 75 lpd. Rates of consumption increased slightly over the next five years, until volumetric charging for wastewater was introduced in the late 1990s. Since then, the concurrence of the 2008/2009 Global Financial Crisis and efforts to reduce pipe leakages have reduced gross per capita demand back to the rates observed during the 1994 drought. The overall impact has been to reduce per capita water use by 125 lpd since 1980. These savings have provided significant financial benefits in terms of deferred investments. The additional infrastructure needed to support the current population with the per capita demand of the 1980s would cost in excess of $400 million (Watercare, 2011). Unfortunately, total water use has continued to grow, fuelled by the doubling of the Auckland population over the last thirty years (Watercare, 2011). This has necessitated considerable investment in new infrastructure, including the $170 million Waitako River pipeline in 2001, with projections suggesting another is needed within the next 50 years.

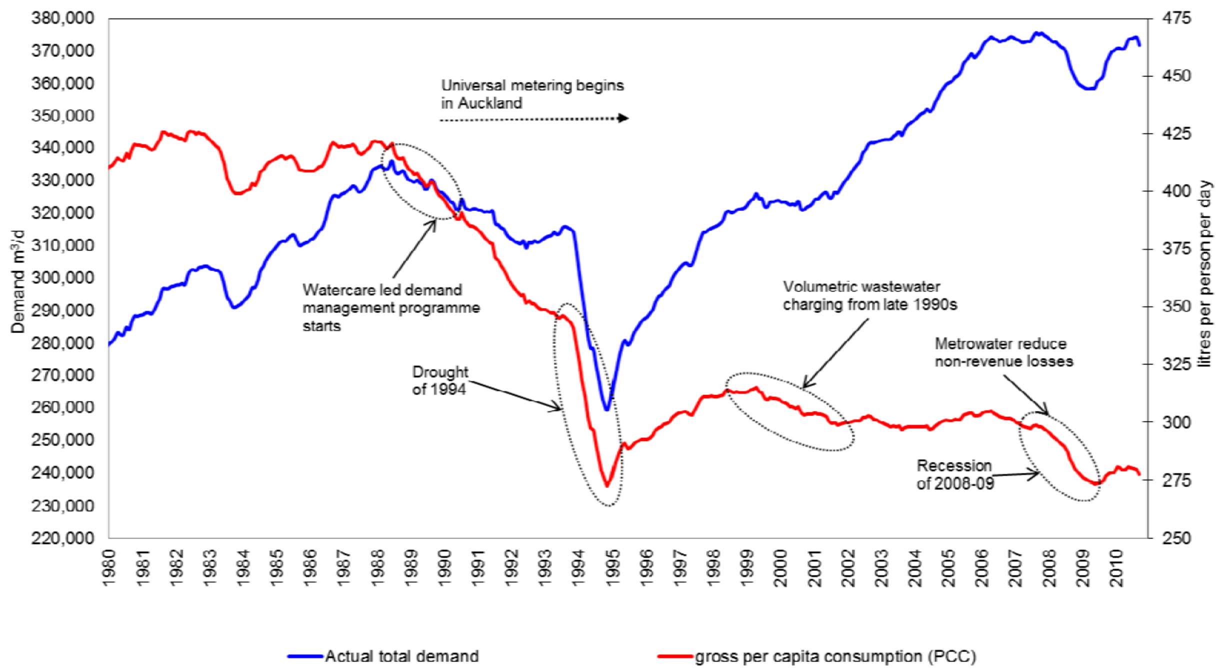


Figure 2.1 Total and Gross per Capita demand in Auckland from 1980 to 2010. Source: Watercare (2011).

Until 2010, seven District Councils were in charge of distributing water to their respective constituents within the Auckland Region, while Watercare Services Ltd managed the water supply and treatment infrastructure (RCAG, 2009). This system has obviously produced some favourable outcomes in terms of improved water efficiency. However, disconnection and inconsistency between regions has also created a haphazard manner of water management. For instance, different councils charged on a one, three, or six monthly frequency, while some regions were not charged for water at all. The divided nature of the councils also created a barrier to water conservation, with different authorities setting different priorities to water demand management (RCAG, 2009). However, the amalgamation of the District Councils into a single Auckland Council in 2010 placed all water provisions and monitoring roles under the responsibility of Watercare Services Ltd. This has created a novel opportunity to create a consistent, region wide monitoring program, set targets to reduce water demand, and implement regional demand management programmes. For instance, Watercare Services (2011) have already set an aspiration goal to reduce gross per capita consumption to 85% of 2004 levels by 2025. Achieving this goal will require accurate, detailed information about the end uses and efficiency of Auckland's water use. A full end use analysis of residential water uses has already been completed by Heinrich (2007) and BRANZ (2010). These studies concluded that the majority of residential consumption came from toilets (20%), washing machines (20%), showers (22%), and taps (12%). Outdoor water use accounted for 20% of water use over the summer (Nov–Mar), during which per capita demand increased by 36 lpd. However, to date there has been no detailed assessment of water use in the Non-Domestic (ND) sectors – that is the Commercial, Industrial, Institutional sectors (Watercare, 2011). The limited knowledge of water demand from these sectors makes it difficult to design approaches to improve their water efficiency. Given these ND sectors consume about 26% of Auckland's water, they may offer substantial opportunities for water savings.

3 OBJECTIVES

Successful Demand Management strategies rely on accurate, detailed information about the end uses and services provided by water in a given region (Mitchell et al., 2007). Unfortunately, this information is rarely available, particularly for Non-Domestic (ND) water consumption (Reynaud, 2003). Such is the case in Auckland, where until recently water consumption was monitored by a disconnected body of water agencies. These agencies did not have a consistent classification system for ND users. This has created considerable uncertainty about the influence of the ND sectors on overall water consumption in Auckland. Thus, the first objectives of this study were to:

(1) Construct a ND classification system to determine how water use is distributed among the ND sectors and subsectors,

(2) Complete an examination of the primary end uses within each of these categories, and

(3) Using this information, identify areas of ND water use where there are considerable potential for water savings.

The second section of this report examined the seasonal patterns in Auckland's ND water use. Seasonal water consumption creates significant opportunities for deferred investments through reductions to peak water demand (Quirijns et al., 2010). However, there is little information available regarding seasonal ND water use, particularly around what drives these consumption patterns. This information is essential if managers are to correctly identify opportunities to reduce peak ND water use. This study aimed to address this knowledge gap by:

(4) Studying the seasonal consumption patterns of each ND sector and subsector,

(5) Establishing the timing, magnitude, and end uses responsible for peak ND water demand, and

(6) Using this information, establish whether there is potential to reduce Auckland's peak ND water consumption.

This research was carried out in requirement for a Masters of Engineering (Environmental) degree at the University of Auckland. Watercare Services Ltd supported this research with both funding and provision of water consumption records from the last five years.

4 METHODOLOGY

4.1 Non-Domestic Water Demand

This project drew on a broad range of information while examining the usage patterns of Auckland's Non-Domestic (ND) consumers. The most significant dataset used in this report was the monthly water records supplied by Watercare Services Ltd. Water records with less than a monthly sampling frequency were not used because they lacked the temporal resolution needed to examine seasonal usage trends. The dataset included monthly water readings for around 5,500 of Auckland's ND water meters in the period October 2007 to February 2012. This included the Name, Address, Account Class, Account Number, Meter Number, Former District Council, and Monthly Water Readings of each user. This information was produced by collating the water records from each of Auckland's old District Councils, who were responsible for supplying Auckland's water prior to their amalgamation into the Auckland Council. This dataset included an excellent representation of ND users in the Central, Western and Southern regions of Auckland (Table 4.1). Water records were sparser in the North Shore and Rodney Districts, suggesting their District Councils collected monthly usage records for a smaller number of ND users. The Papakura, Rodney, and Franklin Districts were underrepresented. Fortunately, these rural areas were not the primary concern of the study. The total water supplied to water meters in the dataset was around two thirds of the water used by Auckland's ND accounts. As such, the findings of this study should be highly relevant to Auckland.

Table 4.1 Distribution of Non-Domestic Water Meters from the Watercare dataset through the seven District Councils.

District Council	Number of Water Meters
Franklin District	32
Auckland City	3763
Manukau City	1188
North Shore City	127
Waitakere City	464
Papakura District	0
Rodney District	0
Total	**5574**

Perhaps the greatest concern in the Watercare dataset was the inconsistency with which accounts were classified between District authorities. Twelve Account Classes were used to categorise ND users based on the nature of their business. However, Account Class definitions appeared to differ between District Councils, generating significant anomalies in the categorisation of users. For instance, rest home accounts were found in the Hospital, Domestic, and Commercial classes. The poor classification system also created a considerable imbalance in user numbers between Account Classes (Table 4.2). Over half of the users in the dataset were placed in the Commercial Class, while the Trade Waste class had only one user. These discrepancies indicated a complete overhaul of the Account Class field was necessary. The dataset also included errors such as leaks, over billing, negative readings, and customers with months of zero water usage. These had to be addressed before seasonal trends could be extracted.

Table 4.2 Number of Non-Domestic Water Meters in each of the original Account Classes supplied by Watercare Services Ltd.

Account Class	Number of Water Meters
Agriculture & Horticulture	83
Bulk Supply	91
Commercial	2814
Community (E.G. Church)	273
Domestic	906
Hospital	162
Industrial (Dry)	481
Industrial (Wet)	209
Municipal	174
School	179
Sports & Recreation	201
Trade Waste	1
TOTAL	**5574**

4.1.1 *Validation and Processing*

A considerable amount of data validation was necessary to produce a reliable record of ND water demand. This began with the identification of about 200 water meters that had recorded months with negative usage during the study period. A query to Watercare Services Ltd determined that negative values were produced when readings could not be taken in the previous month, and water use for that month was subsequently overestimated. These instances were uncommon, but weakened the reliability of the dataset. Fortunately, the magnitude of the dataset was such that some users could be removed without compromising sample size. As such, accounts with negative readings were deleted to prevent them from affecting the overall results. Next, single monthly readings were calculated for users with multiple water meters. Customer Numbers and Address variables were used to consolidate the records of meters belonging to the same users. This created a dataset where each Address had a corresponding set of monthly readings equal to the sum of their associated water meters. Addresses with multiple Account Classes were examined to identify their correct classification.

The Watercare dataset included 53 months of records, but only half of the accounts had readings for the entire period. In many cases, accounts were opened or closed partway through the study. Some accounts also included ‘zero months’ in which no water use was recorded. Several screening protocols were introduced to reduce the influence of these users on seasonal trends. First, consumers with insufficient water use data were removed by setting a minimum limit of twenty nonzero months. This removed users whose water records were too short to extract useful information about their usage patterns. Some accounts were retained with between twelve and twenty months of data if their average monthly water use exceeded 2000 kL because they were considered significant water users. The remaining users were screened for periods of three or more consecutive months without a water reading. This validation was used to remove accounts with instances of overcharging, undercharging, inaccurate estimates, and quarterly billing frequency. Water readings in October 2007 appeared to be erroneous, since the average usage for this month was considerably lower than other 2007 readings and subsequent months of October. This suggested these readings might not have been for the entire month. As such, water records for October 2007 were removed from the dataset. Next, consumer readings from each Account Class were plotted over time to identify anomalously high readings caused by major leaks or overcharges. Irregular users were also vetted using Equation 1:

$$Irregularity = \left[\frac{Highest\ reading - Average}{Average}\right] * 100 \quad \textbf{(1)}$$

This calculation was performed for every account. Users with an abnormally high score were investigated to determine whether this was the product of genuine variation or an erroneous reading. Inaccurate entries were generally considered to be a reading over ten times the accounts average use. Users with only one or two inaccurate readings had the reading removed and were retained in the dataset. For example, average readings for one user varied around 1000 kL per month, and then jumped to over 110,000 kL in a single month. Watercare Services Ltd identified this reading as a major leak in the network. Accounts with three or more errors were removed. The final step in processing the water use dataset was to convert each accounts monthly reading into average daily use. This eliminated variations between months due to different numbers of days. Daily water use was calculated by dividing the water use for each customer in a given month by the corresponding number of days in that month (Covec, 2004).

4.1.2 *Reclassification of Account Classes*

The original twelve Account Classes used by Watercare Services Ltd are shown in Table 4.2. However, these limited and poorly defined categories did not have sufficient breadth to capture the diversity of ND users. To deal with this, the classification system has been remodelled to reflect the broad range of ND accounts. This began with the development of a two tiered classification system similar to that used by Morales et al. (2009), in which accounts are grouped into either the Commercial, Industrial, or Institutional sectors, and then receive a further subsector classification based on their business type (Table 4.3). Sector definitions were as follows (Gleick et al., 2003d):

- **Commercial:** Private facilities that distribute products or services, i.e. Hotels, Office buildings, Cafés
- **Industrial:** Businesses that manufacture and/or process goods and materials, i.e. Food Processors
- **Institutional:** Entities which provide public services, i.e. Public and Private Schools, Parks, Sports Fields

Initially, subsector categories were chosen based on previous studies of the distribution of ND water use, chiefly Morales et al. (2009) and Gleick et al. (2003d). This process involved the removal of a number of Account Classes, including Trade Waste, Domestic, and Bulk supply. The Trade Waste and Bulk Supply categories were deleted because most/all of their users were removed during pre-screening. The Domestic class was removed because its users were not relevant to this study. A number of subsectors were introduced based on the nature of the businesses observed in the dataset. An 'Other' sector was also included in which accounts that could not be accurately classified were placed. This sector also included a 'Mixed Use' subsector, which included accounts in which no single subsector class could be reasonably expected to use more than 50% of the water supplied to the site.

Table 4.3 Number of Users in each Account Class using the new classification system for Non- Domestic Users.

Sector	Subsector	Number of Users	User types included in the Category
Commercial	Agriculture & Horticulture	58	Farms, glass house, nurseries
	Accommodation	161	Short term accommodation such as Hotels, Motels, Lodges, Inns
	Cafe/Restaurant	162	Fast food, cafe's, restaurants, local bakeries
	Commercial Store (Single)	85	Retail stores, hairdressers, dairy's
	Commercial Store (Multi)	41	Multiple commercial stores outdoors
	Halls/entertainment	51	Amusement parks, Zoos, Community Halls
	Laundromat	63	Dry Cleaners, Laundromats
	Low Story Office	88	Office buildings three stories or below
	Multistory Office	148	Office buildings above three stories
	Petrol Station	46	
	Shopping Centre	37	Indoor Malls
	Supermarket	29	Supermarkets, butcheries, vegetable stores
	Vehicle Yard/Repair	69	Car yards, taxi yards, mechanics
	Total Commercial	**1,038**	---
Industrial	Beverage Processing	20	Milk processing, brewery
	Chemical/Pharmaceutical	62	Laboratories, pharmaceutical companies
	Food Processing/Packaging	114	
	Manufacturer/Refining	190	Electroplaters, manufacturers
	Textile/Printing	41	Newspaper printing, textile
	Warehousing/Distribution	63	Storage box, refrigerated storage, courier, importers
	Total Industrial	**490**	---
Institutional	Community	88	Church, Library, Play centres, Clubs
	Hospital	103	Private and Public hospitals, Health Boards, clinics, dentists
	Indoor Sports Facilities	56	Swimming pools, gyms, indoor sports
	Municipal	83	NZ Defence force, Prisons, Government facilities, Utilities, Marinas
	Outdoor Sports/Recreation	75	Parks, Fields, Stadiums
	Rest Home	59	Retirement villages, Rest homes
	School	114	Private and Public schools
	Tertiary Institute	83	University, Polytechnic
	Total Institutional	**661**	---
Other	Mixed Use	36	Mixture of account classes
	Other Commercial	159	Unidentified Commercial Account Classes
	Other Industrial	42	Unidentified Industrial Account Classes
	Other Institutional	10	Unidentified Institutional Account Classes
TOTAL	**Total**	**2436**	**---**

Once a suitable classification system had been designed, users had to be accurately classified into their appropriate categories. This was a protracted process, because there was only a limited amount of information available for each account. The Customer Description and Address fields were the only features available to identify the business function of each account. The first round of classification involved running search functions through the Customer Description field to find characteristic users. For instance, users with 'hotel' or 'motel' in their Customer Description were placed in the Accommodation subsector. This strategy was repeated using a number of common business terms. Unfortunately, the Customer Description field was often blank, did not reflect the nature of the business, or generally lacked useful information. Thus, the second phase of classification was to use the Google Search Engine to query for business names found in the Customer Description. This helped to identify a large number of additional users. Finally, the Address field was used as an alternative to the Customer Description when there was insufficient information to designate a subsector. Businesses could generally be identified using Google Maps and Google Street View. Users that could not be identified were given the appropriate subsector classification under the 'Other' sector. Properties that were identified as long term accommodation or apartments were removed from the dataset because their water use had already been sufficiently studied by BRANZ (2010). During reclassification, the primary business onsite was used to assign the subsector classification. For instance, while many office buildings had a restaurant on the ground level, they were still classified as Multistory Offices. The reclassification process was particularly difficult where businesses did not intrinsically fit into any one subsector. Classification of these accounts required a degree of subjectivity. In these cases, the decision was noted to ensure consistency when classifying accounts of similar descriptions.

4.2 Water Efficiency and End Use Assessment

The assessment and modelling of water use patterns is an important component of water demand management. However, if unaccompanied by an investigation of the end uses of water, such practices threaten to lock in unsustainable behaviour and fail to address water inefficiencies (Mitchell et al., 2007). End use assessments grant researchers insight into how consumers utilise water, and thus whether potential exists to improve efficiency (White et al., 2004). It is also a useful tool with which to investigate sources of seasonal variations in water demand.

End use studies typically use smart water meters or water audits to examine the water uses of a small sample of buildings (EPA, 1997). Smart meters create a high frequency dataset by taking readings at short intervals. They can also be attached to water appliances to monitor the amount of water they consume. This allows researchers to quantitatively assess the end uses of water in these buildings, and make broad statements about end uses within a sector/subsector. Alternatively, water audits can be conducted that examine total water use, what water is being used for, and where there are opportunities to reduce consumption. Unfortunately, these options were not practical for this study, (1) because the heterogeneous nature of ND water use means there are a wide range of business types that need to be audited, and (2) because of the limited timeframe of the project. Instead, an online survey was used to gather qualitative information about the end uses and behaviours of ND consumers. Due to the substantial number of Auckland businesses and the limited contact details available, the survey could not be sent to every user in the database. Instead, a subpopulation of 'Significant Seasonal Users' (SSUs) was targeted because their usage patterns were particularly relevant to the study. This population was identified based on percentage seasonality and peak volumetric water use (P_i). Two versions of percentage seasonality were calculated using Equation 2 and Equation 3:

$$Percentage\ Seasonality\ (Peak) = \left[\frac{Pi-Ai}{Ai}\right] * 100 \quad \textbf{(2)}$$

$$Percentage\ Seasonality\ (Base) = \left[\frac{Ai-Mi}{Ai}\right] * 100 \quad \textbf{(3)}$$

where P_i is a business's average reading for the month with the highest water demand, M_i is each business's average reading in the month with the lowest water demand, and A_i is the overall average water use for the business. A threshold of 20% seasonality was set as the minimum requirement for 'Seasonal Users'. This threshold could be reached using either definition of percentage seasonality. The 'Significant' classification was given to users that exceeded a volume based threshold. P_i was used for this filter, because it had the dual advantages of reflecting both the average and peak water use of each account. As a result, users with a small daily water demand were removed, while retaining those with regular and significant peaks in demand. The P_i threshold was set at 20 kL/day, since this fell near the average daily water use of the 75^{th} to 80^{th} percentiles. Given the large proportion of water demand from the upper percentiles, this was considered an appropriate threshold. Together, these filters identified a population of 412 SSUs.

The next step was to prepare the content of the survey. Questions were constructed around five main areas – business details, end uses, water efficiency, attitude, and peak water usage. The survey was kept short to encourage higher participation rates. Multi-choice questions formed a large portion of the survey, since they are easy for respondents to answer and can be processed quickly post-survey. Questions drew on both academic research and multiple discussions with experts at Watercare Services Ltd. The first section collected business information such as Address and Watercare Account number, which could be used to cross-reference responses with corresponding water records. Respondents were also asked to categorise their business using the new classification system, so that the accuracy of reclassification could be tested. The second question asked respondents about what they typically used water for in their business, and which of these uses would consume the most amount of water. These questions allowed respondents to choose from the following options from Gleick et al. (2003b):

- Bathrooms
- Cleaning
- Food Processing/Brewing
- Cooling
- Heating
- Irrigation
- Kitchen
- Laundry
- Landscaping
- Process
- Recreation
- Other

Seasonal water use was also investigated by asking respondents when they believed their water consumption peaked, and which end use accounted for this. Water efficiency was assessed using direct questions about how they ranked the water efficiency of their own and other businesses. The survey also gave multi-choice questions about the type of water efficient appliances or behaviours businesses had adapted to reduce consumption from each end use. These devices were supplied by Gleick et al. (2003a). Behaviour and attitudes towards water use were gauged based on behavioural questions, such as whether businesses had conducted water audits or whether they would be interested in working with Watercare Services Ltd to reduce their consumption. A number of miscellaneous questions were also asked. See Appendix A for the full survey.

Once the survey questions had been completed, they were vetted by Watercare Services Ltd and the University of Auckland Ethics Committee. This involved the completion of the Research Project Application form for Ethics Approval, and development of a consent form that businesses must agree to before participating in the survey. A Participant Information Sheet was also written that gave the details of the project, including its aims, how long the survey would take to complete, and so forth. After ethics approval had been granted, an online survey was setup using a Premium subscription to the website eSurveyPro.com. This website was chosen because it was easy to use, created an aesthetically pleasing survey, and provided outputs in the correct excel format for analysis. Once responses had been collected, the survey was sent to around 300 SSUs whose email addresses were available. The survey was left open for a three week period, with a reminder being sent once a week, and a final reminder three days before the survey closed. An opt-out function was included in each of these emails. The survey software also removed the email addresses of those businesses who had already responded.

4.3 Underlying Drivers of Water Demand

A number of variables were identified by Covec (2004) as likely drivers of ND water demand. Climate variables tended to be the strongest predictor of water demand. The National Institute of Water & Atmospheric Research (NIWA) National Climate Database supplied monthly climate information for the 52 month study period. This data came from twelve high quality weather stations distributed across the Auckland region. The climate variables supplied included Total Rainfall (mm), Wet Days, Mean Air Temperature (^{o}C), and Mean Daily Maximum Temperature (^{o}C). Outputs from each weather station were averaged to give monthly estimates of climate conditions over the greater Auckland region between October 2007 and February 2012. A number of other variables were considered to have possible links to ND water use (Covec, 2004). These included Gross Domestic Product (GDP), the Consumer Price Index (CPI), Guest Nights, and Stocks of Finished goods for Total Industrial, Manufacturing, Food Products, and Beverages. These variables were obtained from the Statistics New Zealand Infoshare database. Guest Nights refer to how many thousands of nights tourists stayed in commercial accommodation in Auckland, and was measured monthly. Auckland GDP and CPI are both common measures of economic performance, and are recorded at quarterly intervals. The Stocks of Finished Goods variable refers to the closing stock value of finished goods, works in progress, and trading goods of the given industry in Auckland. This was also measured on a quarterly basis. The quarterly measurement of these economic variables was somewhat problematic for comparison with monthly water use records. Since high frequency variations were of particular interest to this study, monthly estimates were constructed based on the quarterly readings provided by Statistics New Zealand. The Matlab 'spline' function was used to perform Cubic Spline Interpolation to split quarterly readings into monthly estimates. While this did introduce some uncertainty to these datasets, these estimates were more likely to explain monthly variations in water demand. A time series assessment for each of these variables is available in Appendix B.

4.4 Statistical Analysis and Calculations

4.4.1 *Disaggregation of Non-Domestic Water Use*

ND water use can be examined from a range of angles, including (1) the distribution of water use between subsectors, (2) the concentration of water use among individual users, and (3) the distribution of water use between end uses such as Sanitation and Bathrooms (Dziegielewski et al., 2000). This study has used each of these approaches to varying degrees. Two measures of water use were calculated for each ND category. 'Daily water use/demand' was calculated by summing the water readings of all accounts from a given category in each month. Total water consumption for each category was then calculated by taking the average of all the months in the study period. This was repeated for overall ND water use and each sector and subsector. These estimates allowed the study to assess how water demand was distributed between the categories. This method was also used to calculate the peak and base/minimum water use for each category. Instead of taking the average over the entire study period, monthly means were calculated to find the average daily water use of each month in a given category. Maximum daily water use was the month with the highest average, and vice versa. Variations in ND water demand were assessed by graphing monthly changes in water use over time. Time series analysis of water demand from the primary sectors was also completed to identify potential sources of variations in overall ND water use. Next, all ND users were ranked according to their average water consumption, and then equally divided into ten usage classes according to their ranking, i.e. the 0-10% usage class included the 10% of users with the lowest water demand. This method was used to examine the distribution of water use between individuals. The spread of water between individuals within each sector was examined using a contingency table comparing the frequency distribution of users between usage classes and sector classifications. The volume accounted for by each cross tabulation was calculated by summing the average water use of each user captured by each cross tabulation.

'Water use per account' (WUA) was the second measurement of water use within each category. It was found by taking the mean water use of each account, and then calculating the average of all accounts in a given category. The mean was used over median calculations because it emphasises the influence of large ND users on overall ND water consumption. WUA was used to gauge per capita consumption because adequate data was not available to calculate either water use per customer or water use per square area, were the preferred measurements used in other studies (Dziegielewski et al., 2000, Morales et al., 2009). The major disadvantage of WUA was that it did not standardise water use based on business size. As such, estimates of per capita water use tended to have large standard deviations associated with the different water demands of large and small businesses. The imprecise nature of WUA was accounted for by calculating 95% student's t confidence intervals for the WUA of each sector and subsector. Finally, a one way ANOVA was carried out to test for differences between the WUA of the Commercial, Institutional, and Industrial subsectors. Since most categories violated the equal variances assumption, this was accompanied by Games-Howell tests to determine whether WUA for any subsector was statistically larger than the other related subsectors.

4.4.2 *Seasonal Patterns of Non-Domestic Water Use*

Seasonal patterns of water consumption were unravelled using increasingly complex methods that sought to identify the underlying sources of peak ND water demand. At the simplest level, Equation 2 and Equation 3 were used to calculate percentage seasonality for each ND sector and subsector. This provided a standard measure of seasonality to compare between categories. However, this calculation did not identify either the timing or magnitude of peak and base water demand. The calculation of unadjusted average water use for each calendar month was also considered inappropriate, because this did not account for the long-term trend of increasing consumption. As such, within group variation for water use in each month was so great that differences between months were not statistically distinguishable. Instead, a measure of relative water use that removes the underlying trend was calculated using Equation 4:

$$Relative\ Water\ Use_{ij}(\%) = \left[\left(\frac{W_{ij}}{CMM_{ij}}\right) * 100\right] - 100 \quad (4)$$

where W_{ij} represents the total daily water demand for the ***i***th subsector in the ***j***th month, and CMM_{ij} is the Centred twelve month Moving Mean for the ***i***th subsector in the ***j***th month. This method was adapted from the seasonal index scores calculated in Covec (2004). Relative water use represents the proportion of demand in a given month that is above or below the CMM. The CMM captures underlying changes to background demand, so standardising water use against this removes variation between years. This was calculated for overall ND water use, the Commercial, Institutional, and Industrial sectors, and each of their subsectors. Plots of relative water use over time were used to identify periods of peak and base water use. In this report, peak use is defined as the month(s) in a given year with the highest relative water demand, while base water use is the month(s) with the lowest relative demand. Next, relative water use was summarised over the calendar year using Monthly Index (MI) scores. MI scores were produced by averaging relative water use for each calendar month (i.e. January). The background average for these MI scores was then standardised to 100%, so that MI scores were easily differentiable from relative water use. MI scores provide a more accurate depiction of seasonal variations by removing underlying changes to background consumption. ANOVA and tukey pairwise tests were used to assess the statistical significance of differences between peak and base water use within each sector/subsector. Boxplots and confidence intervals were also constructed to determine whether peak (base) demand was significantly greater (less) than background water use. Because MI scores are standardised measurements, they do not inherently reveal whether seasonality in a particular subsector translates into notable changes in volumetric consumption. For instance, a 10% increase in consumption in a subsector that consumes 500 kL/day is only an increase of 50 kL/day, while a 5% increase in average demand of 2,000 kL/day adds an additional 100 kL/day to peak demand. To assess the influence of each subsector on peak water use, MI scores were used to estimate the contribution from each subsector to peak ND water demand in February and March. This was achieved using Equation 5:

$$Additional\ Water\ Use_{ij} = \left(MI_{ij} * CMM_{ij}\right) - CMM_{ij} \quad (5)$$

where MI_{ij} refers to the mean MI score of the ***i***th subsector in the ***j***th month. 'Additional water use' is the estimated volume in kL/day that is added to the background consumption of a given subsector (i), in a particular month (j), due to seasonal changes in demand. This equation was applied to water use in February and March of 2011 to assess the influence of each subsector on peak ND demand. Model accuracy was assessed by calculating the correlation coefficient between the observed versus estimated additional water use of each subsector. Finally, to assess the underlying drivers of seasonality, linear correlation coefficients were calculated to test for relationships between relative water use in each subsector and the independent variables described in previous sections.

4.4.3 *End Uses and Efficiency of Significant Seasonal Users*

Prior to the survey, the water use of SSUs was examined to determine whether these users had a significant influence on overall ND water demand. This involved calculating what percentage of water use in each category was derived from SSUs. This established whether water consumption in each sector/subsector was driven by SSUs or the remaining accounts. Next, the influence of SSUs on peak demand was examined. This was achieved by dividing each subsector into groups of SSUs and non-SSUs, and using the method described above to calculate the contribution of each group to peak water use in February and March 2011. Additional water use from SSUs and non-SSUs in each subsector was then graphed for comparison.

Once the influence of SSUs on overall and peak demand had been established, the end uses identified by survey respondents were examined. First, the range of services that water provides to ND users was assessed by calculating the percentages in each sector of respondents who had a particular end use (i.e. Irrigation) on their property. Next, conditions were narrowed to identify which end uses were identified by respondents in each sector as the greatest source of water demand in their business. This assessment was also carried out for subsectors that received at least three responses to the survey question. An analysis of the end uses responsible for peak water consumption in February and March was also completed. This was achieved by cross-referencing respondents with their water records to establish timing of peak water use. For the purposes of this analysis, peak water use was defined as the three months with the most water usage. Then the end uses identified by respondents with peak demand in February and/or March were tallied for each sector. These tallies were compared to determine which end uses were responsible for increased water demand in these months. Peak months for each respondent were also compared to those months respondents *believed* they consumed the most water. Respondents were ranked out of three, based how many of their three highest months of demand they correctly identified in the survey. These scores were averaged for each subsector to provide insight into business awareness of water consumption. 95% confidence intervals were calculated from sample size, population size, and answer proportions (CRC, 2012).

The efficiency of water use in the ND sectors was evaluated next. A summary table was used to compare the water efficiency scores given by the survey respondents to each of the subsectors. Average scores were given for both the rating respondents gave their own businesses, and ratings for their wider industry. Next, the prevalence of water saving devices and behaviours was assessed. Bar charts were used to compare how widespread particular water saving devices were for each end use. Next, the prevalence of alternative sources of water was measured by looking at the number of respondents with access to water other than that supplied by Watercare Services Ltd. Finally, the behaviours and attitude of respondents towards water received some attention in open-ended questions. These questions were summarised into yes/no answers, and then discussed in detail in the text. 95% confidence intervals were calculated for each of these assessments.

5 RESULTS

5.1 Sector level Disaggregation of Non-Domestic Water Use

5.1.1 *Overview of Non-Domestic Water Use*

The final version of the dataset provided by Watercare Services Ltd included a total of 2,436 Non-Domestic (ND) accounts from the Auckland region. The total daily water demand of these users averaged around 49,000 kL/day over the period November 2007 to February 2012 (Table 5.1). This demand peaked in February at almost 53,000 kL/day, and dropped to its lowest (base) levels of 47,000 kL/day in January. Water Use per Account (WUA) was sizeable, averaging around 22 kL/day. The division of this water usage into the three primary sectors revealed some interesting patterns. The Commercial sector; including Agriculture as a subsector; incorporated the largest number of users (1038), dwarfing both the Institutional (661) and Industrial (490) sectors (Table 5.1). However, number of accounts did not determine water demand from each subsector. In fact, Commercial water demand was the lowest of the three sectors: 2000 kL/day less than the Institutional sector, and 6000 kL/day less than Industrial water demand. Demand from the Industrial sector reflects the large WUA of Industrial accounts, which was twice that of Institutional users, and three times that of Commercial users. This consumption pattern suggests that Industrial accounts exert a disproportionate influence on overall ND water consumption. Peak water use was also greatest in the Industrial sector, surpassing 20,000 kL/day in February. Institutional water use peaked in March at 16,000 kL/day, while Commercial demand peaked in February at almost 14,000 kL/day. The 'Other' category contained the lowest number of accounts, the smallest WUA, and the lowest total water use.

Table 5.1 Summary table of the distribution of water demand within the primary ND sectors. The three main sectors are presented, along with an 'Other' category that is assembled from unidentifiable or Mixed Use properties.

Sector	Number of Accounts	Water Use per Account (kL/day)	Mean Daily Water Use (kL)	Minimum Daily Water Use (kL)	Maximum Daily Water Use (kL)
Commercial	1,038 (43%)	14.4 ± 1.8	12,801.5 (26%)	12,195.3 (June)	13,838.0 (February)
Institutional	661 (27%)	24.8 ± 2.2	14,837.6 (30%)	14,061.1 (September)	16,272.4 (March)
Industrial	490 (20%)	46.1 ± 2.6	18,867.6 (39%)	16,780.7 (January)	20,383.1 (February)
Other	247 (10%)	11.5 ± 3.6	2,453.4 (5%)	2,309.2 (July)	2,586.1 (October)
Total	**2,436**	**23.3 ± 3.5**	**48,960.1**	**47,216.4 (January)**	**52,931.0 (February)**

Water use varied considerably over the course of the study. Initially, overall ND water demand averaged around 40,000 kL/day (Figure 5.1). This demand progressively increased through the next four years, such that ND water demand reached approximately 58,000 kL/day by the end of the study. This constitutes an average increase in daily water use of about 500 kL per month. The growth observed appears to be primarily driven by the Industrial sector, demand from which increased from 13,000 kL/day to around 24,000 kL/day. Thus, the Industrial sector accounted for about 11,000 kL of the additional 19,000 kL of water that was added to daily ND water use between 2008 and 2012. In comparison, the other sectors experienced relatively slow growth, with daily Commercial water use increasing by 3,000 kL and daily Institutional water use by around 5,000 kL.

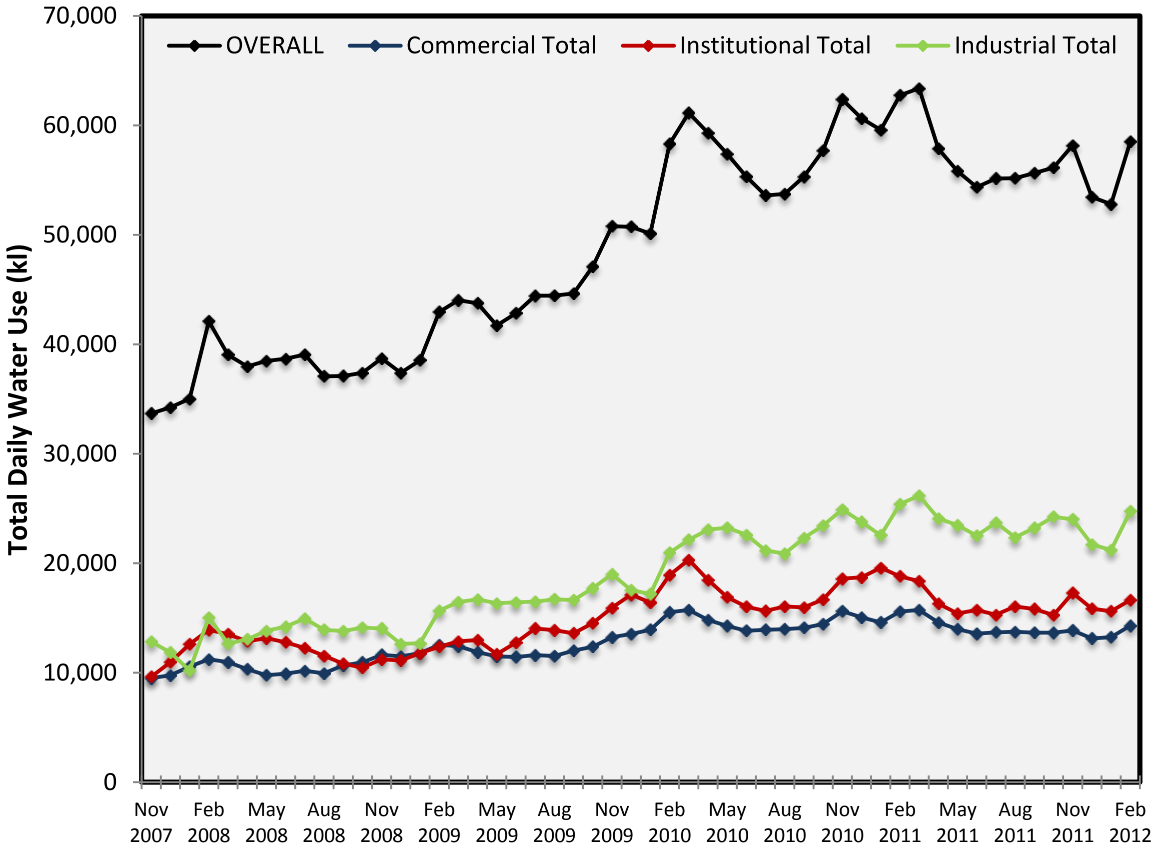


Figure 5.1 A time series analysis of total water use from the Commercial (blue), Industrial (green), and Institutional (red) sectors over the study period. Variations in overall Non-Domestic (black) water use through time are also illustrated.

5.1.2 *Characteristics of Water Use in the Non-Domestic Sectors*

Water use varied considerably between accounts, reflecting the irregular distribution of water among ND consumers. These differences were particularly notable when accounts were divided into percentile groups based on their average water demand. This analysis found that the 20% of accounts with the least demand consumed for only 1% of the water supplied to ND users (Table 5.2). Meanwhile, over 65% of ND water was used by the largest 10% of consumers. This variation is characteristic of the diverse range of users within the ND sectors. For instance, the ND classification covers everything from retail stores with small water demands, to food processing industries that use thousands of kilolitres a month. The allocation of high demand accounts between sectors was a key determinant of water consumption in each sector. The Industrial sector included 83 accounts in the 90-100% usage class; with a further 77 in the Commercial sector and 74 in the Institutional sector (Table 5.2). Despite the relatively even distribution of these accounts, the actual volumes consumed by accounts in the 90-100% usage class differed markedly between sectors, suggesting there is still a considerable degree of variation within the top 10% of consumers. Industrial accounts in the 90-100% usage class consumed more water than their counterparts in the Commercial and Institutional sectors combined. In fact, the 15,000 kL/day used by 90-100% Industrial accounts was greater than total demand from either the Institutional or the Commercial sectors (Table 5.2). Moreover, these 83 Industrial users accounted for over 80% of Industrial water demand. This suggests the Industrial sectors high WUA reflects a right skewed distribution of water demand. Accounts in the 90-100% usage class consumed only 40% of Commercial water use and 65% of Institutional water use, indicating a broader distribution of water use within the Commercial and Institutional sectors. The Commercial sector also included the most users in the 80-90% bracket, which accounted for over 2,400 kL of the sectors daily use. Water use in the Commercial sector was distributed relatively equally between the remaining usage classes, primarily due the large number of accounts in usage classes between 20% and 60%. Accounts in the Institutional sector were spread equally between the usage classes, creating a similar distribution to overall ND water demand.

Table 5.2 The distribution of daily water use (kL) between the major Non-Domestic sectors and usage classes calculated across all Non-Domestic accounts. The number of accounts in each cross section are given inside the brackets.

Usage Class	Commercial		Institutional		Industrial		Overall
0-10%	64.1kL	(78)	40.7kL	(60)	54.6kL	(71)	184.1kL
10-20%	156.7kL	(94)	112.8kL	(60)	98.9kL	(55)	424.8kL
20-30%	355.9kL	(129)	126.9kL	(44)	105.6kL	(38)	685.5kL
30-40%	453.8kL	(120)	243.9kL	(61)	133.6kL	(36)	927.7kL
40-50%	633.0kL	(122)	404.5kL	(75)	175.6kL	(33)	1,284.6kL
50-60%	884.8kL	(123)	448.1kL	(60)	213.2kL	(30)	1,760.3kL
60-70%	896.4kL	(96)	756.3kL	(76)	366.9kL	(39)	2,333.7kL
70-80%	1,302.9kL	(95)	1,132.8kL	(78)	761.5kL	(54)	3,415.2kL
80-90%	2,450.8kL	(103)	1,915.1kL	(73)	1,247.8kL	(50)	5,993.9kL
90-100%	5,603.1kL	(77)	9,656.6kL	(74)	15,709.8kL	(83)	31,950.3kL
Total Daily Water Use	**12,801.5kL**	**(1,038)**	**14,837.6kL**	**(661)**	**18,867.6kL**	**(490)**	**48,960.1kL**

5.2 Subsector level Disaggregation of Non-Domestic Water Use

5.2.1 *Distribution of Water between Subsectors*

The Commercial sector was divided into the largest number of subsectors – thirteen including the Agriculture/Horticulture subsector (Figure 5.2). This reflects both the size and diversity of activities within the sector. Water demand varied considerably between the Commercial subsectors, ranging from under 200 kL/day for Supermarkets, to over 3,100 kL/day for Accommodation. Water consumed by the Accommodation subsector accounted for around 6.4% of overall ND water demand. Multistory Offices were the second largest Commercial subsector, consuming on average 2,300 kL/day, or approximately 4.7% of overall ND demand. The Laundromat, Agriculture/Horticulture, and Shopping Centre subsectors each consumed over 1,100 kL/day, and had a significant impact on total Commercial water use. The remaining eight categories each used less than 800 kL/day, and combined accounted for less than 7% of overall ND water demand. Industrial accounts were split into six subsectors, a reflection of the small number of users within the sector (Figure 5.2). Demand from the Food Processing/Packaging subsector was the largest of all subsectors, using about 8,700 kL/day, or around 18% of overall ND water use. Demand from the Manufacturing/Refining subsector was roughly half this amount, with water use averaging around 4,500 kL/day. Beverage Processing had the third greatest demand of the Industrial subsectors, using around 3,300 kL/day or 7% of total ND water use. The remaining Textile/Printing, Chemical/Pharmaceutical, and Warehousing/Distribution subsectors each used less that 900 kL/day. The final classification scheme included eight Institutional subsectors (Figure 5.2). The Municipal subsector demonstrated the greatest demand, with total water use averaging almost 5,000 kL/day, and accounting for 10% of overall ND demand. The second largest Institutional consumer was the Hospital subsector, which used around 2,600 kL/day. Daily water use for each of the Outdoor Sports/Recreation, Rest Homes, Schools, and Tertiary Institute subsectors ranged from 1,200 kL to 1,800 kL. The demand from Indoor Sports Facilities was also significant at almost 1,000 kL/day. The Community subsector had the lowest daily water demand of just 576 kL.

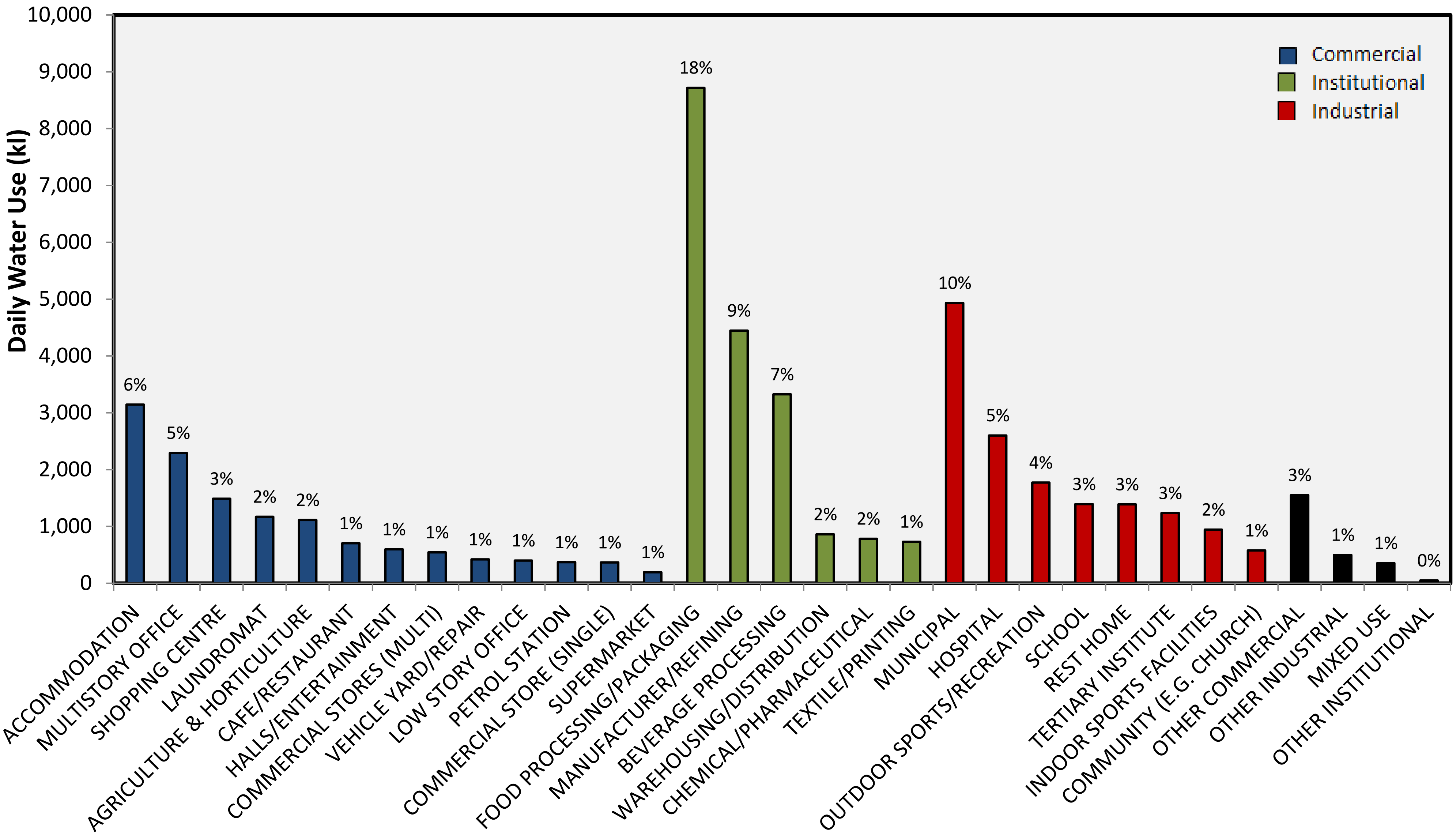


Figure 5.2 Total daily water demand from Non-Domestic accounts in Auckland, divided into representative subsectors. Subsectors grouped into the Commercial (blue), Industrial (green), Institutional (red), or Other (black) sectors based on colour. The percentage of Overall Non-Domestic water use consumed by each subsector is given to 1s.f.

5.2.2 *Characteristics of Water Use in the Non-Domestic Subsectors*

Total water use in each subsector was the product of the number of accounts and their respective WUA. Both of these variables differed considerably between subsectors. Within the Commercial sector, Café/Restaurant was the largest category with 162 accounts, followed by Accommodation and Multistory Offices with 161 and 148 accounts respectively (Table 5.3). The large number of users in the Accommodation and Multistory Office subsectors was complemented by reasonably high WUA. WUA was estimated to fall in the interval 22.8 ± 5.3 kL/day for Accommodation and 19.1 ± 3.3 kL/day for Multistory Offices. The small Confidence Intervals (CI) of these subsectors reflect the large sample size and relatively homogenous distribution of water use between accounts. Meanwhile, the 162 accounts in the Café/Restaurant subsector had a WUA of just 5.1 ± 0.7 kL/day, accounting for the small daily water demand of the subsector. High WUA offset the small number of users in the Agriculture/Horticulture, Laundromat, and Shopping Centre subsectors to generate daily demand in excess of 1,000 kL. However, smaller sample sizes were reflected in the wider CI calculated for these subsectors. The Laundromat subsector had the widest estimate of WUA at 24.1 ± 18.8 kL/day, while the interval for Shopping Centres was 46.4 ± 17.6 kL/day. Games-Howell tests of significance concluded that WUA for Shopping Centres was significantly greater than all other Commercial subsectors, except for Laundromats. WUA for Laundromats was indistinguishable from any other Commercial subsector. The imprecise estimate of WUA for Laundromats reflects the broad variation between users within the subsector, which includes both small dry cleaners and large commercial operations that service hospitals and accommodation facilities. Agriculture/Horticulture had a similar sample size to Laundromats but a narrower interval of 20.5 ± 6.5 kL/day (Table 5.3), which suggests there is less variation between accounts in this subsector.

Table 5.3 Variation in the number of accounts and water use per account between the Non-Domestic Subsectors. Water use per account is the mean water demand of all users within the subsector, averaged over the study period. A 95% Confidence Interval for each subsector was also calculated using the Students T distribution.

Subsector	Number of Accounts	Water Use per Account (kL/day)	95% Confidence Interval (kL/day)
Agriculture & Horticulture	58	20.5	±6.5
Accommodation	161	22.8	±5.3
Cafe/Restaurant	162	5.1	±0.7
Commercial Store (Single)	85	5.3	±1.5
Commercial Stores (Multi)	41	13.8	±3.0
Halls/Entertainment	51	12.1	±6.4
Laundromat	63	24.1	±18.8
Low Story Office	88	5.2	±1.0
Multistory Office	148	19.1	±3.3
Petrol Station	46	9.1	±3.0
Shopping Centre	37	46.4	±17.6
Supermarket	29	7.4	±2.4
Vehicle Yard/Repair	69	6.4	±1.4
Total Commercial	**1038**	**14.4**	**±1.8**
Community	88	7.2	±2.0
Hospital	103	28.6	±13.9
Indoor Sports Facilities	56	19.8	±8.6
Municipal	83	65.7	±43.3
Outdoor Sports/Recreation	75	24.5	±11.1
Rest Home	59	25.6	±6.4
School	114	12.7	±2.6
Tertiary Institute	83	17.5	±10.0
Total Institutional	**661**	**24.8**	**±6.2**
Beverage Processing	20	241.1	±173.7
Chemical/ Pharmaceutical	62	13.5	±4.4
Food Processing/Packaging	114	87.4	±46.5
Manufacturer/ Refining	190	27.5	±13.3
Textile/Printing	41	20.1	±17.0
Warehousing/ Distribution	63	14.6	±10.2
Total Industrial	**490**	**46.1**	**±14.3**

Results for the Institutional sector found that the high water demand in the Municipal subsector was driven by an estimated WUA of 65.7 ± 43.3 kL/day (Table 5.3). This average was more than twice that of other Institutional subsectors, but the wide CI meant Municipal WUA could not be statistically distinguished from other subsectors at the 95% level. Given there were almost 90 Municipal users, this wide CI was derived from a large degree of variation between accounts in the subsector. This variation reflects the diverse range of activities defined as Municipal and a number of outliers with massive water demands. The Hospital subsector included over 100 accounts and a WUA of 28.6 ± 13.9 kL/day, which explains the large proportion of ND water consumed by the subsector. The subsector's smaller CI reflects a more consistent spread of water between accounts and the reduced influence of outliers. The School subsector included almost 120 users, with an average WUA of 12.7 ± 2.6 kL/day. This reasonably low WUA meant daily water demand from Schools was similar to that of Outdoor Sports/Recreation, Tertiary Institutes, and Rest Homes. The CIs for the School and Rest Home subsectors were extremely narrow, suggesting a consistent distribution of water use between accounts in these subsectors. Indoor Sports Facilities consumed almost 20 kL/day per account but had only a small number of users, explaining the subsectors relatively low daily water use. The Community subsector easily had the lowest WUA of the Institutional subsector

High demand in the Industrial sector was primarily driven by the Food Processing/Packaging subsector, which in turn was the product of over 110 accounts with a WUA of 87.4 ± 46.5 kL/day (Table 5.3). The breadth of this interval reflects a large standard deviation, which was produced by a small number of accounts with demand over ten times the subsector's WUA. The Beverage Processing subsector recorded the highest WUA of any category, averaging 241.1 ± 173.7 kL/day. Thus, despite having only 20 users, the subsector's total water use was close to 3,500 kL. The extremely wide CI for this subsector reflected both the small number of accounts sampled, and distinct split between the majority of accounts with demand less than 200 kL/day, and the minority who consumed between 300 and 1300 kL/day. Contrast this with the Manufacturing/Refining subsector, which consumed 4,500 kL/day. This subsector had almost 200 accounts, but a WUA of only 27.5 ± 13.3 kL/day. The narrow CI in the Manufacturing/Refining subsector reflects the reasonably constant level of demand between these accounts. Water demand from a small number of accounts was still well above average, but these were less frequent than in the other subsectors.

5.3 Seasonal Patterns of Non-Domestic Water Use

5.3.1 *Overall Seasonal Variation*

A general comparison of water use between months in successive years could not identify a clear seasonal pattern to ND water consumption. This is illustrated in Figure 5.3 below, where total water use varied more within each month than between months. This within group variation reflects not only fluctuations between months of different years, but also the overall growth of ND water demand (Figure 5.1). The timing and volumetric size of peak water use can only be captured by correcting for the underlying growth in water demand between years.

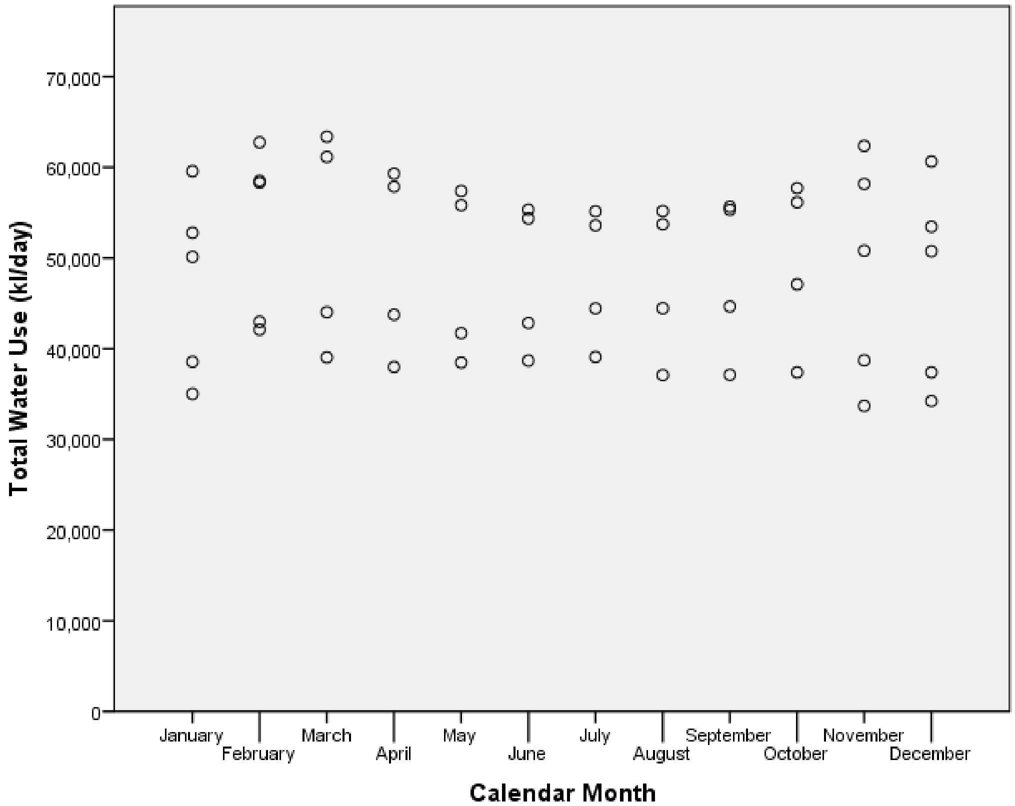


Figure 5.3 An assessment of overall Non-Domestic water use through the average calendar year.

The most effective strategy to identify regular/seasonal or irregular patterns in a time series is to remove the underlying trend. In this case, comparing water use for each month to the corresponding Centred Moving Mean (CMM) was used to graph variations in water use around the background average. This analysis highlighted the regular occurrence of peak water demand of 5-15% above the background average every February and March (Figure 5.4). For the three summer periods captured by the CMM, March consistently experienced the largest relative water demand, with the greatest peak occurring in March 2010 when water demand exceeded +13%. The relative water use for the February and April of 2010 were also the highest recorded for these months. Lowest or base consumption ranged between -5 and -10%, although timing varied between years (Figure 5.4). In 2008, base water use fell to around -5% from August through to January 2009. There was considerably more variation in 2009, with water use falling from May to a low of -6% in September. In 2010, water demand dropped steadily between June and August to -7.5%, but had returned to average by October. Finally, in 2011 base water use occurred in May through to August. In all three years, base water use dropped to at least 5% below the background average. Relative WUA tracked daily water use over most of the study period.

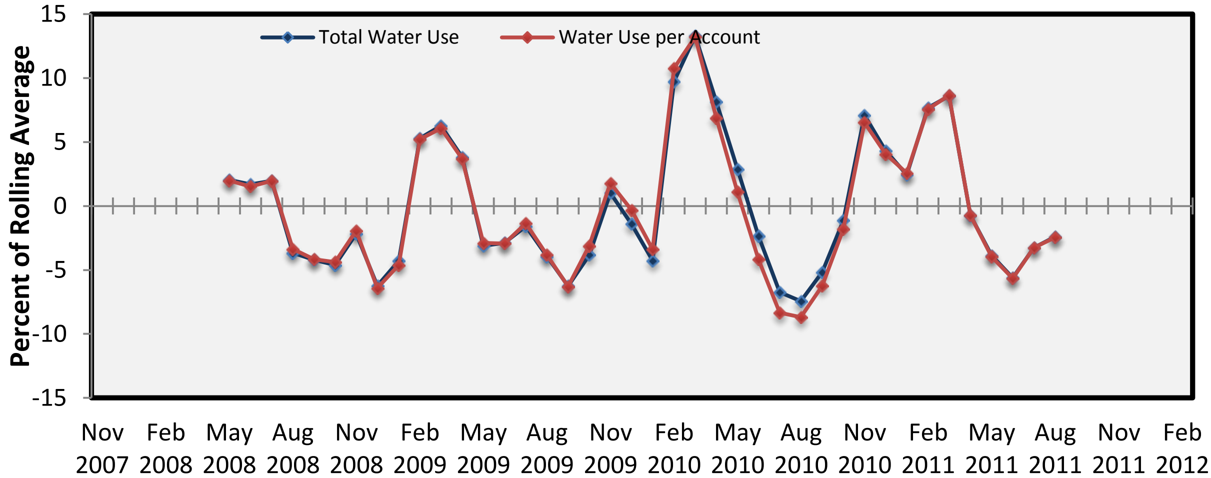


Figure 5.4 Time series analysis of overall Non-Domestic water demand relative to the Centred Moving Mean (CMM).

Monthly Index (MI) scores represent the average water use of each month, relative to the background average, thereby significantly reducing the variation within average calendar months. This decreased variation within months allowed ANOVA tests to confirm differences between months were statistically significant at the 95% level. MI scores suggest that ND water use peaks in February and March, with a smaller peak occurring in November (Figure 5.5). The primary February/March peak ranged in size from 105% to 115% of average water use, and was generally highest in March. Moreover, in no year did the MI score drop below 105%. The consistency of this peak suggests water use in February and March is an important feature of Auckland's ND water use. The smaller November peak had an average MI score of 103%, and an interquartile range between 99% and 105%. This suggests demand for water is not consistently high in November. Base water use appears to occur between August and October (Figure 5.5). During this period, water use dropped to around 95% of the background average. These months also experience the lowest internal variation, implying this is a regular trend. ANOVA and tukey pairwise testing confirmed there was a statistically significant difference between the MI scores for February/March compared with the months June through to October.

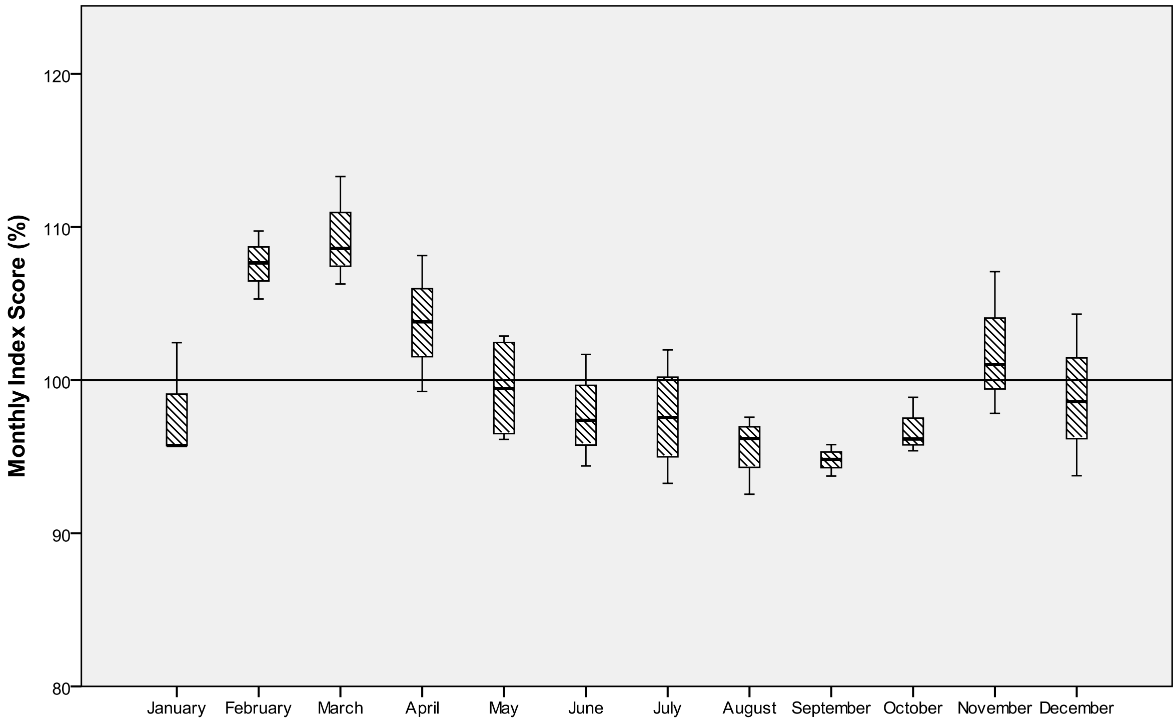


Figure 5.5 Monthly Index Scores for overall ND water use over the average calendar year. MI scores represent the water use for a given month relative to the centred moving mean. ANOVA and tukey pairwise tests confirm there are significant differences between peak and base consumption. Peak (base) periods are also significantly above (below) the background average.

5.3.2 *Seasonal Patterns of Water Use within Sectors*

The disaggregation of the overall seasonal pattern in ND water consumption is important to establish individual sources of this seasonality. Examining relative water use in each sector establishes a coarse understanding of the factors influencing ND seasonality. In all sectors, fluctuations in relative daily water use and relative WUA tracked one another over time. This confirms that seasonal fluctuations are produced by the consumption patterns of individual users, rather than changes to the number of users. Temporal patterns of water usage differed significantly between each major ND sector (Figure 5.6). Water use in the Commercial sector exhibited a regular seasonal pattern throughout the study period, with increased water demand generally occurring from November through to April. Peak magnitude differed between most years. In the summer of 2008/2009, Commercial water use peaked in February at +8% of background use, and then dropped to +6% for March. An earlier surge in water use was also observed in November of 2008, while water use in the corresponding December and January fell to the background average. In contrast, a November peak was not apparent for the summer of 2009/2010. However, relative water demand in February and March of 2010 was the highest in the study period, sitting respectively at +13% and +12%. The summer of 2010/2011 exhibited a nearly identical trend to that of 2008/2009, with the exception that no November peak was observed. Although only two full base periods were captured in the detrended data, below average Commercial water use of -5% to -10% consistently occurred between May through to October (Figure 5.6).

Relative Industrial water use was far more unstable and differed at notable periods from the Commercial sector (Figure 5.6). Mainly, the timing and magnitude of peak and base consumption differed between years. February and March consistently returned the highest relative water demand of between +5 and +10% above the background average. April also experienced relatively high consumption in 2009 and 2010, but only average usage in 2011. Further peaks of +8.8%, +2.9%, and +6% were also observed in July 2008, November 2009, and November 2010 respectively. Given the large water demand from the Industrial sector, these peaks could have made a considerable impact on overall ND water use for these months, particularly in November. Water use dropped to almost -15% in December and January for the summers of 2008/2009 and 2009/2010 (Figure 5.6). In the 2010/2011 period, water use fell to just -1.5% for December and -3.6% for January.

The Institutional sector experienced the largest peak in relative water use of any sector (Figure 5.6). This occurred in March 2010, when water demand grew to over +21% of the background average. February and April of this year experienced comparably high demand of +15% and +8.4% respectively. Relative water use also peaked from November 2010 to April 2011, reaching its maximum of +14.6% in March 2011. In 2009, water use in February and March was small compared to other summers, with the March peak only reaching +4.9%. The timing of base water demand differed each year (Figure 5.6). In 2008, water demand decreased through all observed months to a base of -12.5% in October, after which it increased to the small peak in March 2009. For 2009, two separate incidents of low water demand were observed – once in May and the other in September. In 2010, water use dropped steadily below average from May until reaching base water use was reached in July.

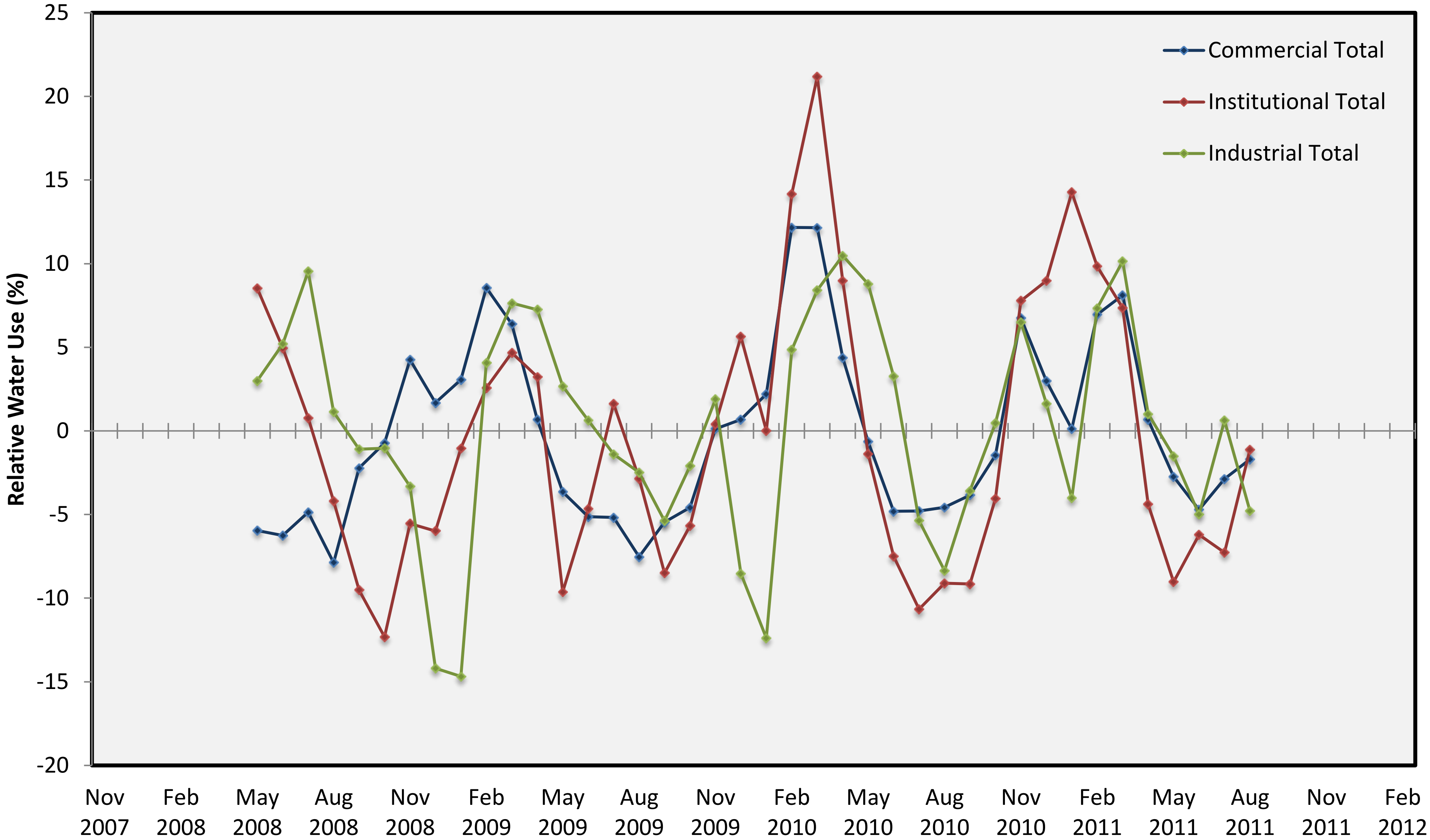


Figure 5.6 Water demand in the Commercial (Blue), Institutional (Red), and Industrial (Green) sectors, relative to the associated twelve month centred moving average over time.

MI scores created a useful summary of the seasonal fluctuations observed for water use within each of the primary sectors (Figure 5.7). Seasonality was greatest within the Institutional sector, which experienced MI scores of around 110% in both February and March. Base MI scores for the Institutional sector also dropped to below 90% in September and October, with a relatively linear transition occurring between these two periods. MI scores in the Industrial sector peaked in February though to April, with March experiencing the highest use of almost 110%. Following April, scores declined through the year to approximately 95% in September. A small peak of 103% was observed in November, before water use plummeted in December and January to 90% of the background average. This was well below the base scores of the other sectors. Commercial MI scores demonstrated a smooth transition from peaks in February and March of around 108%, to base use of 95% in June. Interestingly, there was little variation between the same months of different years, confirming water use follows a relatively consistent pattern each year. Confidence intervals for MI scores in February and March in all sectors did not include 100%, which confirms there is a significant peak in ND water use during these months. The following sections further disaggregate the ND sectors to uncover sources of this variation.

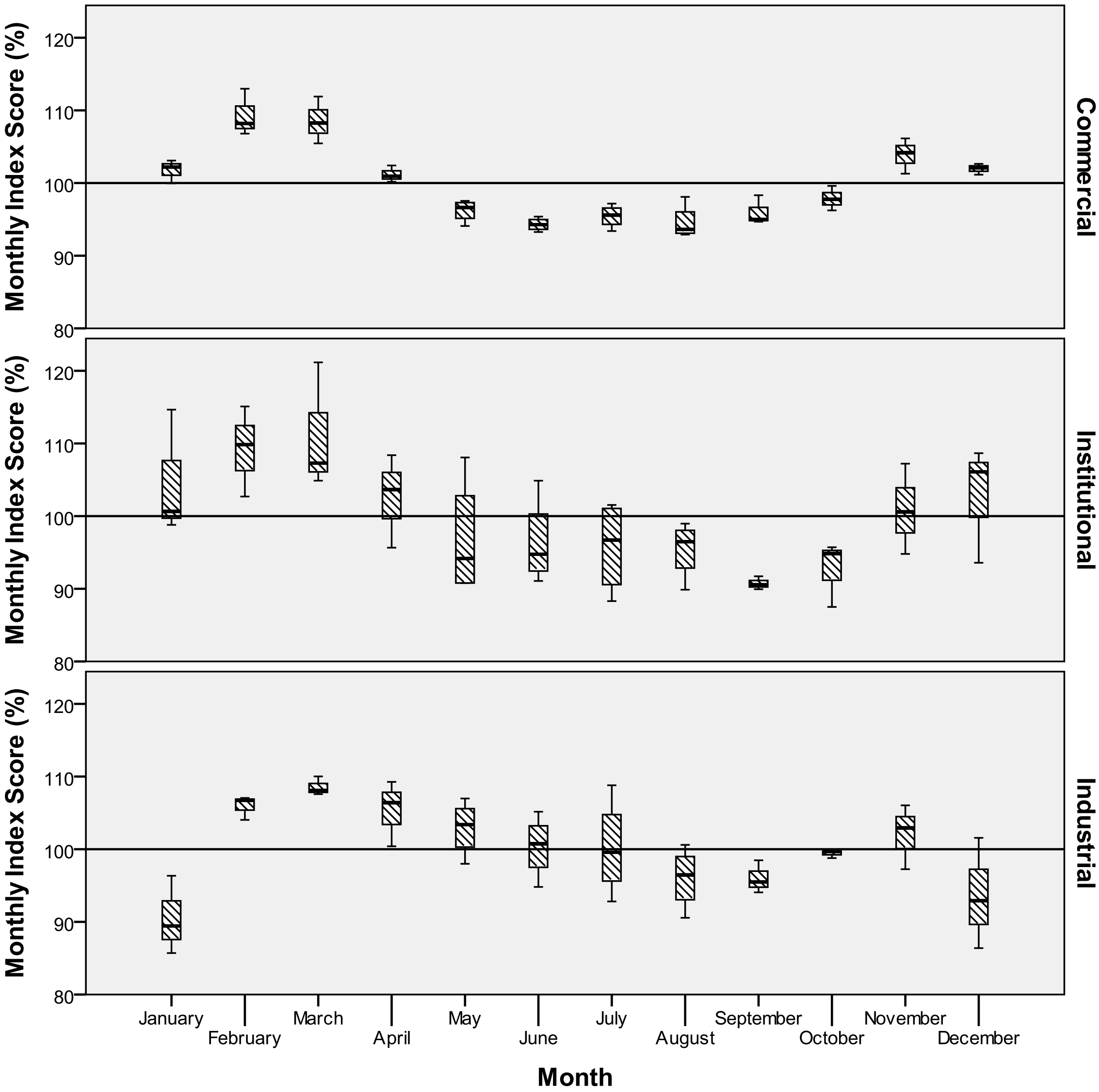


Figure 5.7 MI Scores for the Commercial, Institutional, and Industrial sectors over the average calendar year. MI scores compare the water use in any given month to a moving average, and then take the average for each month. Thus, a score of 110% in a given month means water use in that month is 10% above the moving average. ANOVA and Tukey pairwise confirmed there was a statistically significant difference between the average MI scores of the peak and base period within each sector.

5.3.3 *Seasonal Patterns of Water Use within Subsectors*

The deconstruction of the ND sector down to the subsector level revealed additional complexity that had previously been masked by sector level aggregation. An initial assessment of water demand from the ND subsectors showed that seasonality differed markedly between groups (Table 5.4). In the Commercial sector, Agriculture/Horticulture was the greatest source of seasonal variation, with percentage seasonality exceeding 30% for both calculations. Peak water use for this subsector averaged 1,400 kL/day; about 300 kL above the daily average for this sector. There was a similar difference between peak and average use for both the Accommodation and Multistory Office subsectors, despite much lower percentage seasonality. Peak water use for Laundromats and Shopping Centres also exceeded 1,000 kL/day. However, this occurred in July for Laundromats and December for Shopping Centres. The difference between mean and maximum water use was less than 100 kL/day in both categories.

Water use within the Industrial subsectors varied more than the Commercial subsectors (Table 5.4). Moreover, due to the larger volumes consumed by Industrial users, peak consumption was of greater magnitude. Peak water demand for the Beverage Processing, Food Processing/Packaging, and Manufacturing/Refining subsectors each greatly exceeded 3,000 kL/day. The Food Processing/Packaging subsector had the largest peak by volume, with water consumption topping 9,000 kL/day in February. This was 500 kL/day greater than average daily water use. However, percentage seasonality for this subsector was low compared to the other major Industrial categories. Percentage seasonality was highest for the Beverage Processing subsector at 16.8%, whose peak water use represented an increase of 650 kL/day above average usage. Percentage seasonality of around 10% for the Manufacturing/Refining subsector generated a peak in consumption around 450 kL/day above the subsectors daily average. Water demand from the remaining Industrial subsectors was relatively minimal, although peak water use from Warehousing/Distribution averaged almost 1,000 kL/day in March.

Peak water use exceeded 1,000 kL/day for all of the Institutional subsectors, with the exception of the Community subsector (Table 5.4). Three Institutional subsectors recorded percentage seasonality of over 20%, including the Outdoor Sports/Recreation, School, and Tertiary Institute subsectors. Water use for Outdoor Sports/Recreation peaked in January at 2,300 kL/day, around 500 kL/day above average consumption. Peak water use for both the School and Tertiary Institute subsectors occurred in March, reaching 1,700 and 1,600 kL/day respectively. The Indoor Sports Facilities and Municipal subsectors both averaged around 10% seasonality. For the Municipal subsector, this resulted in a March peak of 5,300 kL/day, or about 400 kL/day above average, while the Indoor Sports Facility subsectors February peak was only around 100 kL/day above average. Percentage seasonality in the Rest Home subsector averaged around 7.5%, with peak water use of 1,500 kL/day occurring in February. Finally, seasonality for Hospitals was around 5%. However, due to high average demand for the Hospital subsector, this translated into additional demand of around 150 kL/day in August.

Table 5.4 Summary table of percentage seasonality and peak water use for for each of the Non-Domestic subsectors.

Sector	Subsector	Percent Seasonality (Peak)	Percent Seasonality (Base)	Peak Water Use (kL/day)	Peak Month	Daily Water Use (mean) (kL)
Commercial	Agriculture & Horticulture	32.5	30.6	1,464.3	February	1,112.62
	Accommodation	9.9	7.8	3,408.2	March	3,143.00
	Cafe/Restaurant	1.8	3.0	733.9	September	704.40
	Commercial Store (Single)	3.9	5.0	383.2	October	366.57
	Commercial Stores (Multi)	6.1	5.2	580.6	August	542.66
	Halls/Entertainment	14.4	9.8	682.0	February	597.24
	Laundromat	9.0	12.6	1,294.5	July	1,170.16
	Low Story Office	6.9	4.7	424.5	February	400.14
	Multistory Office	13.1	5.5	2,587.4	February	2,292.70
	Petrol Station	5.3	8.1	388.0	August	368.97
	Shopping Centre	6.1	6.2	1,557.7	December	1,488.2
	Supermarket	11.5	6.5	217.7	July	195.65
	Vehicle Yard/Repair	21.3	7.6	502.2	February	419.16
	Total Commercial	**8.1**	**4.7**	**13,838.0**	**February**	**12,801.5**
Industrial	Beverage Processing	16.8	11.7	3,985.6	October	3,323.75
	Chemical/Pharmaceutical	8.2	14.1	837.0	November	784.45
	Food Processing/Packaging	7.5	10.8	9,270.2	February	8,719.59
	Manufacturer/Refining	11.0	9.0	4,872.6	February	4,445.91
	Textile/Printing	24.2	34.1	873.7	May	731.08
	Warehousing/Distribution	18.4	14.3	987.2	March	862.86
	Total Industrial	**9.4**	**10.3**	**20,383.1**	**February**	**18,867.6**
Institutional	Community (E.G. Church)	6.3	5.6	611.1	February	576.83
	Hospital	5.0	5.5	2,742.8	August	2,601.68
	Indoor Sports Facilities	11.4	8.2	1,054.9	February	943.54
	Municipal	9.1	11.9	5,312.3	March	4,931.9
	Outdoor Sports/Recreation	31.0	34.2	2,304.2	January	1,769.68
	Rest Home	8.4	6.5	1,505.3	February	1,387.63
	School	24.6	13.3	1,727.2	March	1,392.04
	Tertiary Institute	27.7	21.8	1,575.0	March	1,234.32
	Total Institutional	**10.7**	**6.7**	**16,272.4**	**March**	**14,837.6**
Other	Mixed Use	8.3	5.4	375.9	July	355.22
	Other Commercial	11.7	10.2	1,703.4	February	1,550.30
	Other Industrial	14.4	11.0	587.9	October	499.58
	Other Institutional	7.8	9.1	52.2	October	48.30
	Total Other	**6.3**	**7.4**	**2,586.1**	**October**	**2,453.4**
Total	**Total**	**9.0**	**4.2**	**52,930.9**	**February**	**48960.1**

While the previous analysis gives some insight into the seasonality of each subsector and its impact on peak water consumption, uncertainty remains in terms of large variations in water use within months. As a result, the true patterns of consumption within each subsector cannot be established. The standardised MI scores create a detailed image of the seasonal distribution of water use within each subsector. The Agriculture/Horticulture subsector demonstrated one of the clearest patterns of seasonality, with MI scores surpassing 125% from December through to February (Figure 5.8). This was followed by a rapid decrease in MI score to less than 75% for May to August. A clean seasonal pattern was also observed for the Accommodation subsector. Water use in February averaged around 108%, and peaked in March at 111%. A secondary peak occurred in November, with a relatively constant MI score of 105%. Base water use was observed between these peaks, falling to a low of around 94% in June. The seasonal pattern observed for the Laundromat subsector was substantially different from most subsectors. Base water consumption took place from November through to February, when water use was typically highest in other subsectors. Conversely, peak water use occurred from March through to September, with the largest MI scores occurring in March, followed by July and September. The Multistory Office subsector demonstrated a typical seasonal pattern, with peak use occurring over the summer. MI scores averaged around 115% in February, and were slightly lower for March. Water demand was at its minimum in August, although water use was well below average from June to October. November and April both exhibited above average water use.

Water use was highly variable in the Beverage Processing subsector, which was reflected in both seasonal patterns and wide estimates of MI scores (Figure 5.9). MI scores were inflated from October to December, with water demand peaking at 120% in November. A secondary peak also occurred through February (105%) and March (110%). Water demand was at its lowest in January, with an average MI score of less than 90%. Water use from May to September was also below the background average. In the Food Processing/Packaging subsector, water use peaked at close to 110% in March, and remained at least 5% above average from February to July. Water use dropped to below 95% in September, December and January, with some years registering MI scores under 90%. Peak and base periods were relatively clear in the Manufacturing/Refining subsector. Peak water use occurred in February and March, with MI scores ranging between 105% and 110%. For base water use, December and January returned MI scores of below 90%. Water use for October was also well below average.

Water use in the Hospital subsector was relatively stable through the calendar year, with water use peaking at 105% in February and March (Figure 5.10). In contrast, base water use reached 90% in November and January. Water use was also below average for October and December. MI scores for the Municipal subsector suggested water use was relatively unseasonal. Water use reached just 105% in February, July, and December, while MI scores of 90% were observed in May, September and October. Usage through the rest of the year varied slightly around the average. The Outdoor Sports/Recreation subsector demonstrated a very clear seasonal trend. Average water use exceeded 130% from December through to February, peaking at almost 150% in January and February. Water consumption fell through March and April, with base demand of 75% occurring from June to August. Water use was also seasonal for Rest Homes, with water use peaking in December, January and February from between 105% to 110%. Base water use was more significant, varying around 95% from May through to October. Water use in the School subsector exhibited a more complex seasonal pattern than other categories. Peak water use was notable in February and March, with MI scores of 115% and 130% respectively. A secondary peak occurred in November, with an MI score of 110%. Base consumption did not appear to occur for a constant period, with MI scores dropping to around 90% in July, September, October, and December. Water use in the Tertiary Institute subsector exhibited relatively constant demand from April to October. However, water use fell in November and reached base consumption of 80% in December and January. Demand then rapidly increased to 110% in February, and peaked at almost 140% in March.

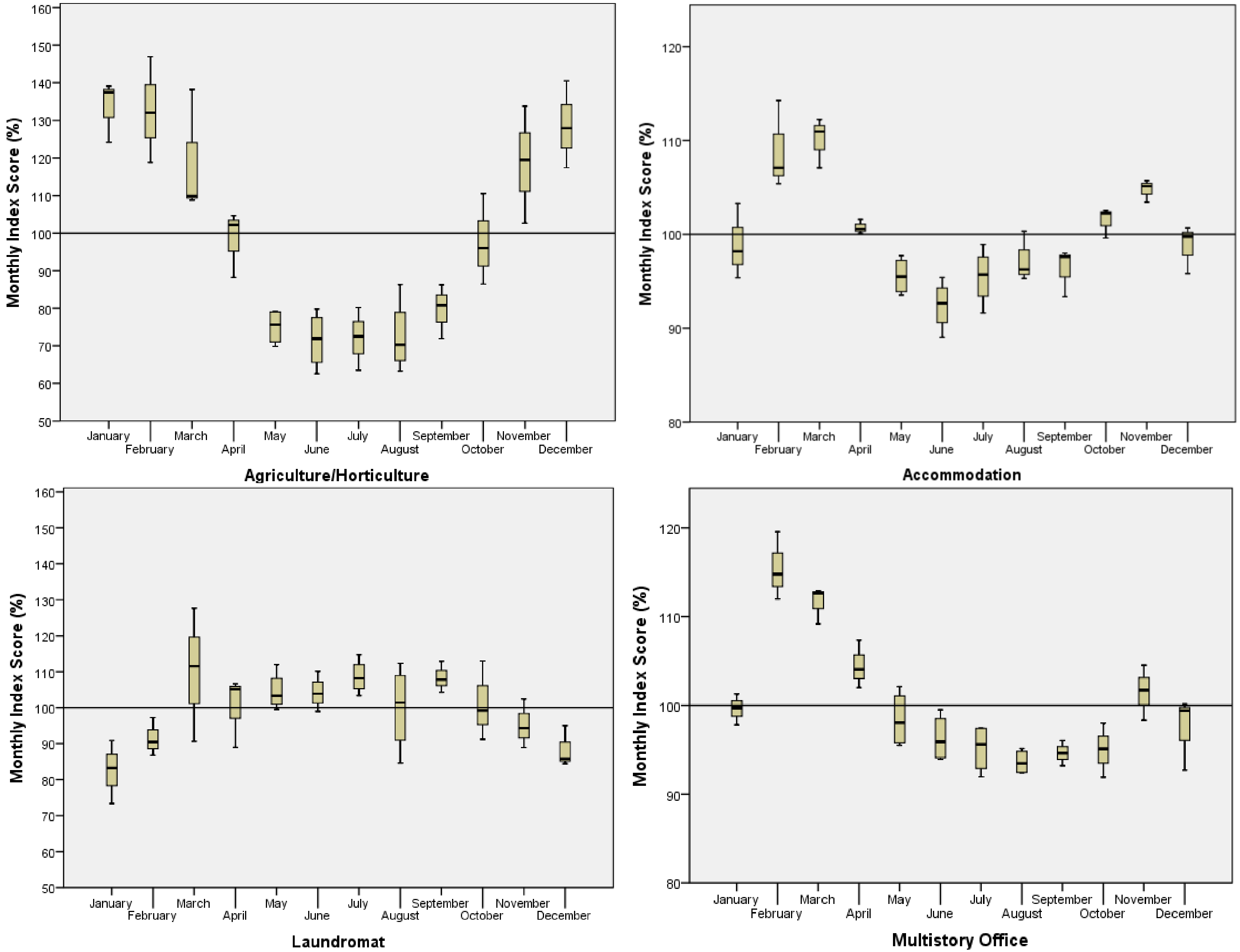


Figure 5.8 Boxplots of the Monthly Index scores for the Agriculture/Horticulture, Accommodation, Laundromat, and Multistory Office subsectors.

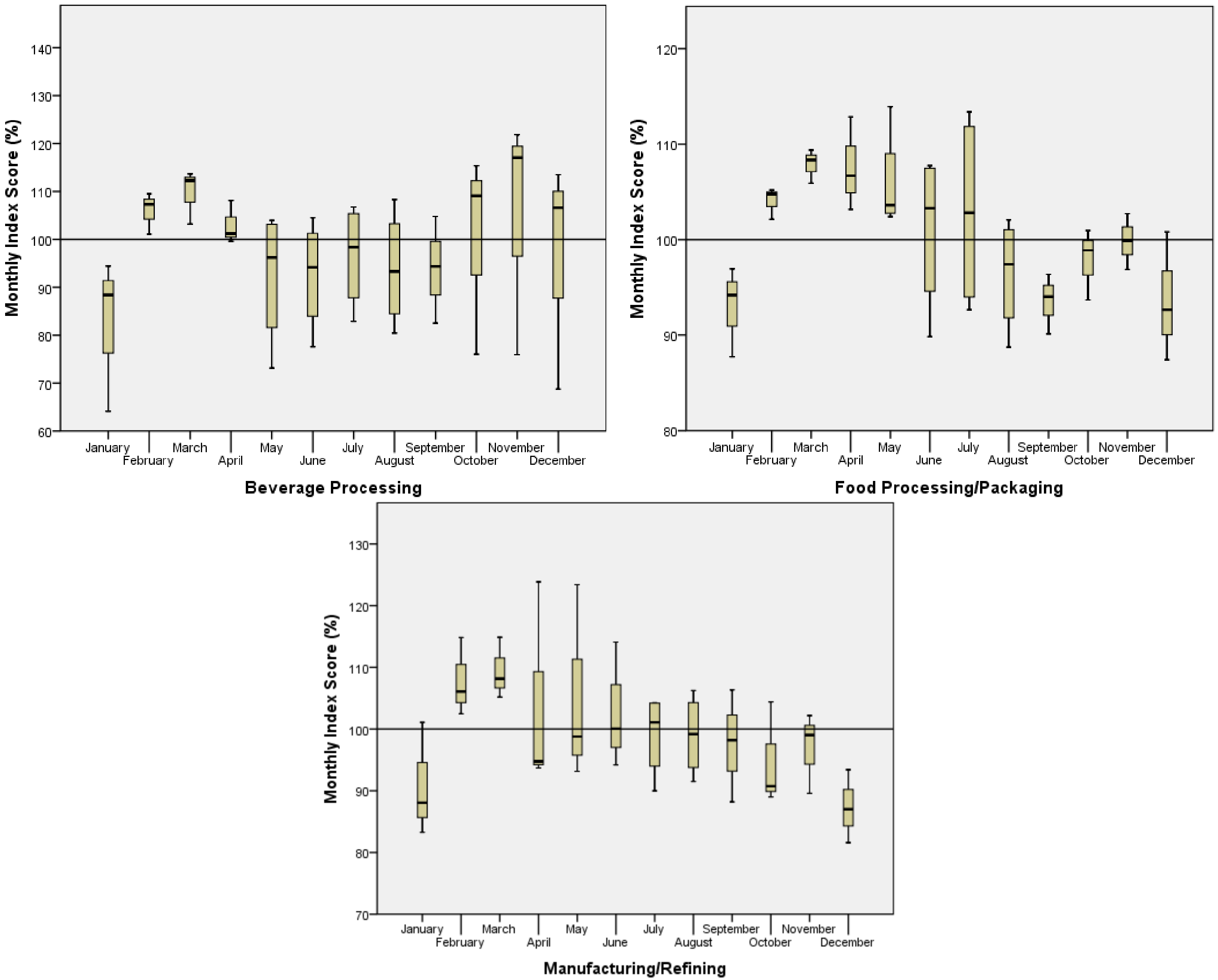


Figure 5.9 Boxplots of the Monthly Index Scores for the Beverage Processing, Food Processing/Packaging, and Manufacturing/Refining subsectors.

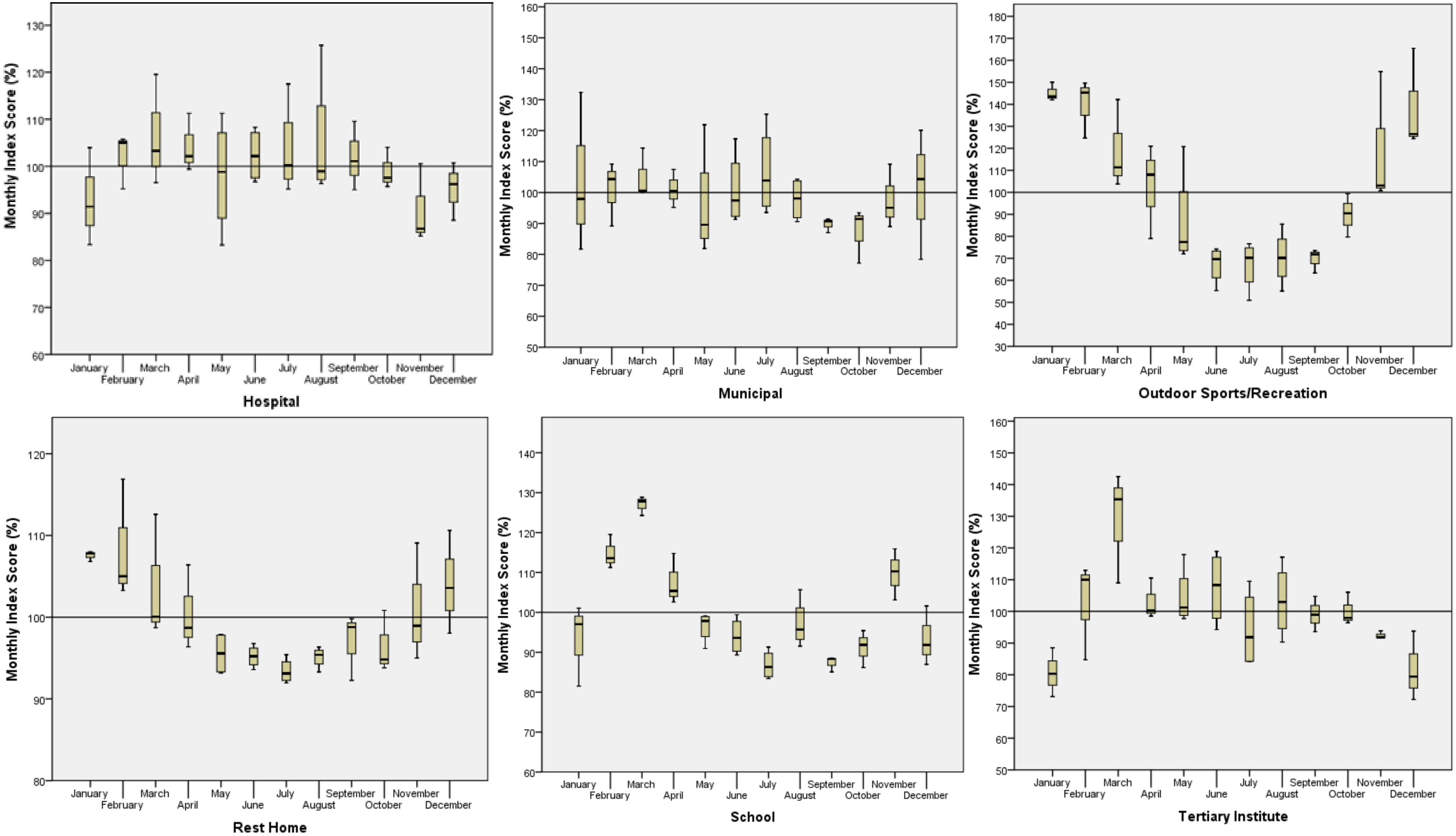


Figure 5.10 Boxplots of the Monthly Index Scores for the Hospital, Municipal, Outdoor Sports/Recreation, Rest Home, School, and Tertiary Institute subsectors.

5.3.4 *Investigating Sources of Peak Water Use*

The disaggregation of the overall seasonal pattern in ND water consumption is important to develop an understanding of this seasonality. However, seasonal subsectors must also consume significant volumes of water to influence the overall ND seasonality. Since ND water demand peaks in February and March, the volumetric contribution of each subsector to water use in these months is of particular interest. MI scores can be used to calculate additional water use for each subsector in a given month. This technique predicted additional water use of 4,182 kL/day for February 2011, compared with an actual peak of 4,467 kL/day. Contrasting predicted versus actual February water use for each subsector returned a significant Correlation Coefficient (R) of 0.99. Peak water demand for February was derived from a number of subsectors, and offset by below average demand in the Commercial Stores (Multi) and Laundromat subsectors (Figure 5.11a). The Outdoor Sports/Recreation subsector made the greatest contribution to peak February water use, consuming an additional 700 kL/day of water. The Beverage Processing subsector contributed 600 kL/day of additional demand, followed by the Multistory Office and Manufacturing/Refining subsectors, which each consumed and extra 400 kL/day. Agriculture/Horticulture, Accommodation, and Food Processing/Packaging each used around 300 kL/day more than average. Another six subsectors each contributed over 100 kL/day to the February peak. It is interesting to note that the impact of the Shopping Centre, Municipal, Rest Home, Hospital, Tertiary Institute and School subsectors was minimal, despite their relatively large demand. Conversely, the Outdoor Sports/Recreation subsector consumed the most additional water in February, despite a comparatively normal average consumption. Peak water use for March 2011 was estimated to contribute an additional 5,339 kL/day, compared with an actual volume of 5,019 kL/day. The relationship between estimated and actual March water use for each subsector also returned an R-value of 0.99. The Industrial subsectors had the greatest impact on peak water use in March (Figure 5.11b). The Food Processing/Packaging subsector contributed an additional 900 kL/day during March 2011, followed by around 600 kL/day for Beverage Processing, and 550 kL/day for Manufacturing/Refining. The Tertiary Institute subsector also added additional water demand of 450 kL/day. The Accommodation, Multistory Office Building, Municipal, Outdoor Sports/Recreation, and School subsectors each consumed between 300 and 400 kL/day of additional water in March 2011. Additional water demand from the Agriculture/Horticulture and Hospital subsectors was about 200 kL/day. This reveals a shift between February and March in the sources of peak consumption. The Food Processing/Packaging, Hospital, Schools, and Tertiary Institute subsectors each noticeably increased their water consumption in March, while water demand dropped in the Agriculture/Horticulture and Outdoor Sports/Recreation subsectors.

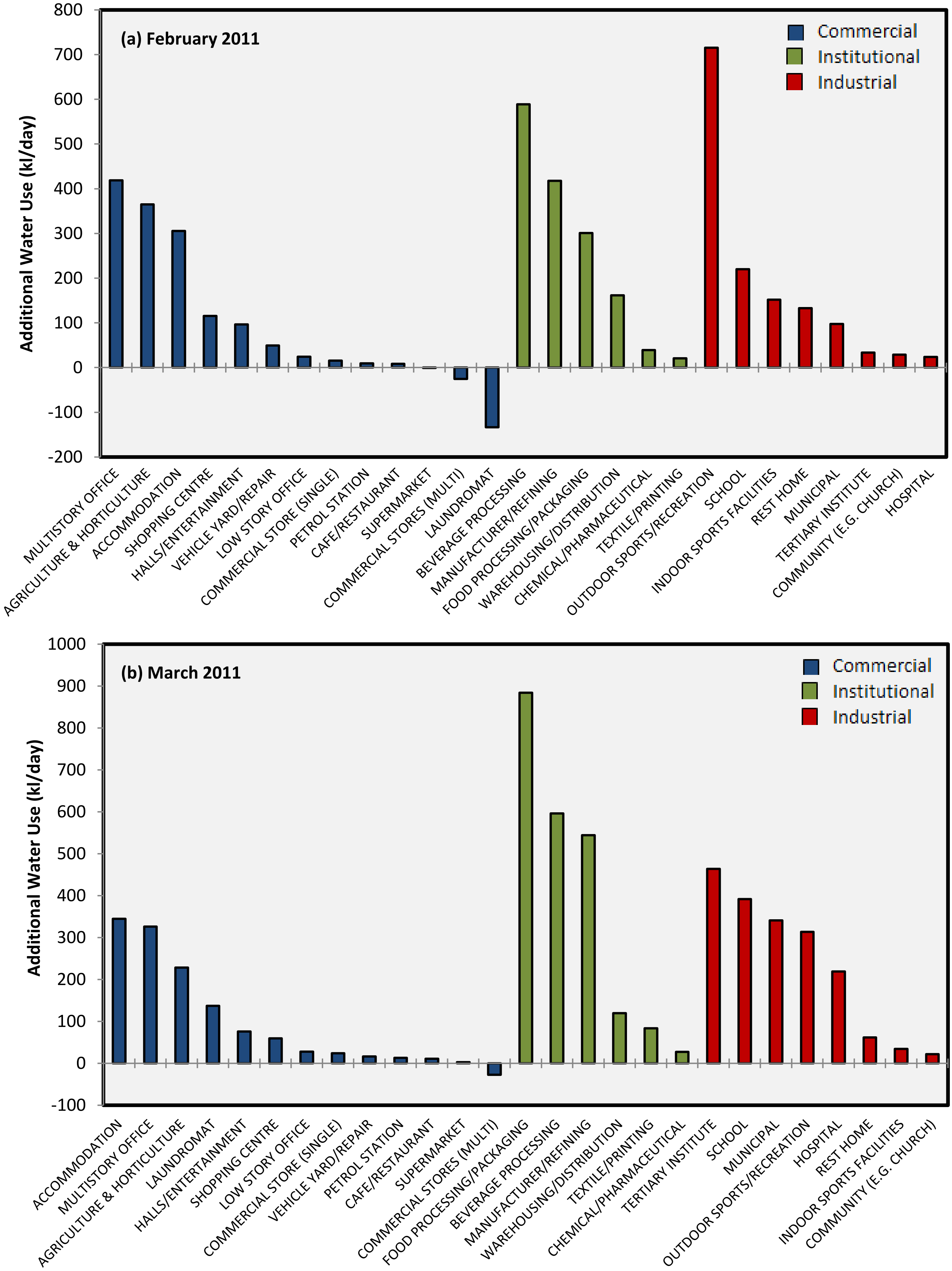


Figure 5.11 An analysis of the distribution of peak water demand in February and March between the Non-Domestic subsectors. Additional water use for each subsector was calculated by multiplying the average Monthly Index score by the Centred Moving Mean of February (a) or March (b) 2011, and then subtracting the Centred Moving Mean.

5.3.5 *Underlying Sources of Peak Water Use*

Relative water use in most of the Commercial subsectors was strongly correlated with climate (Table 5.5). This relationship was strongest for the Agriculture/Horticulture subsector, with all correlations statistically significant at the 1% level. Relative water use for these subsectors had a strong, positive correlation with average and maximum temperature, and a negative correlation with rainfall and Wet Days. Somewhat surprisingly, water use for this subsector was also significantly correlated with Gross Domestic Product (GDP) and Guest Nights. The Accommodation and Multistory Office subsectors demonstrated a weaker correlation to climate, but in a similar pattern to the Agriculture/Horticulture subsectors. Relative water use for Accommodation also had a weak positive correlation with GDP, and a strong positive correlation with Guest Nights. Water use for the Laundromat subsector was not related to either rainfall or Wet Days, but did have a weak negative relationship with both temperature variables. This subsector also demonstrated a weakly negative relationship with both GDP and Guest Nights. The Food Processing/Packaging, Beverage Processing, and Manufacturing/Refining subsectors did not exhibit a statistically significant correlation with climate, GPD, Consumer Price Index (CPI), or Guest Nights. Moreover, water use in the Food Processing/Packaging and Beverage Processing subsectors did not correlate with their respective Stocks of Finished Goods. Scatterplots did not demonstrate any alternative non-linear relationships between these variables. The Manufacturing/Refining subsector demonstrated a statistically significant relationship with Manufacturing Stocks of Finished Goods. Finally, relationships between the economy, climate, and water use varied widely between the Institutional subsectors (Table 5.5). Water use in Hospitals was unrelated to climate, but showed a weakly negative correlation to GDP. Similarly, the Municipal and Tertiary Institute subsectors were not related to any of the independent variables. Water use in the Outdoor Sports/Recreation subsector had a strong positive association with temperature and a negative relationship with rainfall and Wet Days. GDP had an unexpectedly strong correlation with water use in the Outdoor Sports/Recreation subsector. These correlations were all significant to the 1% level. Water use in the School subsector was positively associated with the climate and Guest Night variables.

Table 5.5 An analysis of the relationship strength between relative water use in each of the significant Non-Domestic subsectors and a range of independent variables. Subsectors are colour coded into the Commercial (Blue), Industrial (Green), and Institutional (Red) sectors. Relative water use is the water demand in a given month relative to the Centred Moving Mean. Independent variables include average temperature, average maximum temperature, rainfall, number of wet days, Gross Domestic Product (GDP), Consumer Price Index (CPI), Guest Nights, and Stocks of Finished goods for the Industrial sector and the Manufacturing, Beverage, and Food subsectors.

		Mean Air Temperature (°C)	Maximum Temperature (°C)	Rainfall (mm)	Number of Wet Days	GDP	CPI	Guest Nights	Total Industrial Sales	Manufacturing Sales	Beverage Sales	Food Product Sales
Agriculture & Horticulture	Pearson Correlation	.902**	.907**	-.574**	-.736**	.766**	.035	.819**	.874**	-.547**	-.735**	.902**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.830	.000	.000	.000	.000	.000
Accommodation	Pearson Correlation	.667**	.675**	-.564**	-.603**	.473**	.110	.731**	.631**	-.411**	-.543**	.661**
	Sig. (2-tailed)	.000	.000	.000	.000	.002	.500	.000	.000	.008	.000	.000
Laundromat	Pearson Correlation	-.472**	-.477**	.293	.303	-.457**	.044	-.405**	-.538**	.323*	.215	-.561**
	Sig. (2-tailed)	.002	.002	.066	.057	.003	.789	.010	.000	.042	.182	.000
Multistory Office	Pearson Correlation	.706**	.697**	-.391*	-.562**	.322*	.014	.539**	.683**	-.186	-.457**	.659**
	Sig. (2-tailed)	.000	.000	.013	.000	.043	.929	.000	.000	.251	.003	.000
Beverage Processing	Pearson Correlation	.193	.192	-.132	-.143	.174	.168	.158	.158	-.109	.029	.150
	Sig. (2-tailed)	.234	.235	.417	.377	.282	.300	.330	.330	.505	.860	.356
Food Processing/ Packaging	Pearson Correlation	-.018	-.027	.002	-.046	-.119	.048	-.037	.054	.193	.264	.012
	Sig. (2-tailed)	.914	.868	.988	.777	.463	.768	.819	.740	.232	.099	.942
Manufacturer/ Refining	Pearson Correlation	.035	.027	.027	-.090	-.209	-.029	-.097	-.009	.469**	.091	-.103
	Sig. (2-tailed)	.829	.871	.868	.582	.196	.857	.553	.956	.002	.577	.526
Hospital	Pearson Correlation	-.131	-.165	.245	.188	-.361*	-.017	-.203	-.153	.541**	.355*	-.247
	Sig. (2-tailed)	.419	.308	.128	.244	.022	.918	.209	.345	.000	.024	.124
Municipal	Pearson Correlation	.101	.126	.006	-.232	.022	.075	.131	.138	-.139	.068	.127
	Sig. (2-tailed)	.535	.438	.969	.151	.893	.648	.420	.395	.393	.676	.433
Outdoor Sports/Recreation	Pearson Correlation	.867**	.887**	-.527**	-.711**	.727**	-.012	.755**	.904**	-.455**	-.603**	.910**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.943	.000	.000	.003	.000	.000
School	Pearson Correlation	.525**	.524**	-.486**	-.530**	.270	.003	.458**	.548**	-.170	-.323*	.547**
	Sig. (2-tailed)	.001	.001	.001	.000	.092	.987	.003	.000	.293	.042	.000
Tertiary Institute	Pearson Correlation	-.086	-.094	-.011	-.103	-.241	.081	-.132	-.141	.172	.152	-.187
	Sig. (2-tailed)	.599	.565	.947	.525	.134	.618	.416	.385	.290	.349	.247

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

5.4 End Uses and Efficiency of Significant Seasonal Users

5.4.1 *Water Demand from Significant Seasonal Users*

The subpopulation of Significant Seasonal Users (SSUs) consisted of 358 accounts, or roughly 15% of the accounts in the final dataset (Table 5.6). Total water use from SSUs averaged around 48.5% of overall ND water use. SSUs accounted for only 32% of Commercial demand, suggesting SSUs have a minor influence on water demand in this sector. This could reflect the makeup of the Commercial sector, where water use is distributed across a large number of accounts, rather than concentrated in a few (Table 5.2). This suggests the survey responses from SSUs may not be particularly relevant to the Commercial sector. Of the Commercial subsectors, only Agriculture/Horticulture, Halls/Entertainment, and Laundromats had more than half their consumption derived from SSUs. SSUs consumed only 22% of water use in the Accommodation subsector, and 40% of water use from the Multistory Office subsector. The Commercial sector also received the lowest number of responses to the survey (Table 5.6). In fact, only five of the thirteen Commercial subsectors received any responses, and only the Agriculture/Horticulture and Multistory Office subsectors had at least three responses.

Over 50% of water demand in the Industrial and Institutional sectors came from accounts in the SSU subpopulation (Table 5.6). SSUs also accounted for much of the demand in each of the Industrial subsectors, consuming more than 50% of water in all but the Chemical/Pharmaceutical and Food Processing/Packaging subsectors. SSUs in the Food Processing/Packaging subsector still accounted for around 45% of water demand. The Industrial subsectors were also fairly well represented by the survey, with responses from around 20% of Industrial SSUs. Most of these respondents came from the Food Processing/Packaging, Beverage Processing, and Manufacturing/Refining subsectors. These responses should be relevant to overall Industrial water consumption, as SSUs account for most of the sector’s demand. For the Institutional subsectors, over 70% of water used by the Municipal, Outdoor Sports/Recreation, and Tertiary Institute subsectors was consumed by SSUs (Table 5.6). SSUs accounted for between 35-45% of the water used by the Indoor Sports Facilities, Rest Home, and School subsectors. Around 20% of SSUs in the Institutional sector responded to the survey. Most of these came from the Municipal and School subsectors. The Indoor Sports Facilities and Outdoor Sports/Recreation subsectors also received at least three responses, while only the Community subsector received no responses.

The total number of respondents to the survey was 61, giving it an overall margin of error of 11.4%.

Table 5.6 Summary of information for the subpopulation of Significant Seasonal Users (SSU), and the number of respondents to the survey from each subsector.

Sector	Subsector	Number of Accounts	Number of SSUs	Number of Survey Respondents	Water in Category consumed by SSUs (%)
Commercial	Accommodation*	161	19	2	22.3%
	Agriculture & Horticulture*	58	20	3	58.8%
	Cafe/Restaurant	162	1	0	5.7%
	Commercial Store (Single)	85	3	0	15.8%
	Commercial Stores (Multi)	41	2	0	10.1%
	Halls/Entertainment	51	8	2	59.7%
	Laundromat*	63	11	2	61.6%
	Low Story Office	88	1	0	7.7%
	Multistory Office*	148	33	5	39.8%
	Petrol Station	46	3	0	27.5%
	Shopping Centre	37	7	0	25.6%
	Supermarket	29	2	0	20.7%
	Vehicle Yard/Repair	69	5	0	19.9%
	Total Commercial	**1038**	**115**	**14**	**32.1%**
Industrial	Beverage Processing*	20	13	4	70.4%
	Chemical/Pharmaceutical	62	11	1	35.9%
	Food Processing/Packaging*	114	33	8	44.8%
	Manufacturer/Refining*	190	37	6	51.8%
	Textile/Printing	41	6	1	79.3%
	Warehousing/Distribution	63	10	1	54.9%
	Total Industrial	**490**	**110**	**21**	**52.4%**
Institutional	Community (E.G. Church)	88	6	0	16.6%
	Hospital*	103	16	2	40.7%
	Indoor Sports Facilities	56	12	3	36.4%
	Municipal*	83	22	8	70.5%
	Outdoor Sports/Recreation*	75	27	4	78.6%
	Rest Home	59	14	2	43.2%
	School*	114	20	6	44.8%
	Tertiary Institute*	83	16	1	83.5%
	Total Institutional	**661**	**133**	**26**	**58.1%**
Total	**Overall Non-Domestic**	**2436**	**358**	**61**	**48.5%**

* Significant contributor to February/March peak

5.4.2 *Significant Seasonal Users and Peak Water Use*

The influence of the SSU subpopulation on seasonal water use is clear when consumption patterns are compared between SSUs and 'non-SSUs'. SSUs appear to make a major contribution to additional water use in February (Figure 5.12a). The Accommodation subsector was an exception, with most of the additional water demand in February being derived from non-SSUs. Water demand from SSUs in the Laundromat subsector was also lower than non-SSUs; although since overall Laundromats used less water in February; SSUs still drove seasonality within the subsector. Additional water demand from SSUs doubled that of non-SSUs in the Agriculture/Horticulture and Multistory Offices subsectors. In the three largest Industrial subsectors, additional water use from non-SSUs was less than 100 kL/day, whilst SSUs accounted for over 300 kL/day. In the Hospital subsector, demand from non-SSUs was almost 100 kL/day below average and demand from SSUs was 100 kL/day above average. SSUs also accounted for most of the additional water demand from Indoor Sports Facilities and Schools. Finally, SSUs in the Outdoor Sports/Recreation subsector added an extra 600 kL/day to peak water use in February.

Additional water use in March was divided more equally between the subsectors. Non-SSUs also appeared to account for a greater proportion of additional water use than in February (Figure 5.12b). In both the Accommodation and Hospital subsectors, non-SSUs made up a greater proportion of the additional water use than SSUs. In other subsectors, the difference between the groups was diminished, despite water demand from SSUs generally still being at least twice that of non-SSUs. In the Laundromat subsector, demand from non-SSUs was just below average, while SSUs consumed an additional 200 kL/day. SSUs in the three largest Industrial subsectors still accounted for the majority of peak water demand in March. In the Municipal, Outdoor Sports/Recreation, School, and Tertiary Institute subsectors, additional demand from SSUs was between 300 and 400 kL/day. Conversely, demand from non-SSUs for these subsectors was less than 100 kL/day.

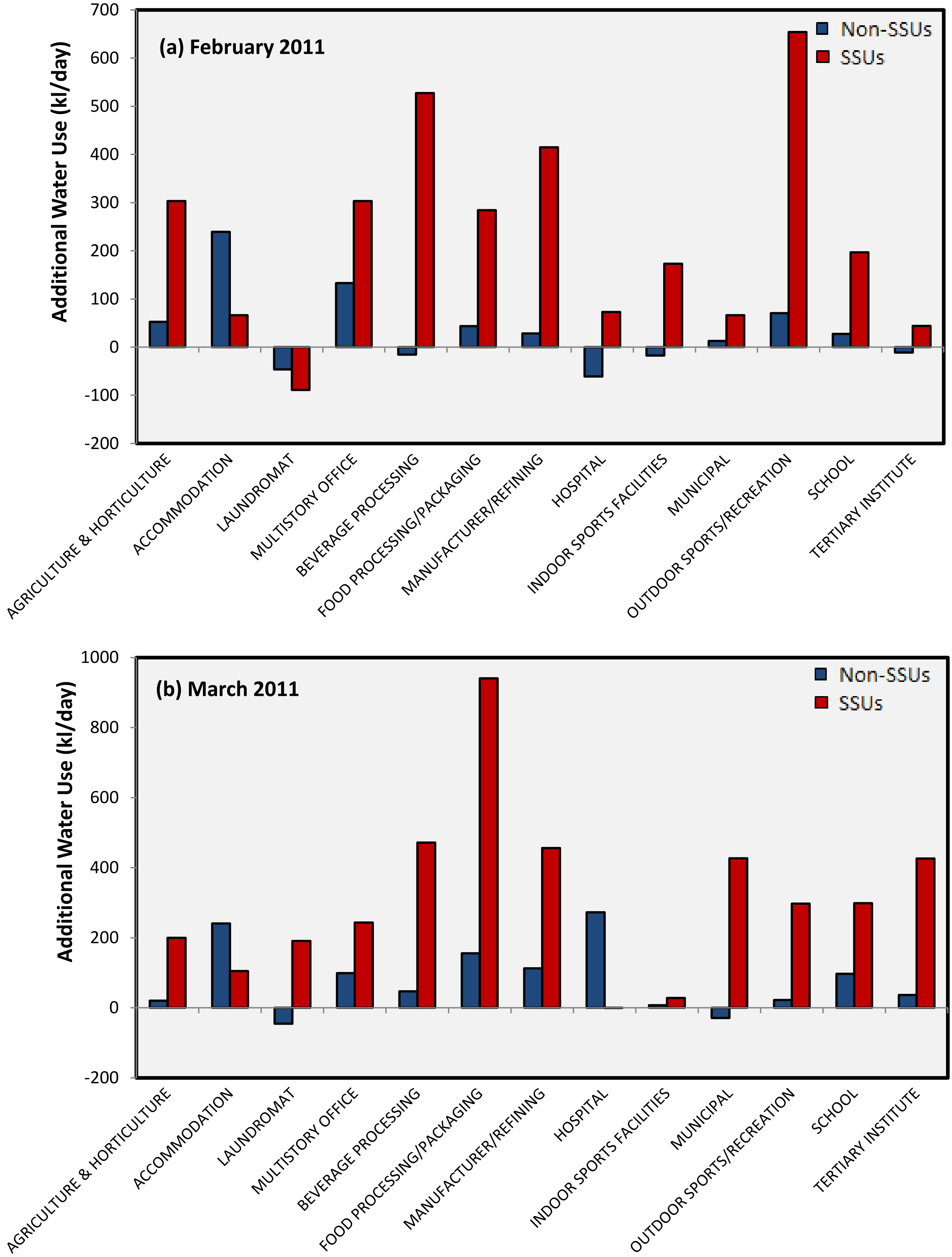


Figure 5.12 Comparison of the distribution of February (a) and March (b) peak water use between Significant Seasonal Users (red) and non-SSUs (blue). Additional water use from each category is calculated using the average Monthly Index score for each and multiplying by their Centred Moving Mean for February/March 2011.

5.4.3 *End Uses of Water*

The survey results suggest there is a broad range of end uses for water within the ND sectors (Figure 5.13). The most common water use for all sectors was Bathrooms, with between 80-90% of respondents in each sector identifying this as an end use for their business. The Kitchen was the second most common response in all sectors. In the Commercial sector, other common water uses included Cooling, Cleaning, Heating, and Laundry, with between 30-50% of Commercial respondents identifying these as sources of demand. In the Industrial sector, 80% of businesses identified Process as an end use. This was followed by around 55% for Cooling, 40% for Heating, and 30% for Food Processing/Brewing and Cleaning. The Institutional sector included the widest range of end uses. Over 30% of Institutional respondents identified Cleaning, Food Processing/Brewing, Cooling, Heating, Irrigation, Laundry, and Landscaping as end uses of water for their businesses. Only Process was selected by less than 30% of respondents. This illustrates the wide range of end uses that exist within the ND sectors.

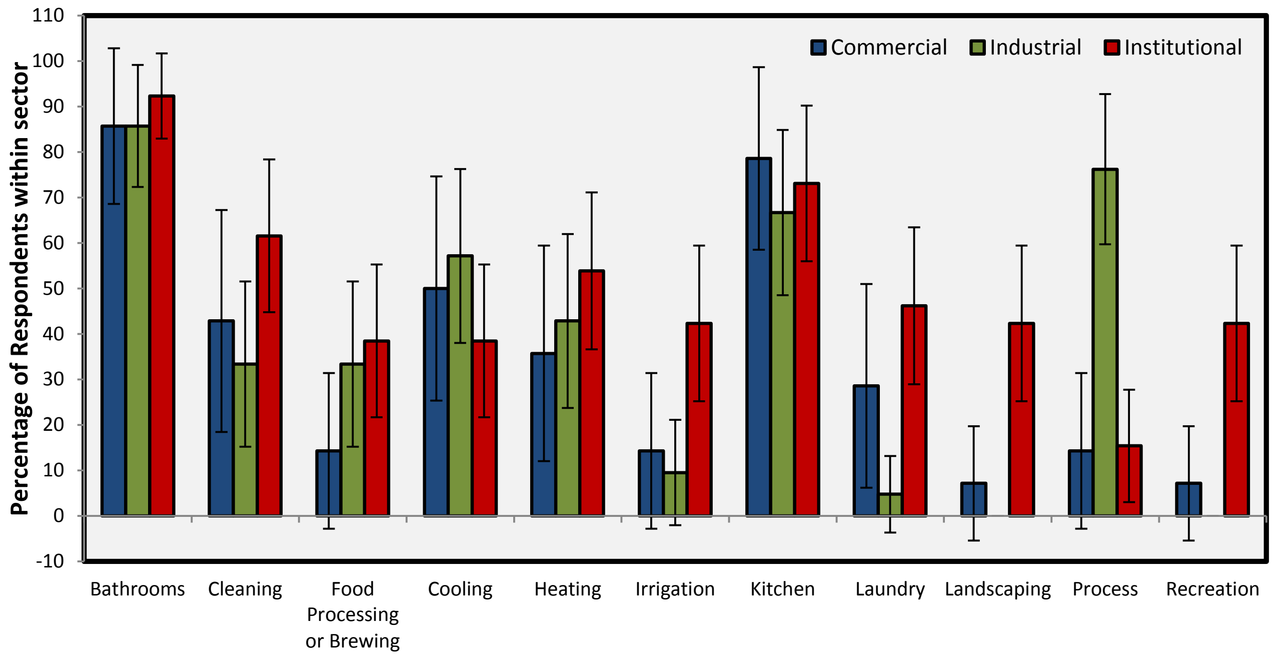


Figure 5.13 The distribution of end uses between the major Non-Domestic sectors, measured as the proportion of survey respondents within each sector.

Many respondents were uncertain about which end use consumed the most water in their business. This was most apparent in the Institutional sector, where over 20% of respondents were unable to identify the largest use of water on their property (Figure 5.14). In the Commercial and Industrial sectors, this was closer to 10%. However, clear differences were still obvious between the sectors. Process was the primary water use for the majority of

Industrial SSUs, with 60% of businesses indicating it was their largest water demand. In the Commercial sector, respondents were divided between Bathrooms, Cleaning, Cooling, Irrigation, Kitchen, and Laundry, with each being identified by about 15% of respondents as the largest water use in their company. This suggests there is a wide range of significant water demands in the Commercial sector. Finally, in the Institutional sector almost 40% of respondents selected Bathrooms as their largest source of water demand. Irrigation and Recreational uses were each selected by about 10% of respondents as major end uses.

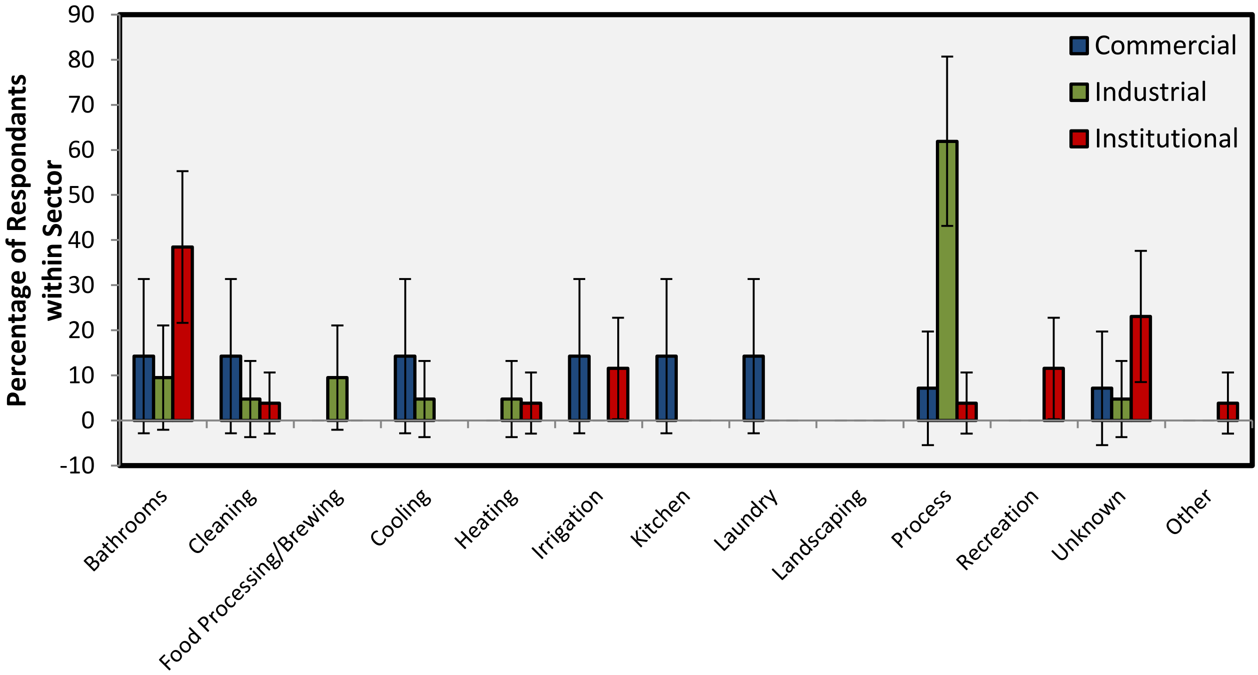


Figure 5.14 Analysis of the major end uses of water within each of the Non-Domestic sectors. Respondents identified major end uses as the largest source of water demand in their business.

It should be noted that at the subsector level, the margin of error becomes too great for accurate estimates of end uses to be established. Hence, the following assessment may not reflect the true distribution of end uses in each subsector. These findings should only be regarded as the results of a pilot study. Of the Commercial subsectors, only Agriculture/Horticulture and Multistory Offices received at least three responses to the survey (Figure 5.15). In the Agriculture/Horticulture subsector two of the three respondents indicated that their largest demand for water came from Irrigation, while the last respondent selected Process. The Multistory Office subsector was divided, with two respondents selecting Kitchens, one Cooling, and one Bathroom. This may indicate either lack of knowledge or diversity of end uses between these properties.

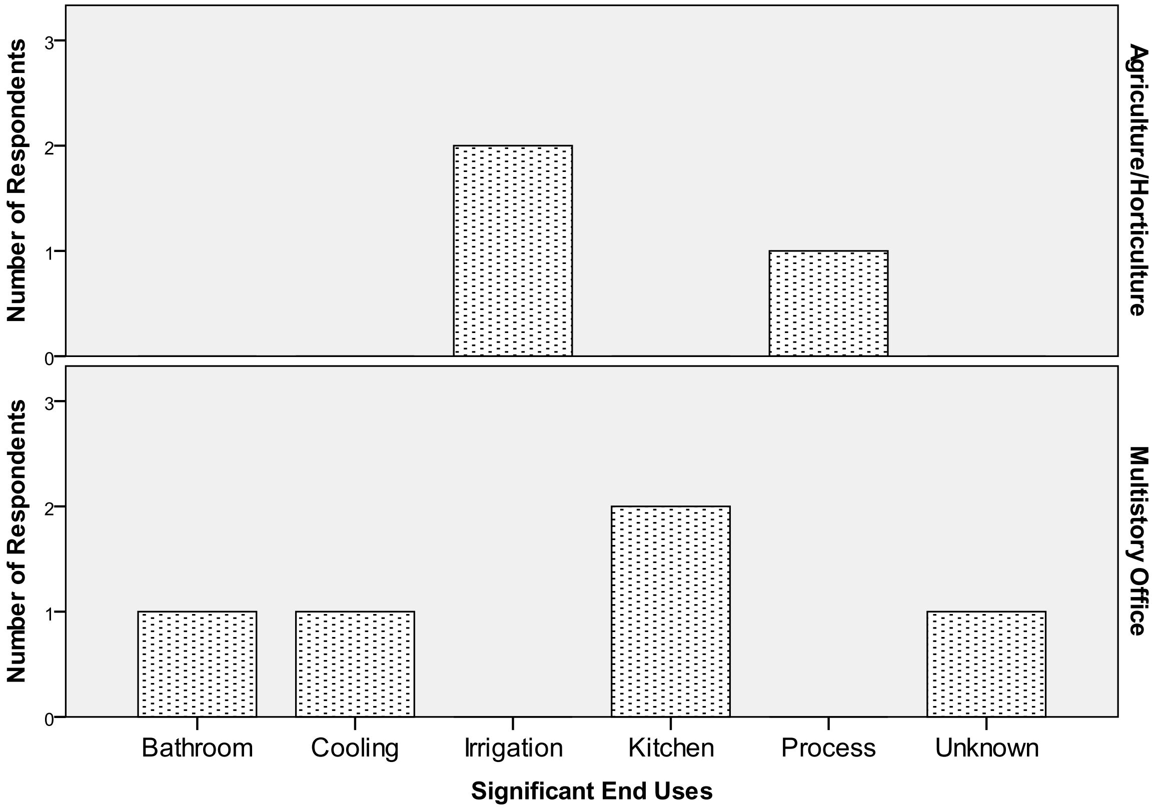


Figure 5.15 The distribution of major end uses within the Commercial subsectors. Respondents identified major end uses as the largest source of water demand in their business. Only those subsectors that received at least three responses to the question are shown.

In the Industrial sector, only Beverage Processing, Food Processing/Packaging, and Manufacturing/Refining received at least three responses (Figure 5.16). All six respondents in the Manufacturing/Refining subsector selected Process as the largest contributor to water demand for their business. Most respondents in the Beverage Processing and Food Processing/Packaging subsectors also selected Process as their largest end use. However, other respondents for these subsectors also identified Heating, Food Processing/Brewing, Cooling, Cleaning, and Bathrooms as major end uses.

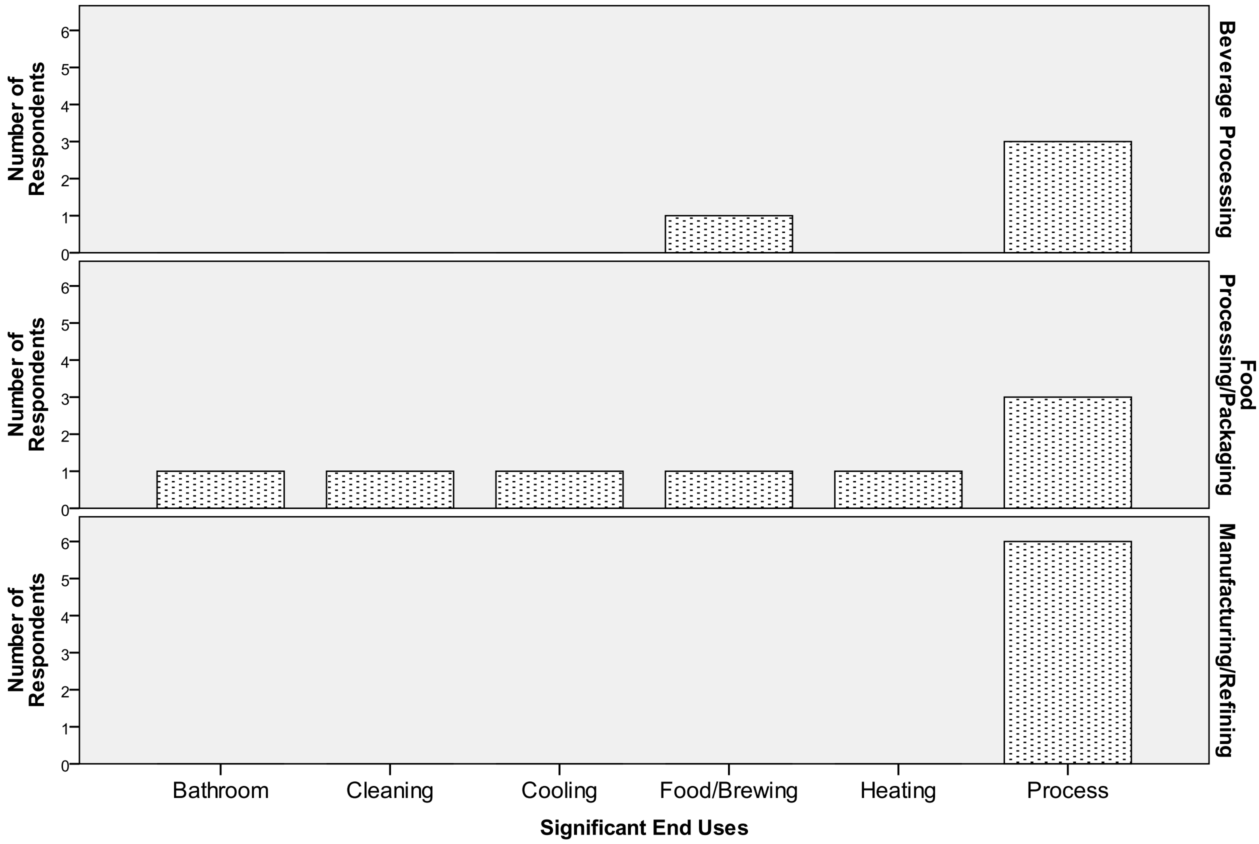


Figure 5.16 The distribution of major end uses within the Industrial subsectors. Respondents identified major end uses as the largest source of water demand in their business. Only those subsectors that received at least three responses to the question are shown.

Four Institutional subsectors received at least three survey responses, allowing their significant end uses to be assessed. Respondents for Indoor Sports Facilities identified Bathrooms and Recreation as the largest sources of water consumption for their business. In the Municipal subsector, four of the eight respondents did not know which end use consumed the most water on their property. The remaining four indicated that Heating, Cooling, and Bathrooms were their greatest sources of water demand. In Outdoor Sports/Recreation, two of the four respondents identified Irrigation as their largest water use. The two remaining selected Recreation and Unknown. Finally, in the School subsector four respondents indicated that Bathrooms were their greatest source of water demand, while Irrigation and Recreation were each selected only once.

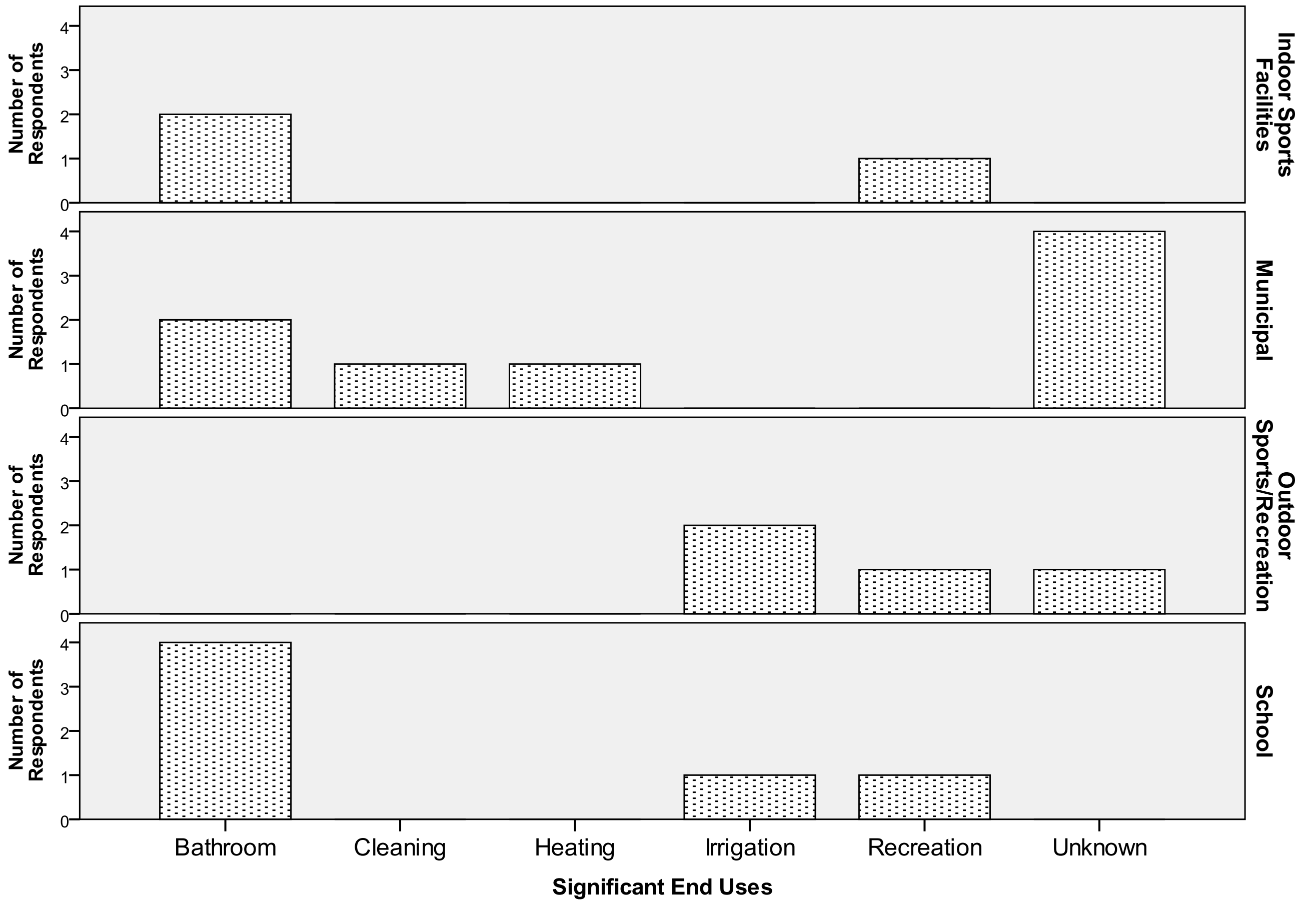


Figure 5.17 The distribution of major end uses within the Institutional subsectors. Respondents identified major end uses as the largest source of water demand in their business. Only those subsectors that received at least three responses to the question are shown.

5.4.4 *Seasonal End Uses of Water*

Given the large contribution from SSUs to peak water demand, it is particularly important to identify which end uses are responsible for seasonal increases to consumption within this subpopulation. Peak water demand for individual SSUs generally occurred over summer, although many users experienced maximum demand in other seasons. A large number of respondents whose peak demand occurred in February identified either Irrigation or Process as the source of increased water consumption (Figure 5.18a). The five respondents who selected Process belonged to the Industrial sector. Three of those who selected Irrigation were Commercial respondents, and another two were from the Institutional sector. Four respondents identified Cooling as the main source of increased demand in February, most of which were Commercial businesses. 'Other' was a common response, with common explanations of additional water use being increased staff onsite or start of the school term. In March, respondents indicated that peak water use was primarily associated with increased Process water uses (Figure 5.18b), with seven of these users coming from the Industrial sector. Seven respondents could not explain why their water consumption peaked in March. Cooling and Irrigation were also identified as major contributors to increased consumption in March. Institutional and Commercial respondents were the main users associated with Irrigation, whereas most of the respondents who selected Cooling were Commercial users.

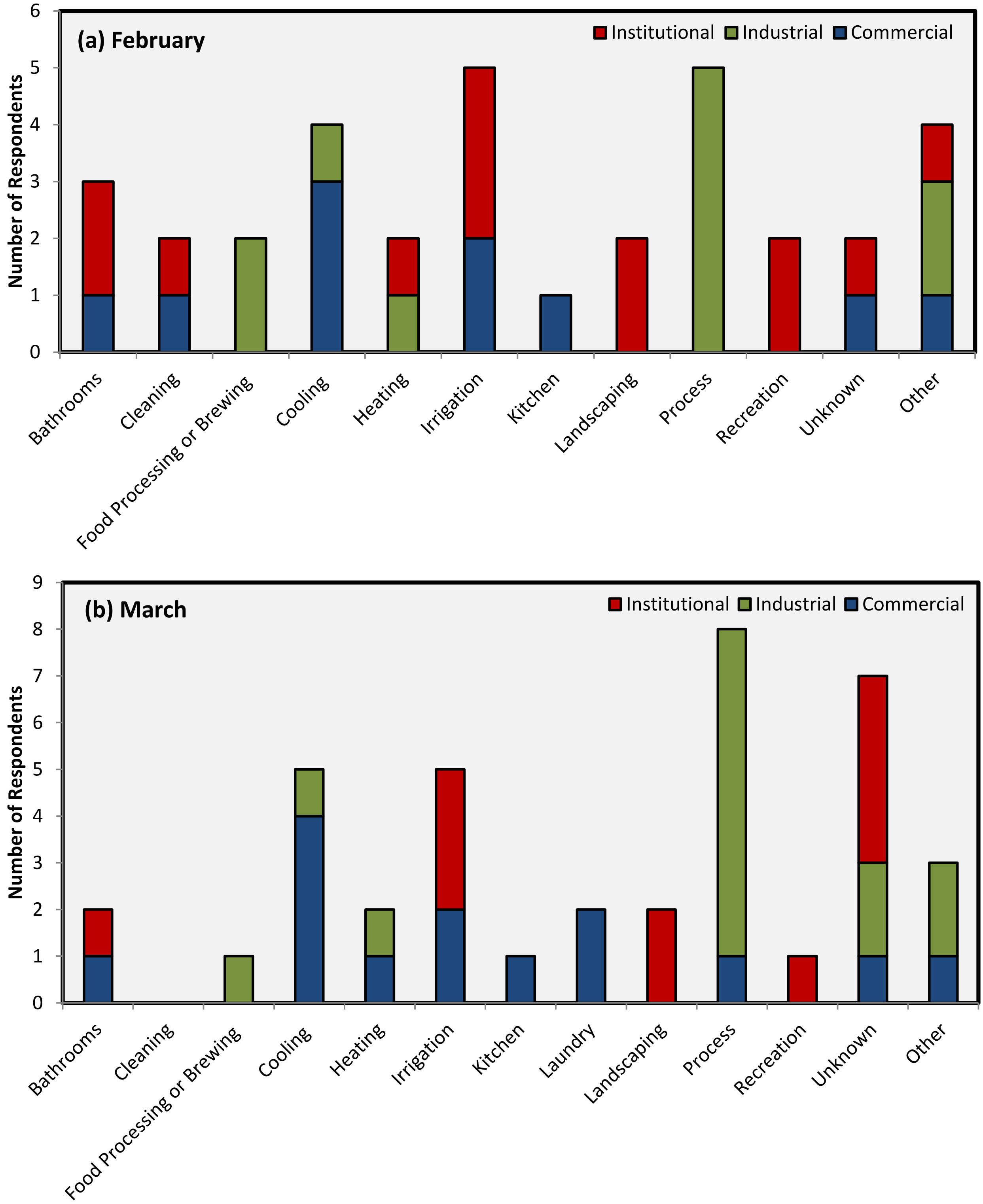


Figure 5.18 Analysis of the end uses responsible for increased water demand in February (a) and March (b), and their distribution between the Commercial (Blue), Industrial (Green), and Institutional (Red) sectors.

5.4.5 *Non-Domestic Water Efficiency*

Water efficiency in each subsector was estimated by asking respondents to rank the water efficiency of their own and other businesses in Auckland. A score of 10 was considered water efficient and 1 highly inefficient. On average, respondents gave their own business a similar rank for water efficiency for the wider industry (Table 5.7). Water efficiency for the overall Agriculture/Horticulture subsector averaged around 5, while individual businesses ranked themselves closer to 7. Multistory Offices rated their water efficiency at 7 for both options. Overall, respondents in the Commercial sector ranked their own efficiency at 6.4, and 6 for other businesses in the sector. In the Beverage Processing subsector, individual businesses were rated at just 2.5, while the wider industry scored 6 out of 10. The Food Processing/Packaging sector averaged a water efficiency score of 6, while businesses owners only gave themselves a score of 4.3. Manufacturing/Refining respondents rated their water efficiency at close to 6 for both options. Industrial respondents gave their own businesses an average score of 5.3, but the overall industry a score of 6.4. Indoor Sports Facilities had a mean of 5.7 for the Industry and 6 for individual businesses. Businesses ranked the wider Municipal subsector at 6.7, while giving their own businesses an average score of 6. Water efficiency for the Outdoor Sports/Recreation subsector averaged 5.7 for the subsector and 5.3 for individual accounts. Schools had the highest efficiency rating of 7.5 for their industry, but just 5.7 for individual properties. Tertiary Institutes scored 6 for their business and 5 overall. Institutional respondents ranked water efficiency on their own property higher than the wider sector.

Table 5.7 Water efficiency within each of the major Non-Domestic subsectors. Only those categories that received at least three responses to the question are shown.

Subsector	Your Business	Your Industry
Agriculture/Horticulture	7.00	5.33
Multistory Office	6.80	6.75
Commercial Total	**6.36**	**6.02**
Beverage Processing	2.50	6.00
Food Processing/ Packaging	4.29	6.00
Manufacturer/Refining	5.80	6.00
Industrial Total	**5.32**	**6.40**
Indoor Sports Facilities	6.00	5.67
Municipal	6.00	6.67
Outdoor Sports/Recreation	5.75	5.33
School	5.40	7.50
Institutional Total	**6.02**	**5.69**

The efficiency of ND water demand was also estimated by examining the prevalence of water saving devices among SSUs. This strategy has the additional advantage of illuminating potential improvements for ND water efficiency. Bathrooms were the most widespread end use within the ND subsectors, but were not generally associated with high water consumption or seasonal usage. More than 50% of respondents who identified Bathrooms as an end use had low flush toilets installed (Figure 5.19a). 30% had low flush urinals, 25% low flow showerheads, and around 20% had installed low flow taps. Only 35% had no water efficient devices for Bathrooms. Of the respondents with Cooling end uses, 40% had no form of water efficient device installed for this end use (Figure 5.19b). Most of the remaining respondents used two basic techniques to reduce water consumption. Chemical treatment to improve concentration ratios in cooling towers was used by 45% of users, while 20% of respondents used conductivity controllers to reduce demand from cooling towers. However, cooling tower water was reused by less than 5% of respondents, as were non-water based vacuum cooling pumps. This suggests there are some opportunities to reduce water demand from cooling. This could be important for not only overall demand, but also peak water use. Irrigation was another water use associated with peak demand during the summer. Fortunately, around 80% of respondents confirmed they only used Irrigation in the early morning or the late evening, reducing wasteful water evaporation (Figure 5.19c). Auto Shutoff nozzles, Drip Irrigation, and Reclaimed water were each used by about 30% of Irrigation respondents. Around 10% of respondents used moisture sensors and planted non-water intensive vegetation to reduce demand for Irrigation. Approximately 10% of respondents who used water for Irrigation did not have any water saving measures in place.

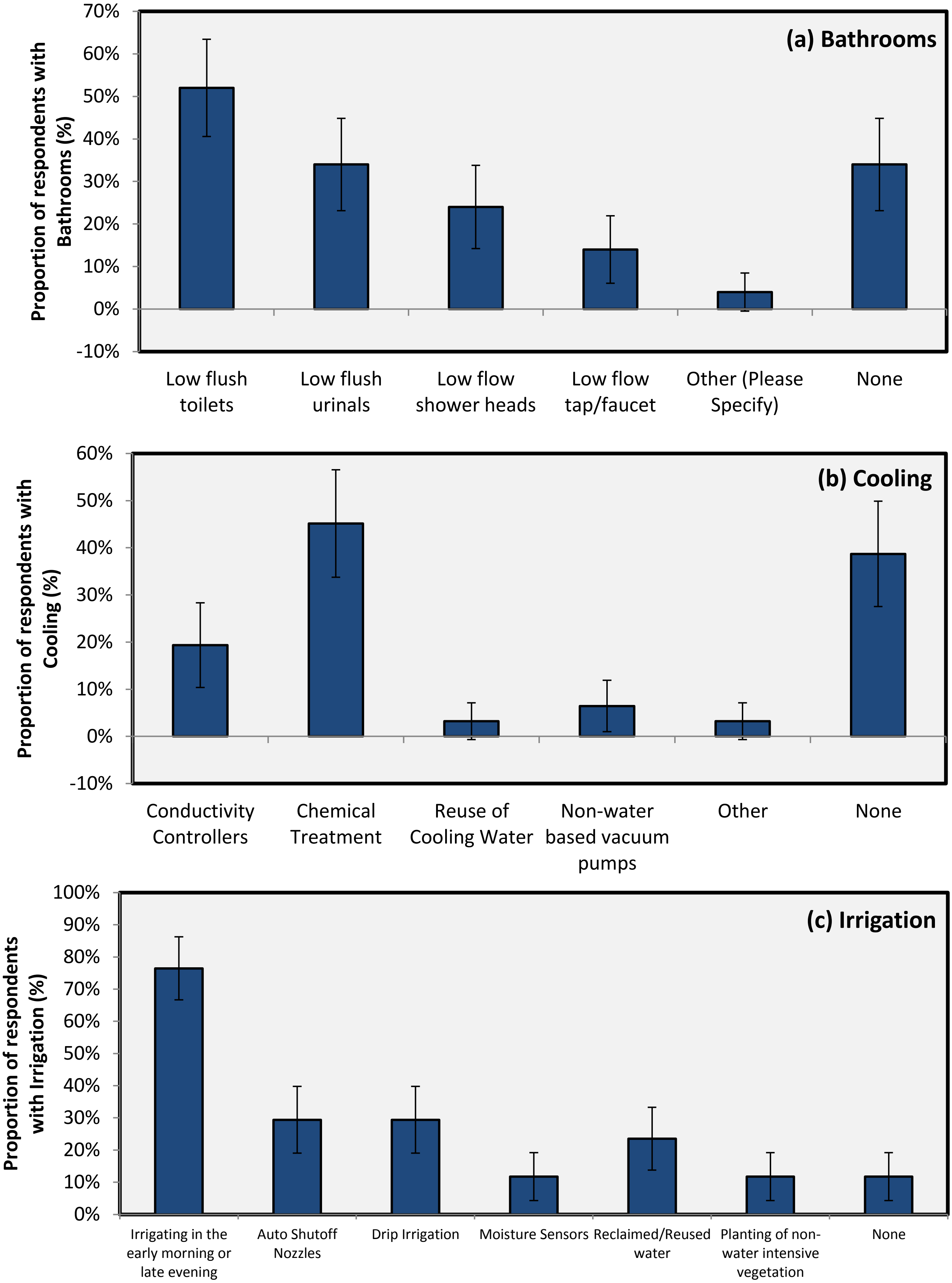


Figure 5.19 Assessment of the prevalence of water efficient devices used for Bathrooms (a), Cooling (b), and Irrigation (c) by Non-Domestic Users. The proportion of respondents refers to the percentage of respondents with the relevant end use who selected each device.

While a large number of SSUs identified Kitchens as a water use in their business, it was not generally classified as a significant end use. However, roughly 60% of SSUs with Kitchens did not have any type of water saving devices in place (Figure 5.20a). Around 30% had water efficient dishwashers, and another 10% had low flow taps installed. A number of Commercial SSUs identified Laundry as a source of elevated water use in March. However, very few respondents selected this as an end use of water in their business. Of those that did, 45% had no water efficient devices installed to reduce Laundry water consumption (Figure 5.20b). Another 45% had water efficient washing machines installed, and 10% of respondents had closed loop laundry and/or ozone cleaning systems. These respondents were probably from the Laundromat subsector, where this end use consumes a large amount of water. Finally, Process was identified by many SSUs as the largest consumer of water for their business. It was also identified in both February and March as a source of elevated water demand. This makes Process an important end use by which to examine water efficiency. Around 40% of respondents that used water for Process did not have any relevant water saving devices installed in their businesses (Figure 5.20c). A similar proportion arose when concentrating on businesses that identified Process as their *largest* demand for water. Almost 60% of respondents had Auto shutoff valves installed. A further 30% also had Rinse Optimisation and Cascade Rinse systems in place. Counter Current Rinses were only used by 10% of respondents, and Reactive Rinses were not selected at all. A further 10% of respondents specified 'Other'. This included daily monitoring of water use, recycled water systems, and even one SSU planning for a "*completely closed washwater loop*."

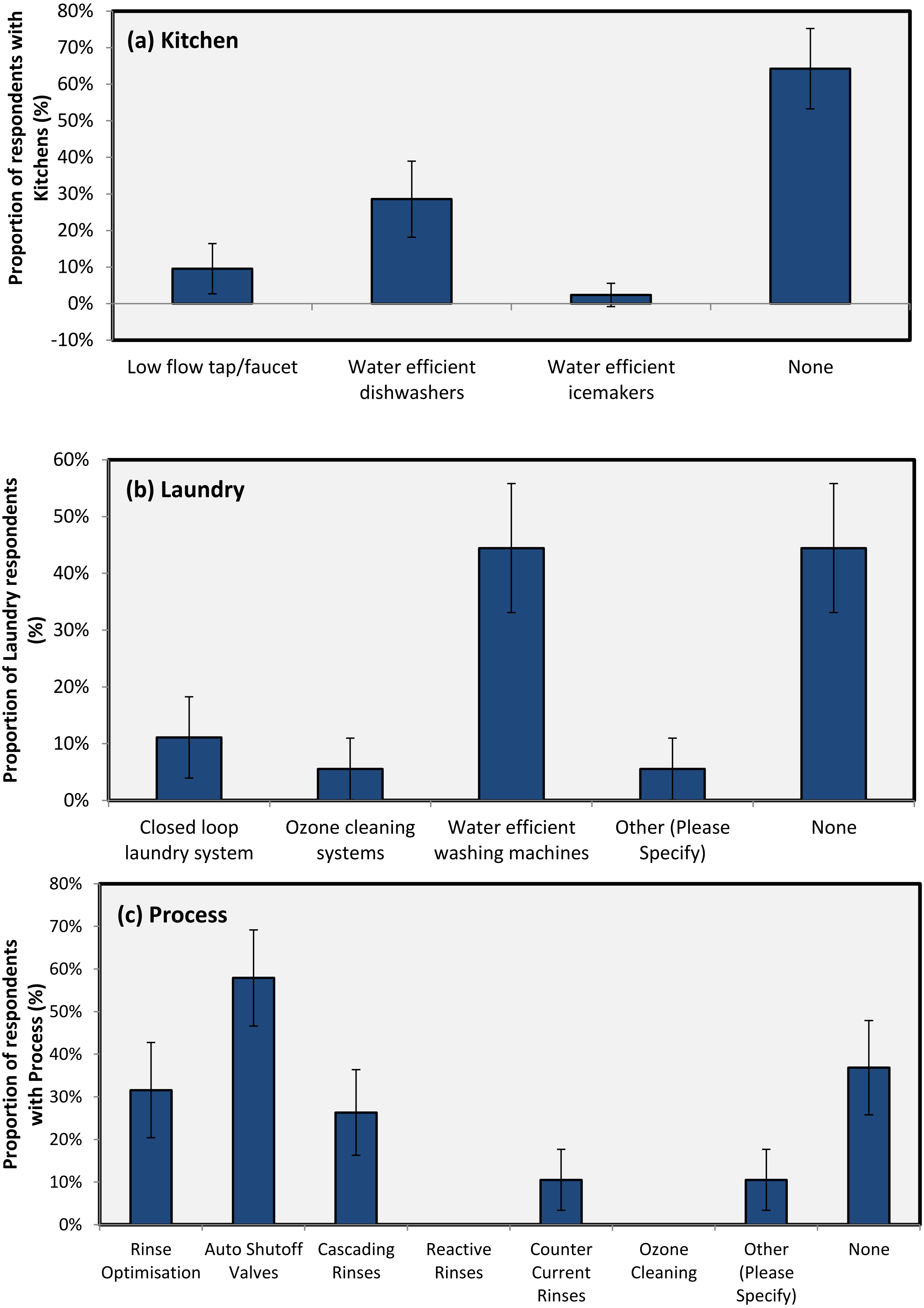


Figure 5.20 Assessment of the prevalence of water efficient devices used for Kitchens (a), Laundry (b), and Process (c) by Non-Domestic users. The proportion of respondents refers to the percentage of respondents with the relevant end use who selected each device.

5.4.6 *Behaviours, and Attitudes towards Water Use*

Respondents' knowledge of their own water consumption patterns was assessed by comparing their answers about peak water use to their original water records. Only thirteen respondents were able to correctly identify their three highest months of consumption, with a further twelve respondents correctly identifying two of their three peak months. Nineteen respondents could only identify one or none of the peak months for their business. Averaging these scores within subsectors was used to analyse general awareness of water consumption (Figure 5.21). On average, respondents in the Laundromat and Multistory Office subsectors on average correctly identified less than one of the three peak months for their businesses. Another three subsectors averaged around 50% accuracy. These were the Indoor Sports Facility, Municipal, and School subsectors. Respondents for the Agriculture/Horticulture, Accommodation, Halls/Entertainment, Beverage Processing and Textile/Printing subsectors correctly identified at least two of three of peak months for their properties. Overall, these statistics suggest many SSUs are not aware of fluctuations in their water consumption. This also suggests answers given about sources of peak consumption in some subsectors may be incorrect.

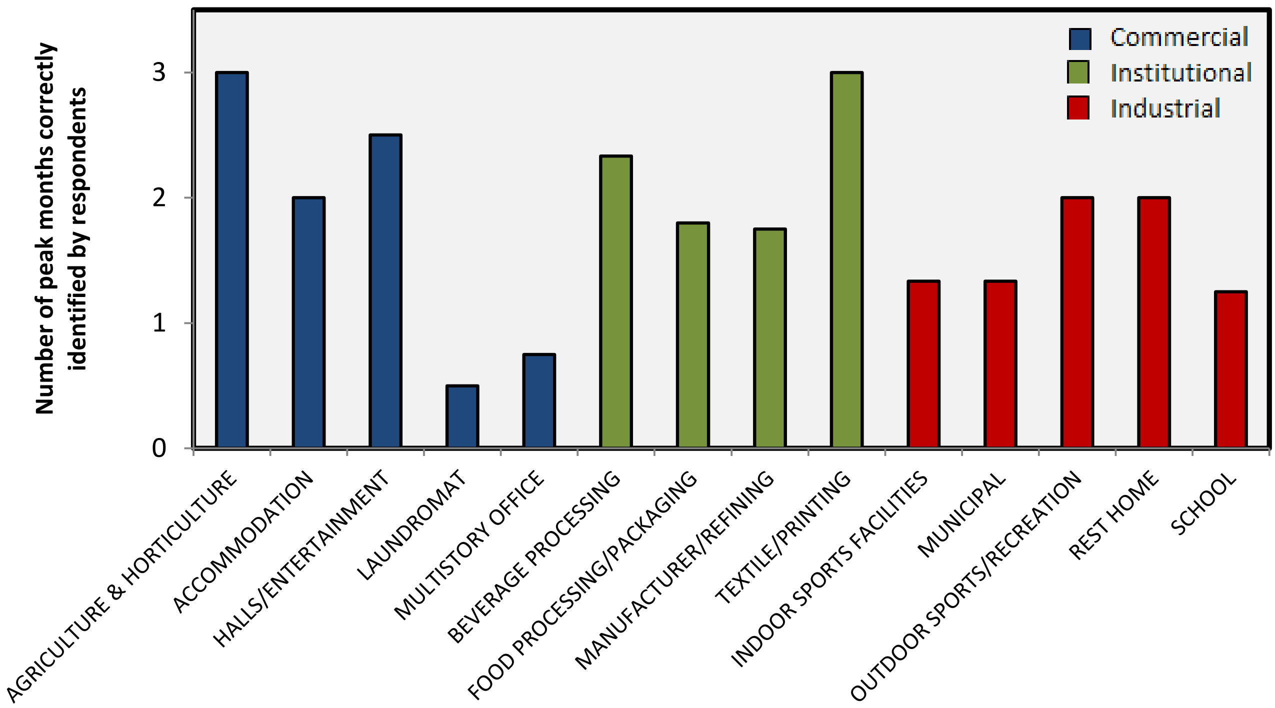


Figure 5.21 Assessment of the general accuracy of users in each subsector when selecting their peak months of water use.

Figure 5.22 illustrates the prevalence of water sources other than the mains supply in Auckland's ND sectors. Overall, it appears most SSUs rely solely on water from Watercare Services Ltd to supply their daily needs. Just under two thirds of Commercial respondents did not have access to any alternative supply. In both the Industrial and Institutional sectors, about three quarters of respondents had no other water source. For those businesses that did use water from other sources, the majority indicated their alternative supply was either bore water, rainwater, or reused water.

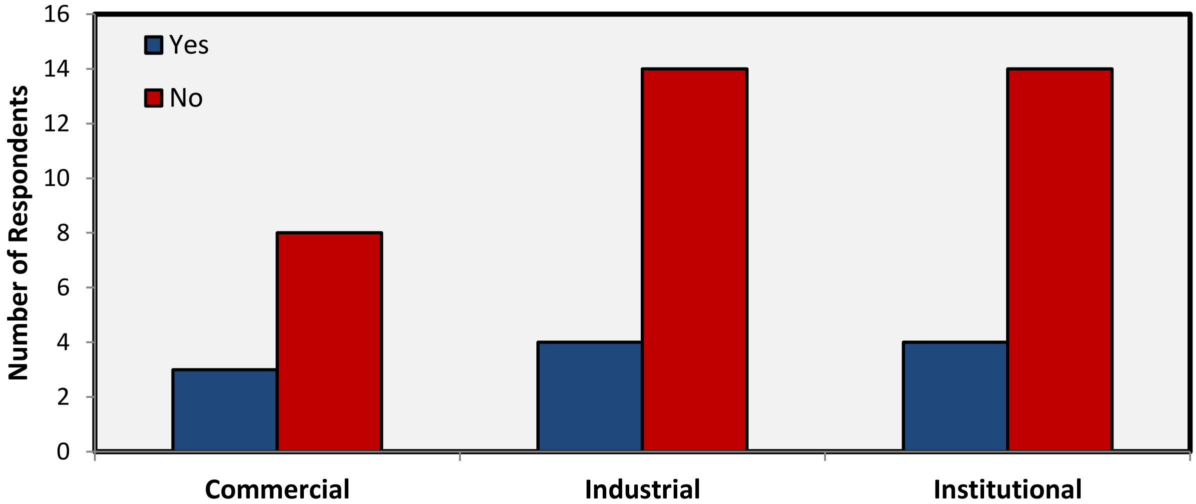


Figure 5.22 Number of respondents in each sector who indicated they used an alternative water source to the mains supply from Watercare Services Ltd.

This final section analyses some of the answers respondents gave to the open-ended questions asked in the survey. Answers have initially been grouped into either yes or no categories to give an overall response to each question. The first question asked whether businesses believed they could be more water efficient. Thirty out of forty-four respondents indicated their business could be more water efficient, while fifteen said there was no room for improvement. In a number of these cases, the latter group indicated that this was because they had already made considerable investments to improve water efficiency in their business. Most of those who believed their water efficiency could be improved explained how their business could achieve this. Explanations are examined in detail below. The second question examined the satisfaction of users with the performance of their water saving devices and initiatives. Respondents were equally divided for this question, and unfortunately most did not elaborate about their respective satisfaction levels. In the third and fourth questions, the majority of users said they had not either carried out a water audit or used smart metering in their business. However, over two thirds of those that had not used smart meters would consider installing them. The majority of respondents were also interested in working with Watercare Services Ltd to improve their water efficiency. This suggests there is enthusiasm within the SSU subpopulation to look at ways of reducing their water consumption.

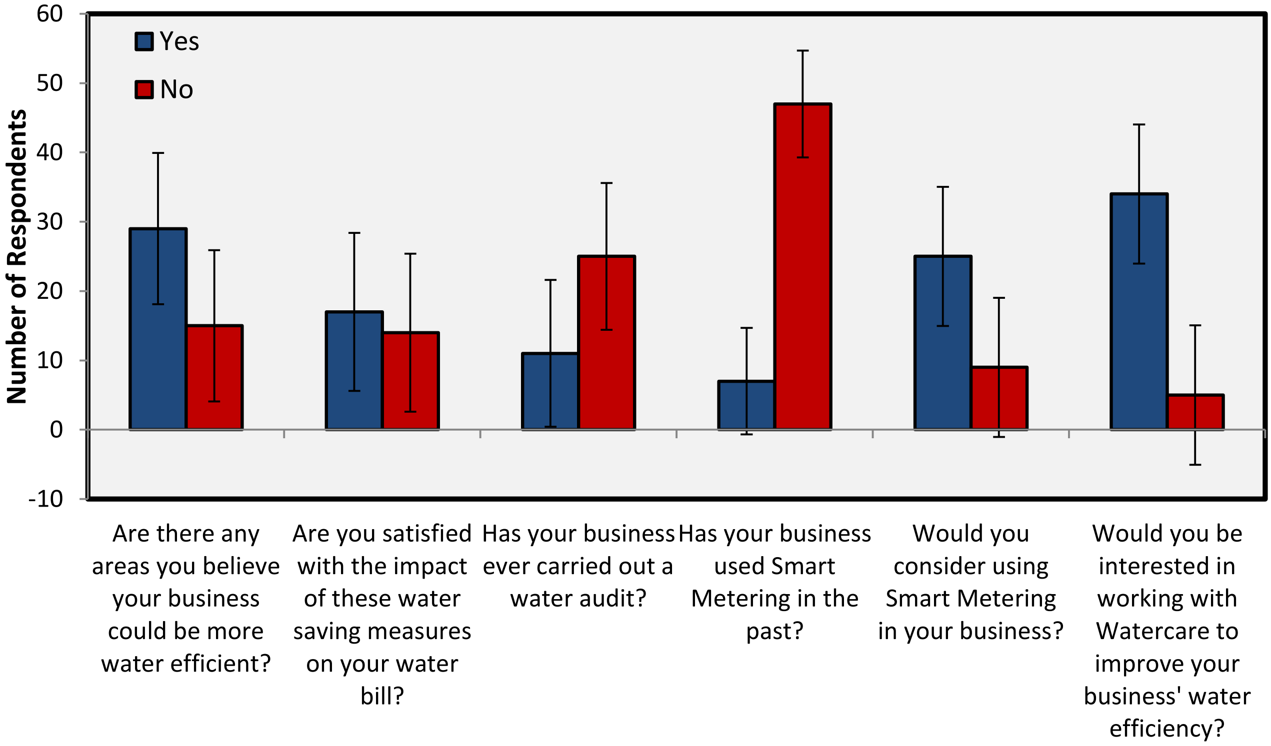


Figure 5.23 Answers of respondents to six yes (blue) and no (red) question asked in the survey.

Many respondents made suggestions about how they could lower either their overall or summer water consumption. The most common suggestion was to improve the mechanisms available to capture, recycle, and/or reuse water for other purposes. For example, washwater recycling loops were identified as an overseas technique that reduces wastage in fibreglass manufacturing, but is not commonly used in New Zealand at present. The use of filters to improve recycling efficiency for Process uses was another example. Respondents also suggested that non-potable water could be used instead of potable water in many circumstances. For instance, grey, recycled or captured rainwater could be used for Irrigation, Bathrooms, Recreation, and Landscaping with no loss of service. Finally, the upgrade or replacement of equipment to improve water efficiency was also suggested. This included ideas such as upgrading old cooling towers, and the installation of UV filters in swimming pools to reduce wastewater. In terms of summer demand, many users answered that their usage could not be reduced, or that their summer use was already low. However, suggestions such as the use of alternative water supplies for Irrigation and Cooling could have a significant impact on summer demand. Upgrading cooling systems to air-cooled or sealed systems could also reduce summer demand, as could improve Process efficiency.

Respondents also recognised a number of barriers to the improvement of water efficiency. Many users expressed concern about the need to ensure water efficiency improvements were economically viable. Price was a significant barrier, since the installation costs of new technology were often not covered by subsequent water savings. Tenants of leased buildings also suggested they could not improve their water efficiency because they were not able to make major changes to a leased building. This stemmed from reluctance to cover the costs of improvements to rented buildings. Finally, many respondents lacked knowledge and understand about water use in their businesses, which creates a significant barrier to demand management. There were often disconnects within large businesses between those using the water, and those paying the water bill. In some cases, this was within a business, between tenants and landlords, or between tenants of the same building. For instance, Multistory Office buildings are generally leased to a number of businesses and overseen by a building manager. This creates a complex relationship between the water users and those who manage water, and probably contributed to poor understanding of water use within the Multistory Office subsector (Figure 5.21).

5.5 Summary of Results

In summary, water demand differed considerably between the various ND sectors and subsectors found in Auckland. Each sector and subsector also demonstrated a distinct seasonal pattern. Overall ND water use peaked in February and March of each year.

- **Commercial:** The Commercial sector included the largest number of accounts and broadest range of subsectors, but had low WUA, and total Commercial water demand was relatively low. Water use was also spread comparably equally between accounts. Water demand was distributed between subsectors in descending order of Accommodation, Multistory Offices, Shopping Centres, Laundromats, and Agriculture & Horticulture, with the remaining subsectors consuming less than 1,000kl/day. Just 32.1% of Commercial water use came from SSUs. Bathrooms, Kitchens, Cooling, Cleaning and Heating were the most common and significant end uses in the Commercial sector. Overall, the Commercial sector demonstrated the most consistent seasonal pattern over the study period, with demand peaking in February/March at

110% of background usage. The Multistory Office and Agriculture/Horticulture subsectors made the greatest contribution to Commercial seasonality, with their water use being driven by temperature and rainfall. Water demand from these subsectors peaked in February, and accounted for by SSUs. Accommodation water use was also seasonal, and was strongly correlated with temperature and Guest Nights. Accommodation water use peaked in both February and March, but SSUs did not play a significant role. Irrigation and Cooling end uses were associated with peak Commercial demand.

- **Industrial:** The Industrial sector included the least number of accounts, but high WUA meant the sector had the largest total water consumption. This demand was highly concentrated in the top 10% of users, and the Food Processing/Packaging, Manufacturing/Refining, and Beverage Processing subsectors. 52.4% of Industrial water demand came from SSUs. Bathrooms, Kitchens, Process, and Cooling were the most common end uses in the Industrial sector. Seasonal fluctuations in Industrial water use varied considerably between years, but a seasonal peak generally occurred in February and March. Industrial water use dropped to base levels in December and January. The Food Processing/Packaging, Manufacturing/Refining, and Beverage Processing subsectors followed the same seasonal trend, contributing considerably to additional water use in February and March. However, their relative water use was not correlated with any climate or economic variable. Process water uses were associated with peak Industrial demand.
- **Institutional:** The Institutional sector had an intermediate number of users, WUA, and total water demand. Institutional water use was distributed relatively equally between subsectors, with the Municipal, Hospital, Outdoor Sports/Recreation, Rest Home, School, and Tertiary Institute subsectors all using more than 1,000kl/day. SSUs accounted for 58.1% of Institutional water demand. Most end uses were common in the Institutional sector, although Bathrooms were generally associated with the greatest water demand. Seasonality in the Institutional sector was relatively high, peaking at 110-120% in February and March. Outdoor Sports/Recreation was the largest source of seasonality, and made the greatest contribution to additional water use in February. Water use in the School and Tertiary Institute subsectors was also highly seasonal, but their demand peaked in March. Water use in these subsectors was strongly correlated with climate. The Municipal and Hospital subsectors also experienced peak water

demand in March, but was not related to any of the climate or economic variables. SSUs drove peak demand in all but the Hospital subsector. Irrigation was the primary end use associated with peak Institutional demand.

6 DISCUSSION

6.1 Distribution and Efficiency of Non-Domestic Water Use

6.1.1 *Overview*

Water demand management cannot be achieved without adequate knowledge of where and how water is being used. This requires more information than the overall water readings of an entire city. Early studies, such as Young (1973), which relied on such data were unable to calculate useful statistics about the different urban sectors, or whether price engendered different responses in different sectors (Williams and Suh, 1986). This is significant because conclusions reached using aggregated data may differ substantially from those in corresponding disaggregated versions of a dataset (Garrett, 2002). Models built on these conclusions fail to account for variables that strongly influence some usage classes, but which may not correlate with overall patterns of demand. Model performance can be improved by incorporating the disaggregated structure used in water Demand Management (DM), which allows the influence of each independent variable to be differentiated between usage classes (Schneider and Whitlatch, 1991). The disaggregation of water consumption can also readily identify potential targets for water conservation. For instance, conservation programs that target usage classes with large daily water demand may be able to achieve greater savings for minimum costs (Dziegielewski et al., 2000). However, such benefits are only available when information is accurate and specific to the study area. Demand management programs that rely on inaccurate information or borrowed findings from other regions are unlikely to produce reliable results (Morales et al., 2009).

Unfortunately, water utilities rarely collect detailed information about where and how water is used in a city. This was certainly the case in the Auckland region, where water use has been monitored in a haphazard manner due to the disconnected nature of the Water Authorities (Watercare, 2011). However, the recent amalgamation of Auckland's District Councils into the singular Auckland Council has placed all water provisions and monitoring roles under the responsibility of Watercare Services Ltd. This has created a unique opportunity to integrate old monitoring records and strategies into a single overarching system. It also allows for a unified demand management approach to reducing water use in the Auckland region. This will required detailed and accurate information about how Auckland's water is distributed between usage classes, consumers, and end uses.

The most recent data available from Watercare Services Ltd shows that currently the Auckland region consumes approximately 140 million kilolitres (kL) of treated water per year (Watercare, 2011). Non-Domestic (ND) water use accounts for 26% of overall demand, or 36.4 million kL per annum. Total water use for the final twelve months of the original dataset provided for this study was 25.7 million kL, which fell to 20.6 million kL after processing (Table 6.1). This represents an original sample size of around 71%, and a final sample size of 57% of total ND demand. The remaining 29% of water use that was not included in the original dataset is likely derived from businesses whose water meters were read on a three or six monthly frequency. This would include some small businesses with water consumption that did not justify high frequency monitoring, and businesses in areas where local authorities did not take monthly water readings. The exclusion of these businesses was necessary because readings at a monthly frequency were needed to investigate seasonal patterns of water demand. Fortunately, the bias created by this systematic exclusion is likely to be minimised by the large proportion of ND water use included in this study, which suggests its findings are highly relevant to Auckland's overall water consumption. Moreover, those users that exert the greatest influence on water consumption were generally included, since large consumption rates warranted high frequency monitoring.

Table 6.1 Proportions of annual water demand between the four major Non-Domestic sectors, retrieved from four sources. Watercare estimates of demand are adapted from the Watercare Demand Management Report (2011). Commercial and Institutional water use are combined for this report, so their total was halved to give rough estimates for comparison.

	Agriculture	**Commercial**	**Industrial**	**Institutional**	**Total**
Watercare Services Ltd (WCS) (2011)	2.8 million kL/y (7.7%)	10.5 million kL/y (28.8%)	11.2 million kL/y (30.1%)	10.5 million kL/y (28.8%)	**36.4 million kL/yr (100%)**
Watercare Services (WCS) (2012b)	0.5 million kL/y (1.5%)	21.7 million kL/y (64%)	6.6 million kL/y (19.6%)	4.9 million kL/y (14.5%)	**33.8 million kL/yr (93% of WCS report)**
Results Before Processing	0.3 million kL/y (1.3%)	13.2 million kL/y (51.4%)	5.6 million kL/y (21.9%)	3.5 million kL/y (13.6%)	**25.7 million kL/yr (71% of WCS report)**
Results After processing	0.5 million kL/y (2.3%)	4.9 million kL/y (23.9%)	7.9 million kL/y (38.5%)	6.2 million kL/y (30.3%)	**20.6 million kL/yr (57% of WCS report)**

The drop in water consumption between the original dataset and its post-processed version stemmed from a number of sources. A large portion of this difference came from the deletion of Apartment buildings, which typically had a large demand for water. The removal of leaks and overestimated readings also accounted for some of the decline. The deletion of accounts with insufficient periods of monitoring also reduced water consumption in the final dataset. However, accounts with short periods of monitoring added too much random variation to overall water use, which could obscure the underlying seasonal patterns targeted by this report. Fortunately, the large sample size enabled these accounts to be removed without overly compromising the broader significance of the results. Since the final sample contained 57% of Auckland's ND water demand, this conclusion appears to be justified.

Watercare Services (2011) divided ND water demand into four sectors – Agriculture, Industrial, Commercial, and Institutional. However, the distribution of ND water use between these categories is open to contention. Watercare Services (2011) estimated the distribution between sectors as Agriculture (7.7%), Industrial (30.1%), and Commercial/Institutional (57.6%) (Table 6.1). Yet a similar report by Watercare Services (2012b) returned markedly different results. According to this report, Agriculture used just 1.5% of ND water, while Commercial use accounted for 64%, Industrial 19.6% and Institutional 14.5%. Finally, this thesis found ND water use was distributed as 2.3% Agricultural, 23.9% Commercial, 38.5% Industrial, and 30.3% Institutional. The substantial differences between these datasets can be partly explained by observations made during data processing. First, rechecking of classifications in the 90-100% usage class; which account for 65% of ND consumption; suggested that the distribution of water between sectors in the post-processed dataset is correct. The reclassification process resulted in a complete rebalancing of water use between the major sectors. In the original dataset, Commercial water use was significantly overestimated by a poor classification system and inadequate data quality control. Conversely, the shift of accounts into other sectors increased Industrial water use by 2 million kL per annum and Institutional water use by 2.5 kL per annum (Table 6.1). This was despite an overall loss of 5 million kL/annum between the original and the processed dataset. The original dataset used the same classification system and displayed a similar distribution of water between sectors as in Watercare Services (2012b), which suggests the misclassification issue was overlooked by the report.

Interestingly, the findings Watercare Services (2011) were similar to those of this study. However, there were still some variations between the two bodies of work. One clear disparity was in Agricultural water use, which Watercare Services reported as 7.7% of ND water demand, while this thesis found the proportion was closer to 3% (Table 6.1). In this case, there is a strong probability that the report from Watercare Services was correct. Rural areas were poorly represented in this study because they generally were not monitored on a monthly basis. Since Agriculture is a significant land use in these regions, it could explain the difference between the two sources. Fortunately, this still suggests the post-processed dataset captures around 40% of Agricultural water use, which gives a strong basis to construct conclusions about Agricultural water consumption. However, due to its small size and number of accounts, Agricultural water use will be assessed in following sections as a Commercial subsector. The proportion of Commercial water use (excluding Agriculture) in the processed dataset was about 5% below what was estimated by Watercare Services (2011). Institutional water use was within 1%, with combined Commercial and Institutional (CI) water demand around 3% below the Watercare Services estimate. The most significant difference was for the Industrial sector, which Watercare Services reported as 30.1% of ND water use, compared with 38.5% in the processed dataset (Table 6.1). This difference again reflects the misclassification of Industrial accounts. Unfortunately, the actual volume of water demand from each sector could not be determined due to these uncertainties. An assumption is made in this study that at least 57% of the water demand of each sector is included in the sample, since this was the overall proportion of ND water use; as established by Watercare Services (2011); captured by the post-processed dataset.

6.1.2 *Industrial Water Use*

The proportion of ND water use consumed by Industrial accounts was substantially higher than expected; not only from Auckland based reports, but also from studies conducted overseas. Maddaus et al. (2000) found that Industrial water use in Queensland, Australia ranged from 2% to 10% of ND water consumption, while the average in the United States of America (USA) was closer to 27% (Solley et al., 1998, WaterSense, 2009). In contrast, Auckland's Industrial demand was the highest of any sector at 38.5% of ND water use (Table 6.1). The primary reason for these differences appears to be the reliance of Auckland's Industrial users on the mains water supplies. According to the survey, three quarters of Significant Seasonal Users (SSUs) do not have access to alternative sources of water (Figure 5.22). In contrast, Kenny et al. (2009) found that in 2005, Industrial users in the USA self-supplied about 69 million kL of water per day. An earlier report estimated that up to 88% of

Industrial water in the USA was self-supplied (Solley et al., 1998). Since many studies only included mains water consumption in their analysis, this explains the disparity between findings in Auckland, and those previously reported in the literature (Maddaus et al., 2000). Regional differences to the makeup of the Industrial sector were also observed. While subsector breakdowns of Industrial water use were rare, a number of studies offered some insight. Morales et al. (2009) broke down Florida's Industrial sector into 11 subsectors. The distribution of water between these subsectors was markedly different from what was observed for Auckland. Over 90% of Industrial water use was consumed by either the Mineral Processing or Warehousing/Distribution subsectors; neither of which was significant in Auckland. Conversely, subsectors that dominated Industrial water use in Auckland, such as Manufacturing, Beverage Processing, and Food Processing, each accounted for less than 5% of Industrial water use (Morales et al., 2009). Another a study in France, which included self-supplied water, found that the Alcohol, Food and Beverage, and Metal Fabrication subsectors dominated ND water demand (Reynaud, 2003). These differences highlight the necessity of local end use assessments to instruct demand management strategies. However, it is interesting to note that Process has been consistently identified as the largest Industrial end use (Gleick et al., 2003c, Isaacs et al., 2009). This complements the findings of this report in which most Industrial SSUs identified Process as the largest water use in their business (Figure 5.14).

The unusual stress placed on Auckland's water infrastructure by the Industrial sector has a number of implications for water DM. Foremost is that, contrary to suggestions overseas (Maddaus et al., 2000), Industrial water consumption must be a primary target for water conservation. The results clearly show that the Industrial sector accounts for the greatest proportion of ND water use, and has the highest per capita consumption (Table 5.1). This would suggest water conservation initiatives that target inefficient Industrial water use could produce substantial water savings (Dziegielewski et al., 2000). Moreover, Industrial water demand was concentrated into just three subsectors, in which end uses are presumed to be relatively homogenous. This suggests conservation strategies could be tailored to address the inefficiencies inherent in the major end uses of these subsectors, and hence significantly reduce expenditure on less significant end uses. The concentration of 80% of Industrial water demand into just 82 accounts (Table 5.2) also suggests water utilities could work directly with individuals, rather than diluting their efforts across a larger number of businesses.

In terms of actual potential for water savings, there are certainly inefficiencies within the Industrial sector that could be exploited. Foremost is the poor ranking of Industrial water efficiency by the survey respondents. Respondents in the Beverage Processing and Food Processing/Packaging subsectors ranked the water efficiency of their own businesses at 2.5 and 4.3 out of 10 respectively (Table 5.7). Manufacturing/Refining was slightly better at 5.8. Further, one third of SSUs who used water for Process had not implemented any relevant water saving measures (Figure 5.20c). These findings are consistent with other studies, which have identified large inefficiencies within the Industrial sector. Of particular concern is the direction of technological changes towards increased water consumption, rather than improved recirculation (Dupont and Renzetti, 2001, Gao et al., 2008). Wasteful water practices can be addressed using both direct and indirect methods. Volumetric pricing is an easy and highly effective indirect strategy that could be employed to reduce both Industrial and overall ND water consumption in Auckland (Olmstead and Stavins, 2007). Water pricing has long been recognised as an efficient method of reducing wasteful water uses and improving the uptake of water efficient technology (Howe, 1982, Nieswiadomy, 1992). For instance, Olmstead and Stavins., (2007) found that a 10% increase in the cost of water could reduce residential water demand by 3% to 4% - a price elasticity of -0.3 to -0.4. Water pricing reduces demand by reallocating water towards its most efficient uses, while conversely increasing revenue to broaden the supply base. Rogers et al. (2002) argues that full cost pricing also improves equity by funding extensions of services, and ultimately enhances water resource sustainability. Prior studies have already found that Industrial water use is highly responsive to price, particularly compared to the Residential and Commercial sectors (Hussain et al., 2002). Williams and Suh (1986) estimated that price elasticity for the Industrial sector averaged around -0.735, but was just -0.141 for Commercial and -0.294 for Residential water use. Other studies found that the price elasticity of Industrial water use ranges from between -0.33 and -0.80, in which a 10% rise in cost reduces water demand by between 3.3% and 8% (Grebenstein and Field, 1979, Schneider and Whitlatch, 1991, Dupont and Renzetti, 2001). Research has also shown that price elasticity varies between the Industrial subsectors. Renzetti (1992) calculated respective price elasticities of -0.3817, -0.3924, and -0.2725 for the Manufacturing, Beverage, and Metal industries. Reynaud (2003) found similar results for the Metal fabrication (-0.241), and Food/Beverages (-0.304) subsectors, although price elasticity for the Alcohol subsector was just -0.095. The report concluded that industries with the largest water demand also had the greatest price elasticities. Overall, these studies suggest that volumetric pricing can significantly improve Industrial water efficiency.

Auckland has had a near universal volumetric pricing scheme in place for almost thirty years (Watercare, 2011). However, water has remained relatively cheap to ensure equitable access to affordable supplies of potable water. There is considerable pressure to ensure water remains affordable to all residential properties (AC, 2011a). However, water is also provided to ND users at a low volumetric charge of $1.34 per kilolitre, excluding fixed and wastewater charges (Watercare, 2012a). This encourages wasteful, inefficient uses of expensive, high quality water (Gleick et al., 2003d), and discourages businesses from adopting new water efficient technology by both high installation costs, and low water prices. Systems that reduce water demand, increase recycling and reuse, and which exploit alternative sources of water (e.g. Rainwater tanks) could significantly reduce water consumption in many Auckland businesses. Unfortunately, the start-up costs of these devices cannot be justified by reduced water consumption so long as water is subsidised by suppliers, which creates a negative cost-benefit ratio against new technologies. The undervaluation of water is a consistent barrier to attaining maximum water efficiency around the world (Rogers et al., 2002, Gleick, 2003, Gao et al., 2008). However, given low prices are needed for residential users, a uniform increase to water rates would not be a suitable solution. A viable compromise could be a block rates structure that increased the per volume cost of water based on volumetric use (Olmstead and Stavins, 2007). This would have the dual benefit of excluding residential users from top water rates, while placing more pressure on ND and high usage accounts to reduce water wastage. Moreover, water conservation is rewarded by decreasing volumetric price. Increasing block rates have been successfully implemented in countries such as Australia, Austria, the United Kingdom, and the USA (Rogers et al., 2002). Key components of such a system include the number of 'blocks,' the volumetric threshold between each block, and the price charged for water consumed in each block.

Alternative approaches to water conservation work directly with groups or individuals and adopt tailored approaches to improve water efficiency (Fane and White, 2003). For instance, government restrictions and subsidies can either encourage water efficient behaviours and devices, or discourage wasteful water practices. Water utilities can also cooperate with key customers to help them identify inefficiencies or wasteful practices. Retrofitting is a popular strategy that is used to improve stocks of water efficient devices (White et al., 2003). However, it is a costly exercise and government subsidies are often necessary to initiate these replacements (Mitchell et al., 2007). Higher water rates are essential to motivate users to enrol in retrofit programs, and may serve to fund retrofit subsidies (Fane and White, 2003).

Retrofits of Industrial buildings are reasonably uncommon, but could generate substantial water savings depending on the end uses and subsectors targeted (Gumbo et al., 2003). Process was the largest end use in the Industrial sector, with 60% of Industrial SSUs identifying it as their largest water demand (Figure 5.14). However, Process in itself incorporates a range of uses, each of which have inherent opportunities for improved efficiency. In Auckland, the three main Industrial subsectors disclose how Process water is used to some extent. In the Food Processing/Packaging subsectors, water is used for transportation, sanitation, processing, and in the finished products themselves (DENR et al., 2009). Conversely, the Manufacturing/Refining subsector primarily uses water for Industrial rinses (Reynaud, 2003). Since in most cases water is not 'consumed' by these uses, there is potential to reduce water by improving efficiency and recirculation. Indeed, as one third of SSUs did not have any device or strategy to reduce Process water consumption (Figure 5.20c), it suggests there is considerable opportunity to decrease Industrial water demand. Cascade Rinse, Rinse Optimisation, and Counter Current Rinse systems were the most promising options. Rinse optimisation refers to the procedure in which the number and timing of rinses are reduced and water from dilute rinses is recycled (Gleick et al., 2003a). This is achieved by carefully monitoring the water flow rates, conductivity, pH, chemical contaminants, and fluid dynamics of the rinse cycles to identify where water is being used in excess. Rinse Optimisation is suitable for most Process uses, although total savings are likely to vary. Chiarello et al. (2000) found that Rinse Optimisation produced water savings of between 25% to 80% in high-technology industries, while similar opportunities were identified in the Manufacturing, Food Processing/Packaging, and Beverage Processing subsectors (DENR et al., 2009). Since only 30% of respondents had employed rinse optimisation for their Process end uses (Figure 5.20c), this suggests the technique could produce significant total savings. Cascade and Counter-Current rinses also offer significant savings through reuse (Schultz, 1999, DENR et al., 2009). Both systems rely on the different water quality requirements of each stage of the production cycle. These systems collect old water from critical rinses that use ultrapure water, and reuse this water where water quality can be lower (Gleick et al., 2003c). For instance, in the Food Processing/Packaging subsector, spray wash units can be divided into sections, with food moving in one direction through the rinses, and water moving in the other (DENR et al., 2009). This counter-current method introduces ultrapure water in the final rinse cycle, and utilises the lowest quality water in the first rinse. DENR et al. (2009) gave counter current rinses a success rating of 4.2 out of 5, suggesting initiatives to increase their current use could yield significant results in Auckland's Industrial sector. The efficiency of water used for sanitation could also be improved, given that none of the SSUs surveyed utilised ozone cleaning for their Process end uses. Ozone is a powerful disinfectant, and is used throughout Food Processing industries in Europe and America (Gleick et al., 2003c). Its use significantly improves sanitary conditions for food processing, reduces biological oxygen demand of wastewater, and limits water demand from sanitation (Guzel-Seydim et al., 2004). Its uptake by Auckland's Food Processing/Packaging businesses, which alone account for 18% of ND water use (Figure 5.2), could have a profound impact on demand from the subsector. Other opportunities in the Food and Beverage Processing subsectors include recycling water used for transport, improving nozzle size and pressure, and many other methods described in DENR et al. (2009). Identification of specific opportunities for water conservation is essential, especially for the top ND consumers. Watercare Services Ltd could encourage these businesses to identify and resolve inefficiencies by offering free or subsidised water audits or smart metering to its largest customers. Given the enthusiasm shown by SSUs to work with Watercare Services to improve their water efficiency, it is expected that such an offer would be well received (Figure 5.23). Government subsidies would also encourage the uptake of new water saving systems and technology. Minimum efficiency requirements for new Industrial buildings should also be introduced. This would prevent excessive expenditure from retrofitting because of the bulk of the installation costs for these fixtures would have been incurred regardless (Mitchell et al., 2007). The only additional expenditure is the difference between the price of the water efficient and traditional fittings.

6.1.3 *Commercial and Institutional Water Use*

The proportion of ND water consumed by the Commercial and Institutional (CI) sectors was similar to that reported by Watercare Services (2011), but was substantially lower than what has been observed overseas (Hussain et al., 2002). Commercial water use in other countries appears to range from 35% to 60% of ND water use (Solley et al., 1998, Maddaus et al., 2000, WaterSense, 2009). In contrast, Commercial water use in Auckland accounted for just 23.9% of ND water demand. Water use in Auckland's Institutional sector was reasonably similar to overseas examples, where Institutional or Public demand accounted for 19-50% of ND water (Solley et al., 1998, Maddaus et al., 2000, WaterSense, 2009). The three primary reasons for low Commercial water consumption in Auckland are: (1) underestimation of Commercial demand due to the exclusion of small businesses, which may collectively consume a considerable amount of water, (2) the larger proportion of ND water use accounted for by the Industrial sector, and (3) the different classification systems used by other studies, which make interregional comparisons difficult (Dziegielewski et al., 2000, Morales et al., 2011). Regional differences to the composition of the CI sectors were also important. For instance, the disaggregation of CI water use into subsectors by Morales et al. (2009) and DNRW (2006) revealed substantial differences from the distribution observed in Auckland by this study. Most significant was that demand from Restaurants in overseas studies ranged from 10-30% of CI demand (Dziegielewski et al., 2000, DNRW 2006), while in Auckland this subsector was insignificant. This disparity supports the hypothesis that this report underestimated Commercial water consumption by excluding small accounts, such as Restaurants. Fortunately, there was also some agreement over which subsectors accounted for the majority of CI water use. Office Buildings and Accommodation accounted for a large volume of Commercial water demand in Auckland, as well as Australia (DNRW, 2006) and the USA (WaterSense, 2009, Morales et al., 2009). The distribution of water between Institutional subsectors was more comparable, with Hospitals, Utilities (Municipal), Educational Facilities (School/Tertiary Institute), and Irrigation (Outdoor Sports/Recreation) each having significant demand for water (Maddaus et al., 2000, WaterSense, 2009, Morales et al., 2009). The main difference was the absence of a Rest Home subsector in most studies, with Morales et al. (2009) being the only report to mention 'Homes for the Aged'.

Individually, the lower water demand from Auckland's Commercial and Institutional sectors does not justify the same scrutiny as the Industrial sector (Maddaus et al., 2000).

However, numerous studies have already established that the distinction between Commercial and Institutional sectors is reasonably inane, as customers in both categories tend to have similar end uses (Dziegielewski et al., 2000). Taken together, the CI sectors account for over 50% of Auckland's ND water use (Table 6.1). While this demand is dispersed between a large number of accounts, the sheer volume of CI consumption justifies the attention of water conservation initiatives (Maddaus et al., 2000). Water efficiency ratings from Commercial and Institutional respondents were generally higher than that of the Industrial sector. However, respondents still believed there were more improvements to make. For example, Agriculture/Horticulture respondents ranked their own business almost two points higher than they ranked subsector, which suggests these users believe other businesses in their subsector are generally water inefficient (Table 5.7). Institutional subsectors ranked about one point above Industrial users, with only the School subsector receiving an efficiency rating over seven. Moreover, prior studies have found that there are substantial water inefficiencies in many of the CI subsectors. For instance, EPA (1997) conducted water audits in a number of CI subsectors, and identified considerable potential for water savings in most categories. Most notable were average water savings of 28% for Office Buildings, 17% for Accommodation, 25% for Healthcare, 20% for Education, and 26% for Landscape Irrigation, all of which accounted for a significant proportion of Auckland's ND water demand (Figure 5.2). While these estimates should not replace onsite water audits in Auckland, they do justify targeted water conservation initiatives in Auckland's CI sectors.

Prior studies suggest that CI water use is relatively unresponsive to pricing changes (Williams and Suh, 1986, Dziegielewski et al., 2000, Hussain et al., 2002). This inelasticity arises because most water users in CI establishments are customers or employees, who are not directly responsible for water rates. Most CI subsectors were also relatively price inelastic (Lynne et al., 1978), with the notable exceptions of Recreation (Moeltner and Stoddard, 2004), Government Accounts (-0.781), Schools (-0.956) (Schneider and Whitlatch, 1991), and Agricultural water use (-0.3 to -0.79) (Bar-Shira et al., 2006, Schoengold et al., 2006). High elasticity for these subsectors can be explained by the dominance of Recreational and outdoor water uses such as Irrigation, which are highly responsive to price (Dziegielewski et al., 2000, White et al., 2003). In relation to Auckland's water use, this suggests CI subsectors such as Agriculture/Horticulture, Outdoor Sports/Recreation, and Indoor Sports Facilities may have a high price elasticity. Thus, the block pricing scheme outlined in section 6.1.2 may encourage water conservation in these subsectors. However, an alternative conservation strategy is needed for the remaining CI sectors. Educational water campaigns are a common tool used to engage with consumers about water supply issues, and alter wasteful behaviours that have propagated through ignorance (Barta et al., 2004). These programs are able to reach beyond just bill payers, and hence can influence the behaviours of the customers and employees of CI businesses (White and Fane, 2001). Campaigns can involve unilateral approaches that touch all users, or can be tailored to particular groups with excessive water demands. Broad educational campaigns reach a wide audience, but also incur the greater costs (Syme et al., 2000). Targeted outreach programs can minimise costs by concentrating on areas where there is a perceived excess in demand, and thus still produce comparable water savings. Many of Auckland's CI subsectors would be suitable targets, including Agriculture/Horticulture, Accommodation, Multistory Offices, Hospitals, Schools, Outdoor Sports/Recreation, and Tertiary Institutes, each of which had significant water demands (Figure 5.2) and considerable potential to reduce their consumption (EPA, 1997). Education could be particularly influential to water use in Multistory Offices and Schools, which demonstrated a relatively poor understanding of the nature of their consumption (Figure 5.21). Further, the survey responses regarding smart meters and cooperation with Watercare Services Ltd suggest there is a willingness among ND users to improve the water efficiency of their businesses (Figure 5.23). This enthusiasm is an encouraging sign of potential to address barriers such as a lack of knowledge, and disconnect between water users and account holders. Studies have shown that water conservation campaigns have a generally positive influence on water efficiency, particularly in areas where water scarcity has already increased public awareness (Nieswiadomy, 1992, Syme et al., 2000). However, these campaigns should be implemented with caution, since improved knowledge of water inefficiencies does not necessarily translate into action (Moore et al., 1994, Abu-Taleb and Murad, 1999). There is also little knowledge about the longevity of water savings produced by these campaigns (Barta et al., 2004).

Retrofitting of CI properties is the preferred alternative to indirect water conservation strategies. Water uses within the CI sectors are extremely diverse, with most of the end uses mentioned in the survey existing in at least 30% of CI businesses (Figure 5.13). This makes it difficult to specify which end uses would generate maximum returns for investment. Moreover, the significance of each end use is dependent on the subsector being targeted. In

Office Buildings, the major end uses are Cooling, Landscaping, and Restrooms, whereas in Hotels the largest sources of demand are Restrooms (Gleick et al., 2003b, WaterSense, 2009). Thus, unlike Industrial water use, the diversity within the CI sectors makes decisions around retrofitting exceedingly difficult. In general, Restrooms, Landscaping, and Cooling appear to generally be the most significant water end uses in the CI sectors (Dziegielewski et al., 2000). Potential improvements to the water efficiency of Landscaping and Cooling are discussed in following sections, since they exert a significant influence on seasonal water demands (Dziegielewski et al., 2000). Bathrooms are often overlooked during ND retrofit programs, because their consumption is low relative to uses such as Process and Cooling (DENR et al., 2009). However, this is a serious underestimation of water demand from this end use; which may account for up to 34% of CI water use (DNRW, 2006). Given that most businesses have onsite Restrooms, and that a between 10-40% of CI respondents selected Bathrooms as their largest end use (Figure 5.14), substantial savings could be made from CI retrofits of this end use. A study by Bamezai and Chesnutt (1994) found that the replacement of pre-existing toilets with water efficient equivalents in CI buildings generated savings of around 0.3 kL per toilet per day. These savings were considerably greater than those produced by residential toilet retrofitting. This was due to the large number of individual users per toilet in the CI sectors, which leads to a higher usage intensity. For instance, savings were greatest in public sites such as Recreational Centres, because these sites service the greatest number of visitors each day (Bamezai and Chesnutt, 1994). While modern standards for toilets have already reduced their water consumption, considerable opportunities are still available due to new technologies such as the ultra-low flush toilet (Gleick et al., 2003a). The average water use for New Zealand toilets is 6.2 litres per flush, which could be halved by ultra-low flush toilets with 4.5L/3L flushes (Heinrich, 2007). Even assuming respondents with ‘low flush toilets’ were referring to these ultra-low flush models, this still leaves 50% of businesses whose toilets consume twice the water required. Opportunities are likely to be greatest in subsectors with large total water use and significant demand from Bathrooms, such as Multistory Offices, Schools, Accommodation, and Hospitals (WaterSense, 2009). Water audits of businesses in these subsectors could provide accurate estimates of the potential savings of Bathroom retrofitting.

6.1.4 *Summary*

In summary, there are clear opportunities to reduce overall water ND demand in Auckland. Individually, the Industrial sector accounts for the greatest proportion of ND water use, and hence has the greatest potential for water savings. Moreover, Industrial water use is concentrated in less than 100 accounts; therefore costs can be minimised through concentrated efforts to the improve water efficiency of these users. Due to the high elasticity of Industrial water use, block water rates have the greatest potential to reduce water consumption in the sector. Combined, the Commercial and Institutional (CI) sectors also consumed a considerable portion of ND water. Price was not expected to have a significant impact on these users, but water conservation campaigns that educate the customers and employees of CI businesses may have more success. Retrofit projects that target large end uses within the ND sectors provide a more direct method of dealing with water inefficiencies. However, subsidies and high water prices may be necessary to encourage their uptake. Least cost solutions are likely to combine these methods to achieve the best outcomes for all stakeholders.

6.2 Seasonal Patterns and Peak Non-Domestic Water Consumption

6.2.1 *Overview*

The seasonal pattern of urban water consumption is well established, with demand generally expected to peak over the summer and falling during the winter (Dziegielewski et al., 2000). Understanding this seasonality and its causes is of particular importance to water utilities, which must absorb the added costs involved with peak demand (Watercare, 2011). These costs arise from the additional infrastructure needed to support peak water use, which would otherwise be unnecessary to supply water through the rest of the year. Reducing peak water use lessens strain on current infrastructure, and defers the need for further investments in supply systems. Thus, understanding of peak demand is essential for the design of optimal water transfer systems (Quirijns et al., 2010). Disaggregation of peak water consumption can add to this understanding, while simultaneously improving the accuracy of short and long term forecasts of urban water demand. In Auckland, Residential peak water demand is well understood. BRANZ (2010) found that Residential consumption was greatest in February and March, and concluded that outdoor water uses such as swimming pools and landscaping were the primary source of this seasonal pattern. However, to date there has been no comprehensive analysis of the seasonality of ND water use in Auckland. This Thesis found conclusive evidence that Auckland's ND water demand also peaks in February and March at between 5% and 15% above the background average (Figure 5.5). In 2011, this peak added another 4,182 kL to daily water use in February and 5,339 kL per day in March (Figure 5.11). Peak water use in February was consistent with the findings of Covec (2004), although the same study did not find a peak in ND water use for March, and identified a peak of 4% in November. The data showed some evidence that ND use increased in November, but there was no statistical means to differentiate this increase from the background average. These findings indicate that ND water use makes a significant contribution to overall peak demand in Auckland. This suggests there is a need for greater understanding of the underlying sources of Auckland's ND seasonal water use.

Seasonality was lowest in Auckland's Commercial sector, moderate in the Industrial sector, and greatest in the Institutional sector (Figure 5.7). Unfortunately, regional differences in climate, water prices, and sector compositions make it difficult to compare this seasonality to other studies (Dziegielewski et al., 2000). For example, Morales (2010) found that percentage seasonality was weakest in Florida's Commercial sector, Commercial seasonality in Southern California was greater than the Industrial sector (Dziegielewski et al., 1990). Seasonality was consistently highest in the Institutional sector. However, seasonality alone does determine a categories influence on peak water demand. Peak timing and background water consumption also affects whether each sector/subsector has any influence on overall peak ND water use in February and March.

6.2.2 *Peak Water Use in Agriculture/Horticulture and Outdoor Sports/Recreation*

Seasonal variation was greatest in the Agriculture/Horticulture and Outdoor Sports/Recreation subsectors. While average water demand from each subsector was below 2,000 kL/day, their respective Monthly Index (MI) scores for February well exceeded 130% (Figure 5.8, Figure 5.10). As such, both subsectors made significant contributions to additional water use in February, despite comparably low average demand. However, the additional water use of these subsectors almost halved in March. The largest end use identified be respondents in these subsectors was Irrigation. In the Agriculture/Horticulture subsector, Irrigation was generally used for dust control and plant growth. In the Outdoor

Sports/Recreation subsector, Irrigation was used on a broad range of properties, including golf courses, sports fields, and regional parks. Water demand from Irrigation is inherently seasonal, because it is applied to supplement natural shortages caused by seasonal climate changes (Dziegielewski et al., 2000, Meinzen-Dick and Appasamy, 2002, Moeltner and Stoddard, 2004). Irrigation consumption increases with temperature, as higher temperatures accelerate evapotranspiration from crops and soil, reducing water available for crop growth (Raghunath, 2007). Conversely, Irrigation is a supplement to natural precipitation, so increased rainfall reduces demand from this end use. In both subsectors, temperature explained over 80% of the variation observed for relative water use, while rainfall and wet days had a moderate negative correlation to water demand (Table 5.5). Thus, the balance of evidence suggests that Irrigation is responsible for seasonal water usage in these subsectors. This explains the high water demand in February and March, since these months correspond with low precipitation and high temperatures (Appendix B). Temperatures also fell in March, subsequently explaining the reduced demand of these subsectors. Both subsectors had a strong correlation with Guest Nights, however, this reflects the strong association between temperature and Guest Nights, rather than a causal relationship.

Since Irrigation appears to account for a large portion of increased water use in February, improving the water efficiency of this end use would have a significant impact on peak ND water demand. Most of the large Irrigation users in Auckland already appear to be engaging in basic water saving initiatives, such as only water crops in the early morning or late evening to reduce evaporation (Gleick et al., 2003a). However, many SSUs have not taken any further steps to improve Irrigation efficiency. Auto-shutoff nozzles and drip irrigation were only used by 30% of Irrigation SSUs (Figure 5.19c). Auto-shutoff nozzles have been reported to reduce water consumption from Irrigation by between 5% to 10% (Gleick et al., 2003a), while Drip Fed Irrigation is estimated to improve water efficiency by 30% to 50% compared to sprinkler systems (Driver et al., 2002). The 47 SSUs in the Agriculture/Horticulture and Outdoor Sports/Recreation subsectors contributed almost 1,000 kL/day to peak demand in February 2011. While water audits would be necessary to calculate the quantitative potential savings from these accounts, there is sufficient evidence to suggest improving their Irrigation efficiency would significantly reduce peak water demand in February.

6.2.3 *Peak Water Use in Multistory Offices and Accommodation*

Seasonal variation in water use for Multistory Offices and Accommodation was less than in the Agriculture/Horticulture and Outdoor Sports/Recreation subsectors (Figure 5.8). MI scores for the Accommodation subsector were around 110% for February and March and were closer to 115% in the Multistory Office subsector. The moderate seasonality of these subsectors was consistent with the findings of Dziegielewski et al. (1990, 2000) and Morales (2010). Nevertheless, each subsector still contributed over 300 kL/day of additional water use in both February and March (Figure 5.11). This was primarily due to the higher average water use in these categories, which exceeded 3,000 kL/day for Accommodation and 2,000 kL/day for Multistory Offices. In the Multistory Office subsector, respondents were uncertain about both the timing and end uses of water on their property. However, end use assessments from other regions provide some insight into the sources of seasonality in these buildings. In America, cooling towers are estimated to consume between 20% to 55% of the water supplied to office buildings (Schultz, 1999, WaterSense, 2009), while in Australia this is closer to 40% (DNRW, 2006). Water demand from cooling towers also follows a similar, albeit muted, seasonal pattern to that of Irrigation (Dziegielewski et al., 2000). Demand is generally highest in the summer, since higher temperatures require more water to maintain a set internal temperature within office buildings. Conversely, periods of low temperature or high rainfall are likely to reduce water consumption from cooling towers. Behling and Bartilucci (1992) found that cooling in office buildings increased water consumption from 1.8 litres/day/m^2 in autumn/winter, to over 4.3 litres/day/m^2 over the summer. Commercial survey respondents also identified Cooling as a source of increased consumption during February and March (Figure 5.18). Seasonal variation in the Multistory Office subsector was consistent with a Cooling end use, demonstrating a positive correlation with temperature and a negative relationship with rainfall. However, there were some abnormalities to this seasonal pattern. Most notable was that water demand from Multistory Offices was below average in December and January, when temperatures were relatively high (Appendix B). Hartley and Powell (1991) refer to this as a calendar effect, which in this case refers to the Christmas/New Year’s holidays. These holidays meant office buildings generally closed for one week in both December and January, which would offset increased water demand for Cooling caused by elevated temperatures. These results suggest Cooling end uses could also be targeted by conservation strategies to reduce peak demand. The water efficiency of cooling towers can be improved in a number of ways. In fact, Gleick et al. (2003d) found that the conservation potential for Cooling could be as high as 15%. Many of the water efficient technologies for cooling towers have yet to be installed in Auckland buildings. For instance, Conductivity Controllers were only used by 20% of respondents with Cooling end uses (Figure 5.19b). The potential water savings of these devices follow the pattern described in Table 6.2, although some of the higher concentration ratios can only be achieved with a high water supply quality (Gleick et al., 2003a). Auckland's Waitakere and Hanua catchments provide grade 'Aa' water before treatment (WCC, Unknown), which suggests these devices could generate savings of between 11% and 45%, depending on the initial concentration ratios.

Table 6.2 Percentage of water savings achieved by increasing the concentration ratios (CR) in cooling towers. Source: Gleick et al. (2003a).

Percent of Make-up Water Saved									
	New CR								
	CR	3	4	5	6	7	8	9	10
Old CR	2	25%	33%	38%	40%	42%	43%	44%	45%
	3		7%	11%	14%	17%	18%	20%	21%
	4			6%	10%	13%	14%	16%	17%

The Accommodation subsector was unique in that SSUs did not make a major contribution to peak demand (Figure 5.12). Unfortunately, this limits the relevance of survey responses to this subsector. However, water use in the Accommodation subsector was similar to Multistory Offices in a number of ways. For example, studies estimate that Cooling accounts for between 11% to 15% of the water consumed by hotels and motels (Schultz, 1999, WaterSense, 2009). The timing and magnitude of Accommodation's peak demand was also somewhat similar to the Multistory Office subsector (Figure 5.8). However, since SSUs did not influence Accommodation peak water demand, seasonality in this subsector likely stems from unilateral variations from smaller businesses. Landscaping (irrigation of gardens) accounts for a further 10% to 16% of water demand from Accommodation users (Schultz, 1999, WaterSense, 2009). Landscaping exerts some seasonal influence, but the magnitude of Accommodation's peak demand suggests Landscaping is unlikely to be the sole source of elevated consumption. The strong correlation between Accommodation's relative water use and Guest Nights is a more feasible source of seasonal variation (Table 5.5). Since Guest Nights are a measure of the number of visitors using accommodation in Auckland, there is likely to be a causal relationship between the two variables. Around 30% of water in this subsector is used for end uses such as toilets and showers (Gleick et al., 2003b, WaterSense, 2009), use from which is dependent on the number of guests. Thus, increased Guest Nights over February and March (Appendix B) were likely to have had a significant impact on additional water use from the Accommodation subsector. This also explains why many Commercial respondents selected Bathrooms and Kitchens as the cause of elevated demand in February and March. In this case, an increased number of users causes peak water use. As such, the primary mechanism to reduce peak ND water demand would be to improve the overall water efficiency of these businesses, rather than targeting specific end uses.

6.2.4 *Peak Water Use in Schools and Tertiary Institutes*

The seasonal variation in water demand from Schools and Tertiary Institutes was reasonably high, with each subsector peaking in March with MI scores of between 130% and 140% (Figure 5.10). The high percentage seasonality of these subsectors was similar to the findings of Dziegielewski et al. (1990, 2000), who found that Schools and Collages had the second highest seasonality of any subsector. Moeltner and Stoddard (2004) also found evidence that water use in Schools peaked over summer months. Despite relatively low daily water use, additional water use for the School subsector exceeded 200 kL/day in February and reached almost 400 kL/day in March (Figure 5.11). Tertiary Institutes contributed almost 500 kL/day of additional water use in March. Once again, Irrigation may partially explain the seasonality of these subsectors. While School respondents did not identify Irrigation as a major end use, many of the Schools observed during reclassification had large sports fields that would require Irrigation. Further, previous studies have found that Irrigation accounted for 25% to 53% of the water used in Schools (Schultz, 1999, DNRW, 2006). However, this does not explain why additional water use in March was greater than in February, when temperatures are higher (Appendix B). Relative water use in the School subsector was also poorly explained by temperature alone (Table 5.5). The difference between water use for Schools in February and March probably reflects operational changes (Dziegielewski et al., 2000). Christmas holidays for Intermediate and Secondary schools in Auckland generally start on the 20th of December and finish on the 7th of February. As such, these periods would markedly reduce water demand from end uses such as toilets and showers; demand from which depends on number of users. This explains why MI scores indicated water use was well below average for December and January (Figure 5.10), despite a high expected demand from Irrigation during this period. One week of holidays in February would also partially offset increased demand Irrigation in this month, such that the subsector only made a small contribution to February peak demand. The pattern observed for Tertiary Institutes would have been derived from similar operational changes. Irrigation was expected to account for approximately 11% of the water supplied to these accounts (DNRW, 2006), but no correlation was observed between climate variables and water demand from Tertiary Institutes (Table 5.5). However, Tertiary Institutes are partially closed over the summer months, which explains the large drop in consumption for December and January. Moreover, March coincides with the start of Semester One for most of Auckland's Universities and Polytechnics. Thus, the influx of students over March coincides with elevated demand from Irrigation, producing a large peak in demand from Tertiary Institutes for this month.

6.2.5 *Peak Water use in Hospitals*

Seasonal variation in the Hospital subsector was reasonably low, with MI scores in February and March well below 110%. Again, this was consistent with the low seasonality in Hospitals observed by Dziegielewski et al. (1990, 2000). However, daily water use for Hospitals was 2,600 kL/day, which meant even with a low MI score the subsector contributed over 200 kL/day of additional demand in March 2011 (Figure 5.11). Interestingly, most of this additional demand came from non-SSUs (Figure 5.12). These factors suggest that seasonal water use within this subsector is subject to a complicated set of drivers, which also appear to be independent of climate and the economy. Further, no Hospital users responded to the survey. Several studies have found that domestic end uses account for about 40% of demand in the subsector (Schultz, 1999, Dziegielewski et al., 2000). As such, seasonal water use is likely to be driven by regular changes to the number of people using hospital services. Increased hospital admissions would elevate demand from domestic end uses, and vice versa. Indeed, a study by Barnard (2009) found that hospital admissions in New Zealand follow a weak seasonal pattern. Hospital admissions were lowest during the summer, which coincides with base water use in Hospitals from November to January. Peak admissions occurred in midwinter, when water use was generally above average. Admissions also experienced a smaller peak in early autumn, corresponding with the increase in Hospital water consumption during March. Again, the source of this seasonal peak is difficult to address, other than by improving overall water efficiency in Hospitals.

6.2.6 *Peak Water use in the Industrial Subsectors*

Seasonality was generally low in the major Industrial subsectors, with MI scores peaking at 108% to 110% in February and/or March (Figure 5.9). However, this was supplemented by excessive background demands of 3,300 kL/day (Beverage Processing), 8,700 kL/day (Food Processing/Packaging), and 4,400 kL/day (Manufacturing/Refining) (Figure 5.2). The Beverage Processing subsector exhibited consistently high demand in both February and March, and experienced a secondary peak from October to December. The Food Processing/Packaging subsector underwent the greatest change between months, almost tripling additional water use between February and March. Manufacturing/Refining also peaked in February and March. It is interesting to note that not only did these subsectors peak simultaneously; they also conjointly experienced a large drop in demand in December and January (excl. Beverage Processing). This implies there is a common driver behind the seasonality of these subsectors. Covec (2004) states that:

"Demand for essential inputs, such as water, is derived from the goods and services that can be produced by that input. Since GDP equals total consumer demand for goods and services, this directly implies that as the level of GDP increases, non-residential water demand also increases. Hence, GDP directly causes non-residential water demand."

Since the main purpose of the Industrial sector is to manufacture goods and process materials, this suggests there would be a strong correlation between water use in the Industrial subsectors and GDP. However, this was not the case, with relative water use displaying no relationship to either GDP or CPI (Table 5.5). In fact, minimum water demand from the Industrial subsectors overlapped with peak GDP (Appendix B). This suggests there is no direct relationship between GDP and water use for these subsectors. It is also possible that the accuracy of estimates for monthly GDP was insufficient to make comparisons with water demand. Since GDP is only measured on a quarterly basis, this could have masked underlying monthly variations to GDP that estimates could not incorporate. Without a higher frequency measurement of GDP, its exact influence on Industrial water use cannot be deduced.

Some of the seasonal variation of the Industrial subsectors can be explained by examination of production cycles, stocks of finished goods, and the major end uses of each subsector. Miron and Beaulieu (1996) found evidence of a 'summer slowdown' in manufacturing output for all Northern Hemisphere countries, and a smaller slowdown over the Christmas period. Since these periods coincide in the Southern Hemisphere, this would suggest a considerable decrease in manufacturing would occur in countries such as New Zealand and Australia. Indeed, Beaulieu and Miron (1990) have already found that Industrial production in Australia falls to an annual low over December and January, before peaking in February. Researchers maintain this summer shutdown is not directly related to temperature, but rather that shutdowns occur over the summer due to employee preferences for summer holidays, and so businesses can lower production costs such as Cooling, which increase with higher temperatures (Miron and Beaulieu, 1996). This explains why climate is not genereally correlated with water use in the Industrial subsectors. In New Zealand, this trend is reinforced by the Christmas and New Years public holidays over summer. This explains the reduced water demand from the Industrial subsectors during December and January.

However, this still does not explain why Industrial water demand peaks in February and March. The most obvious driver of elevated water use in February and March is climate. As already mentioned, increased temperatures over the summer places greater strain on Cooling end uses, which are present in a significant number of Industrial businesses (Schultz, 1999, Reynaud, 2003). Further, Davis et al. (1996) found that Industrial water use was reasonably responsive to cooling degree-days. This would explain why the water consumption of Industrial subsectors generally peaked in two of the hottest months of the year (Appendix B). The lack of correlation to climate can subsequently be explained by intereference from the summer manufacturing slowdown, which coincides with higher temperatures. However, Industrial users overwhemlingly indicated that peak water use for these months was driven by an increase in Process, rather than Cooling (Figure 5.18). Process incorporates a number of end uses, although most fall under either rinsing or sterilisation. These end uses are not intrinsically seasonal, which rather suggests that increased production during February/March elevates water demand from Process end uses. This is partially supported by the Manufacturing/Refining subsector, which demonstrated a statistically significant correlation with Manufacturing Stocks of Finished Goods (Table 5.5). These variables peaked simultaneously, with stock value occasionally lagging behind water use. Moreover, Beaulieu and Miron (1990) found that Australian Industrial production peaked in February, which coincides with elevated water demand from the Industrial subsectors. However, water use in the other subsectors did not correspond with Stocks of Finished Goods for either the Beverage or Food Processing industries. In fact, the base water use of the Food Processing/Packaging subsector corresponded with peak stock values. This could reflect the poor resolution of the economic variables, which again were only available on a quarterly basis. Further, seasonal changes to the price of finished, tradable, and works in progress may not reflect the true production cycles of the corresponding subsector. For instance, the value of food goods may increase in summer due to increased prices per good, rather than increased numbers of goods. Unfortunately, direct measurements of production cycles within each subsector were not available. Overall, the balance of evidence does suggest that increased Industrial production is the key source of elevated Industrial demand in February and March.

While seasonal water demand due to production cycles may be difficult to reduce, the high price elasticity of the Industrial sector does suggest volumetric pricing may be used to address peak water demand (Barta et al., 2004). Further, research has already shown that price elasticity for residential users varies seasonally. Studies have shown that residential water use in highly elastic during summer months, while exhibiting very little response to price in off-peak periods (Howe, 1982, Lyman, 1992, Espey et al., 1997). Unfortunately, there has been little research on the seasonal price responsiveness of the Industrial sector. Considering the high overall price elasticity of the Industrial sector (Dupont and Renzetti, 2001), increased summer water prices are still likely to discourage wasteful practices and encourage unessential production in the summer to shift to off-peak periods. A seasonal pricing structure would also be fair, since it places the costs of the increased capacity and maintenance involved with peak demand on those users who contribute to that demand (Munasinghe, 1992, Arbues et al., 2003). There is still some doubt over the effectiveness of seasonal pricing schemes. Beecher et al. (1994) found that seasonal pricing reduced overall demand, but had no impact on the magnitude of peak usage. Conversely, Pesic et al. (2012) argued that seasonal pricing structures could reduce residential consumption by over 10% in months with high temperatures and low rainfall. Schaible et al. (1991) also found that price had a significant impact on the implementation of new water saving technologies for Irrigation. Given this is a key driver of peak CI water use, seasonal water rates may also encourage CI users to improve their Irrigation efficiency, and hence further reduce consumption in February and March.

6.2.7 *Summary*

In summary, the analysis presented in this study found that seasonal water consumption differed markedly between the ND subsectors of Auckland. High seasonality was often associated with a large contribution to peak demand in February and March, although subsectors with low seasonality but high daily water use also had a significant impact. As such, a number of factors were identified as potential drivers of peak water use in February and March. The most significant end use contributing to peak demand in February was Irrigation, which came from the Agriculture/Horticulture, Outdoor Sports/Recreation, and School subsectors. Cooling in Multistory Offices was also a significant source of increased usage. Thus, improving the water efficiency of Cooling and Irrigation could substantially reduce February peak water demand. On-peak production cycles in the Beverage Processing, Food Processing/Packaging, and Manufacturing/Refining subsectors also contributed to peak demand in February, although their influence was far greater in March. In contrast, demand from both Irrigation and Cooling decreased in March. The timing of School terms, the university semesters, and a spring peak in Hospital admissions also elevated water demand for March. Addressing peak usage due to calendar effects is more problematic, and generally requires overall improvements to the water efficiency of each subsector. Seasonal volumetric pricing would be the ideal strategy to target peak demand in March. Fortunately, off-peak periods for many subsectors occurred in December and January, offsetting corresponding increases to water demand from Irrigation and Cooling end uses. This limited peak ND consumption to February and March, rather than the whole summer.

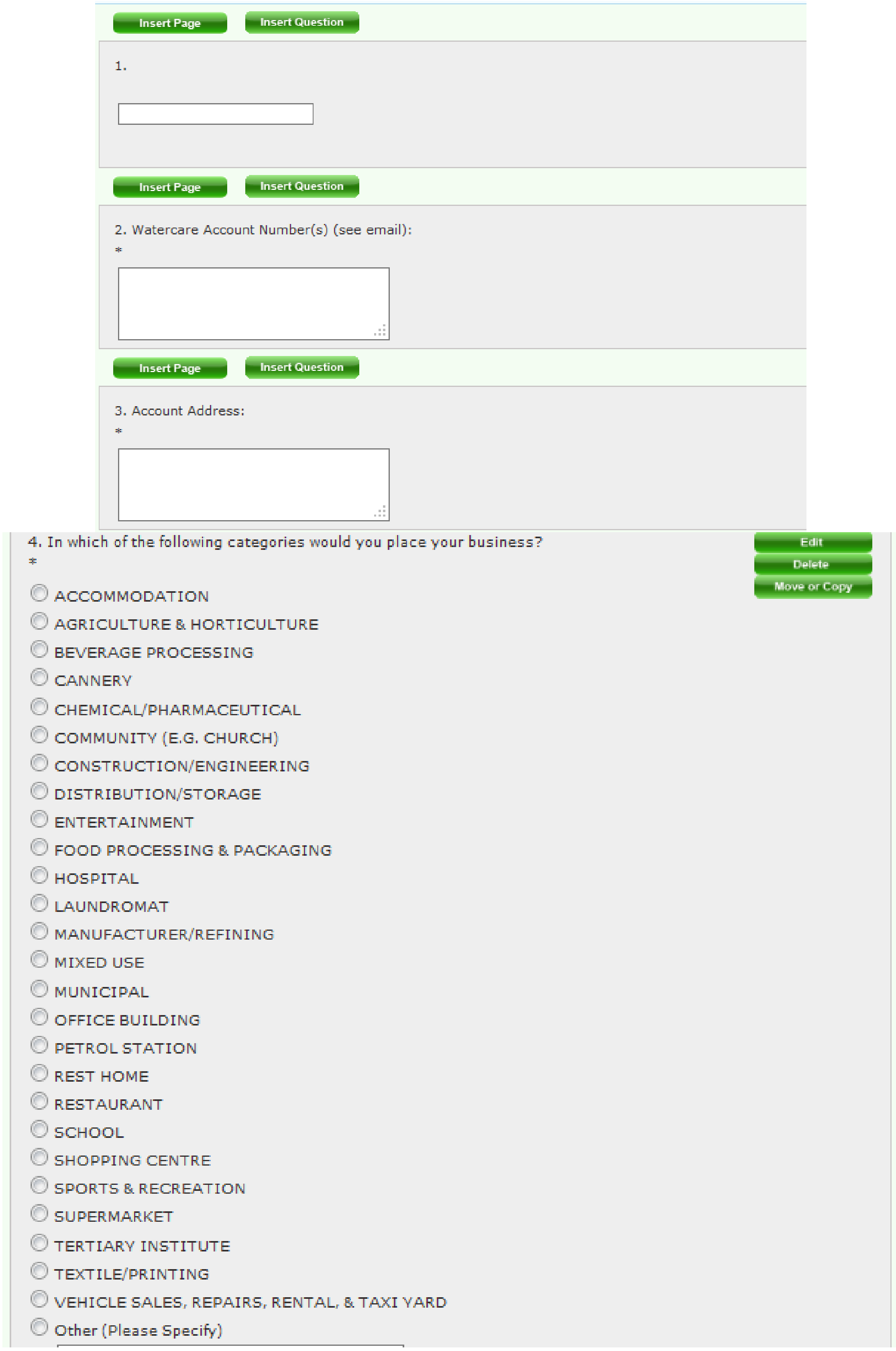
7 CONCLUSION

Water is fundamental to the growth and betterment of human society, but it is threatened by pollution, climate change, and population growth. Traditional water management systems have exploited readily available supplies, while ignoring how this water is used. As a result, the resource has become undervalued, propagating wasteful practices and attitudes towards water consumption. There is growing support for Demand Management (DM) approaches that take a holistic approach to managing water resources. These strategies depend on detailed, accurate knowledge of the end uses and services provided by water in a given city (Mitchell et al., 2007). This information rarely exists, particularly for Non-Domestic (ND) users. This was certainly the case in Auckland, where water authorities have yet to create a unified classification system for ND accounts. Even so, this study was able to disaggregate ND water consumption, and determine which sectors and subsectors were the most prominent in Auckland. This analysis found that the Industrial sector accounted for 39%, the Institutional sector 30%, and the Commercial sector 26% of overall ND water use. Industrial water use was highly concentrated within the top 10% of consumers, as well as the Food Processing/Packaging, Beverage Processing, and Manufacturing/Refining subsectors. This suggests Industrial water demand could be drastically reduced while incurring low cost by working with individual businesses to improve their water efficiency. Industrial water use also had a high price elasticity of between -0.33 and -0.80 (Grebenstein and Field, 1979, Schneider and Whitlatch, 1991, Dupont and Renzetti, 2001). This indicates that increasing block water rates would have a significant impact on Industrial water efficiency. Block rates would increase the volumetric price of water so that users with high demand pay a higher rate, and vice versa. This strategy discourages wasteful water consumption, encourages users to reduce their water use, and safeguards water accessibility for small residential users. The Commercial and Institutional (CI) sectors combined also accounted for a considerable percentage of ND water demand. Within these sectors, the Accommodation, Multistory Office, Municipal, and Hospital subsectors each consumed over 2,000kl/day, with another five subsectors using between 1000kL and 2000kL of water per day. However, water use in these sectors tend to be relatively price inelastic, as most of their users were not responsible for the cost of water. Water conservation campaigns were recommended as a way of reaching all water users in the CI sectors. Retrofitting projects provide a way to target specific end uses that make large contributions to ND water demand. Bathrooms account for a significant proportion of CI water use, particularly in subsectors such as Multistory Offices, Schools, and

Hospitals. Ultra-low flush toilet retrofits would have a significant impact on water demand from these subsectors. Likewise, retrofitting to improve water efficiency and recirculation of Process water would drastically reduce Industrial water demand. However, subsidies and high water prices would be necessary to encourage widespread support for these projects. Combinations of these strategies are likely to produce the best outcomes for all stakeholders.

Seasonal water usage presents several problems for water utilities; principally the additional expenditure required to supply water during peak consumption periods. However, seasonality also presents opportunities for deferred investments by reducing peak demand, hence by lowering the pressure placed on existing water infrastructure (Quirijns et al., 2010). This requires sound understanding of seasonal consumption patterns. Currently, residential patterns of water use are well understood, but there is little information regarding ND seasonality. As such, this project examined the seasonal water consumption patterns of Auckland's ND users. On average, ND water demand peaked at 105-110% in February and March, which in 2011 translated into an additional 4,400 kL/day and 5,000 kL/day respectively. In February, Irrigation from the Agriculture/Horticulture, Outdoor Sports/Recreation, and School subsectors was the greatest source of additional water use. Most users with Irrigation end uses avoided wasteful practices such as watering crops around midday. However, the uptake of water efficient devices for Irrigation was relatively poor. Auto-shutoff valves and Drip Fed Irrigation systems offer substantial savings from Irrigation end uses, but their distribution in Auckland must be improved. Cooling was another seasonal end use that increased water demand in February and March. Cooling was primarily associated with the Multistory Office subsector, which accounted for 300 kL/day of additional water use in February and March. The water efficiency of Cooling end uses could be drastically improved using Conductivity Controllers, although savings would differ between buildings. Calendar effects such as school holidays, hospital admissions, and industrial production cycles also had a significant influence over seasonality (Miron and Beaulieu, 1996). Holiday periods in December and January offset increases from Irrigation and Cooling in the School, Tertiary Institute, and Multistory Office subsectors. Conversely, a seasonal increase in tourist numbers and hospital admissions caused demand from the Accommodation and Hospital subsectors to peak over February and March. Peak demand due to calendar effects was difficult to address, other than by improving the overall efficiency of water use within these subsectors. Finally, the large consumption by the Industrial subsectors meant they also made significant contributions to peak demand, particularly in March. Peak Industrial water demand stemmed from production cycles that influenced Process end uses. Seasonal volumetric pricing would be the preferred solution to discourage Industrial water use through February and March.

APPENDIX A: SURVEY



Insert Page Insert Question

1.

Insert Page Insert Question

2. Watercare Account Number(s) (see email):
*

Insert Page Insert Question

3. Account Address:
*

4. In which of the following categories would you place your business?
*

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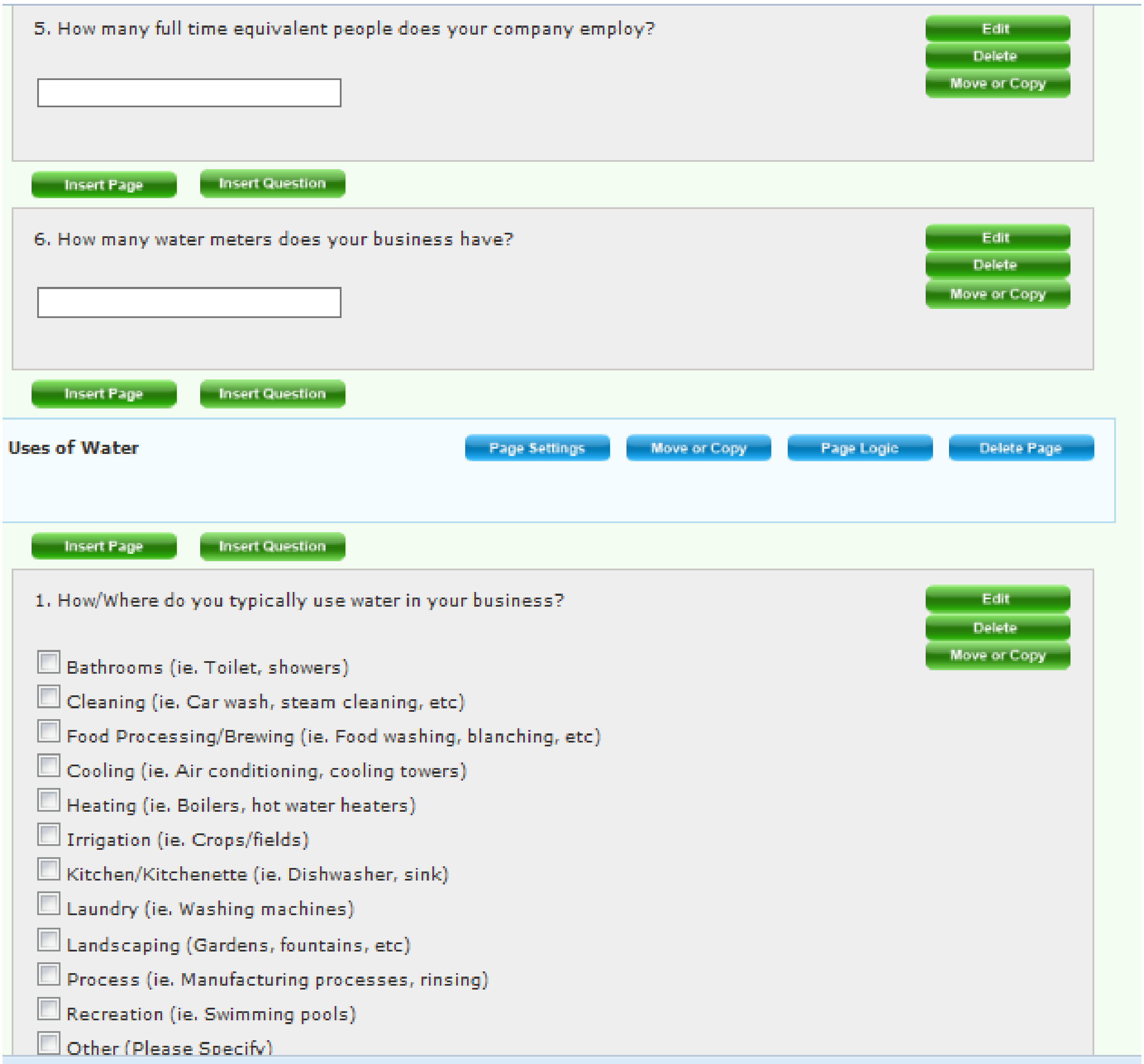
- ACCOMMODATION
- AGRICULTURE & HORTICULTURE
- BEVERAGE PROCESSING
- CANNERY
- CHEMICAL/PHARMACEUTICAL
- COMMUNITY (E.G. CHURCH)
- CONSTRUCTION/ENGINEERING
- DISTRIBUTION/STORAGE
- ENTERTAINMENT
- FOOD PROCESSING & PACKAGING
- HOSPITAL
- LAUNDROMAT
- MANUFACTURER/REFINING
- MIXED USE
- MUNICIPAL
- OFFICE BUILDING
- PETROL STATION
- REST HOME
- RESTAURANT
- SCHOOL
- SHOPPING CENTRE
- SPORTS & RECREATION
- SUPERMARKET
- TERTIARY INSTITUTE
- TEXTILE/PRINTING
- VEHICLE SALES, REPAIRS, RENTAL, & TAXI YARD
- Other (Please Specify)



5. How many full time equivalent people does your company employ?
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6. How many water meters does your business have?
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Uses of Water
Page Settings
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Page Logic
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1. How/Where do you typically use water in your business?
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Bathrooms (ie. Toilet, showers)
Cleaning (ie. Car wash, steam cleaning, etc)
Food Processing/Brewing (ie. Food washing, blanching, etc)
Cooling (ie. Air conditioning, cooling towers)
Heating (ie. Boilers, hot water heaters)
Irrigation (ie. Crops/fields)
Kitchen/Kitchenette (ie. Dishwasher, sink)
Laundry (ie. Washing machines)
Landscaping (Gardens, fountains, etc)
Process (ie. Manufacturing processes, rinsing)
Recreation (ie. Swimming pools)
Other (Please Specify)

2. Which of these uses would consume the MOST water in the everyday operations of your business?

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- Bathrooms (ie. Toilet, showers)
- Cleaning (ie. Car wash, steam cleaning, etc)
- Food Processing/Brewing (ie. Food washing, blanching, etc)
- Cooling (ie. Air conditioning, cooling towers)
- Heating (ie. Boilers, hot water heaters)
- Irrigation (ie. Crops/fields)
- Kitchen/Kitchenette (ie. Dishwasher, sink)
- Laundry (ie. Washing machines)
- Landscaping (Gardens, fountains, etc)
- Process (ie. Manufacturing processes, rinsing)
- Recreation (ie. Swimming pools)
- Unknown
- Other (Please Specify)

Insert Page | Insert Question

3. Does your business use smart metering? If not would you consider using it at some stage?

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Patterns of Water Consumption

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1. What month(s), does your business use the most water?

- January
- February
- March
- April
- May
- June
- July
- August
- September
- October
- November
- December
- Other (ie. Doesn't vary)

2. Is there a specific water use that is attributable to the change in consumption for these months?

- [ ] Bathrooms (ie. Toilet, showers)
- [ ] Cleaning (ie. Car wash, steam cleaning, etc)
- [ ] Food Processing/Brewing (ie. Food washing, blanching, etc)
- [ ] Cooling (ie. Air conditioning, cooling towers)
- [ ] Heating (ie. Boilers, hot water heaters)
- [ ] Irrigation (ie. Crops/fields)
- [ ] Kitchen/Kitchenette (ie. Dishwasher, sink)
- [ ] Laundry (ie. Washing machines)
- [ ] Landscaping (Gardens, fountains, etc)
- [ ] Process (ie. Manufacturing processes, rinsing)
- [ ] Recreation (ie. Swimming pools)
- [ ] Unknown
- [ ] Other (Please Explain)

Insert Page Insert Question

3. Does your business consistently close or use less water at a certain time of year for more than one consecutive week? If so, please specify the period of closure and for what reason (eg. holidays in December, etc)

Insert Page Insert Question

1. How would you rate the water efficiency of the following?

	1 (Very Inefficient)	2	3	4	5	6	7	8	9	10 (Very Efficient)
Your Business	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Your Industry	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

Insert Page | Insert Question

2. Are there any areas in which you believe your business could be more water efficient?

Insert Page | Insert Question

3. Is there anything you believe your business could do to reduce its water consumption over the summer?

Insert Page | Insert Question

4. Do you have any additional sources of water on site other than water supplied by Watercare Services? If yes, where does this water come from, and what is it used for?

1. Does your business have any of the following water efficient devices in the ***Bathrooms***?

- [ ] Not Applicable
- [ ] Low flush toilets
- [ ] Low flush urinals
- [ ] Low flow shower heads
- [ ] Low flow tap/faucet
- [ ] Other (Please Specify)

Insert Page | Insert Question

2. Does your business have any of the following water efficient devices in the ***Kitchens***?

- [ ] Not Applicable
- [ ] Low flow tap/faucet
- [ ] Water efficient dishwashers
- [ ] Water efficient icemakers (ie. Air cooled machines)
- [ ] Other (Please Specify)

3. Does your business have any of the following water efficient devices in the ***Laundry***?

- [ ] Not Applicable
- [ ] Closed loop laundry system (Water is filtered so that it can be reused)
- [ ] Ozone cleaning systems
- [ ] Water efficient washing machines
- [ ] Other (Please Specify)

Insert Page | Insert Question

4. If your business uses ***irrigation or other outdoor water uses***, does it use any of the following water efficient devices or practices?

- [ ] Not Applicable
- [ ] Irrigating in the early morning or late evening (Avoid irrigation during mid day)
- [ ] Auto Shutoff Nozzles (Nozzles shutoff automatically when not in use)
- [ ] Drip Irrigation (Plastic tubes deliver water to plant roots)
- [ ] Moisture Sensors (Irrigation is controlled based on vegetation needs)
- [ ] Reclaimed/Reused water (Use of water other than mains water)
- [ ] Planting of non-water intensive vegetation
- [ ] Other (Please Specify)

Insert Page | Insert Question

Insert Page Insert Question

5. Does your business have any of the following water efficient devices in its ***Cooling Systems***?

- [ ] Not Applicable
- [ ] Conductivity Controllers (Measures salt concentration in cooling towers to increase concentration ratio)
- [ ] Chemical Treatment to improve the concentration ratio in cooling towers
- [ ] Reuse of cooling tower water in other processes such as bathrooms and industrial processes
- [ ] Non-water based vacuum cooling pumps (ie. Air cooled oil ring)
- [ ] Other (Please Specify)

Insert Page Insert Question

6. Does your business use any of the following water efficient devices during ***Industrial Processes or Rinsing?***

- [ ] Not Applicable
- [ ] Rinse Optimisation (Reducing rinse cycles, rinse times, and reusing water from dilute rinses)
- [ ] Auto Shutoff Valves to stop the flow of water when production stops
- [ ] Cascading Rinses (The reuse of water from important rinses on rinses that are less critical)
- [ ] Reactive Rinses (The reuse of acid rinse effluent as influent for alkaline rinse tank)
- [ ] Counter Current Rinses (Clean water enters at final wash box and flows counter to movement of the product through the wash boxes)
- [ ] Ozone Cleaning
- [ ] Other (Please Specify)

Insert Page Insert Question

7. Does your business have any other water efficient programs or appliances in place?

Insert Page Insert Question

8. Are you satisfied with the combined impact these water saving measures have had on your water bill?

Insert Page Insert Question

Further Research

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1. Do you have any further comments or suggestions about aspects of Auckland's water supply?

2. Has your business ever carried out Water Audit? If yes, how did you use the results?

Insert Page Insert Question

3. Would you be interested in working with Watercare Services to help improve the water efficiency of your business (ie. Smart Metering, more information about water use from different appliances, etc)?

Insert Page Insert Question

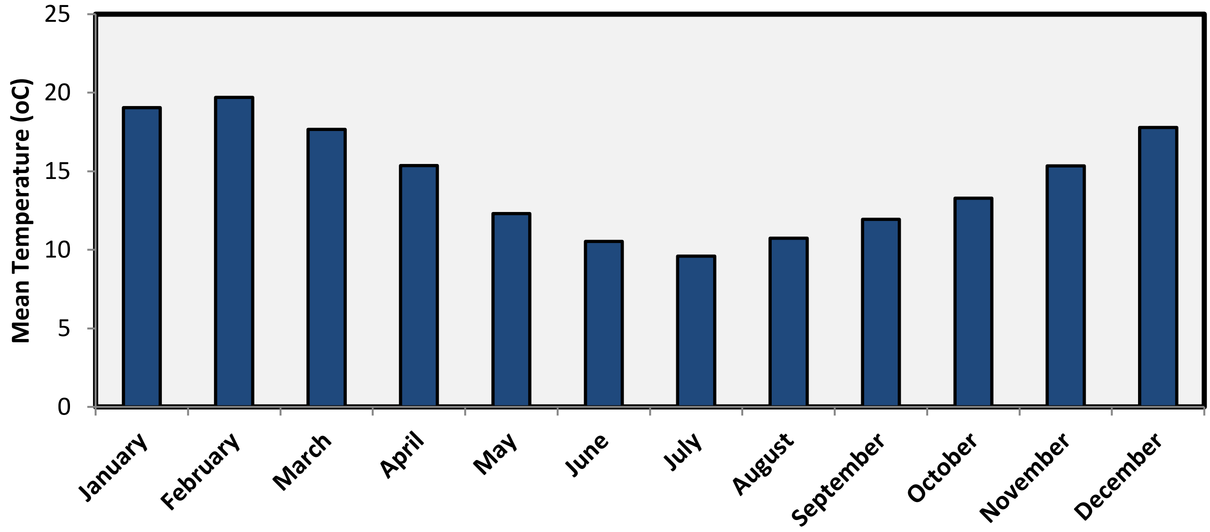
4. We may wish to explore some of these issues in more depth in future. Would you be willing to participate in a short follow up interview?

- Yes I am willing to participate
- No I would not like to participate

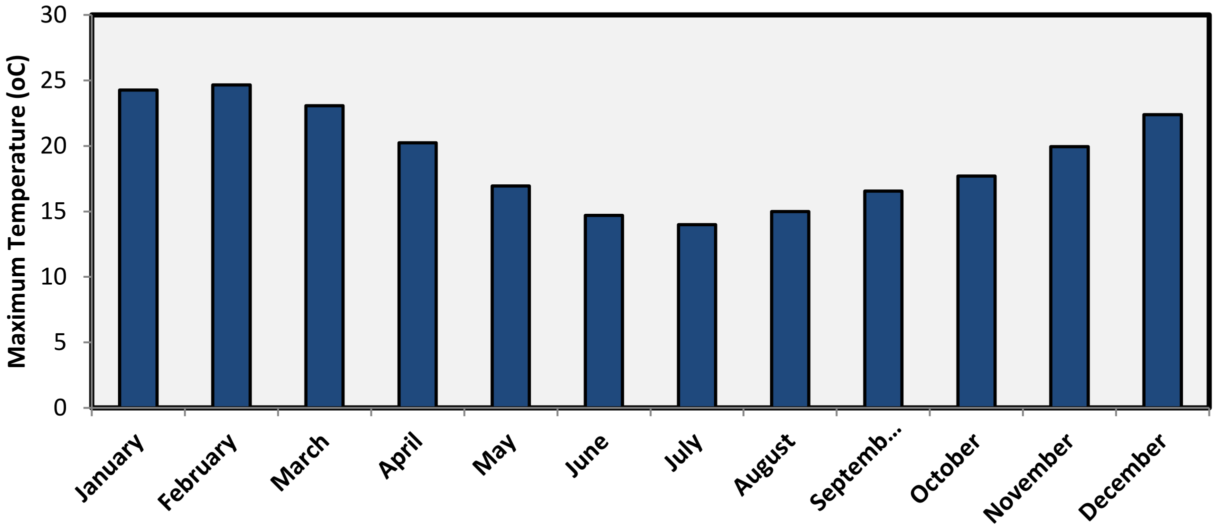
Insert Page Insert Question

APPENDIX B: TIME SERIES OF UNDERLYING VARIABLES

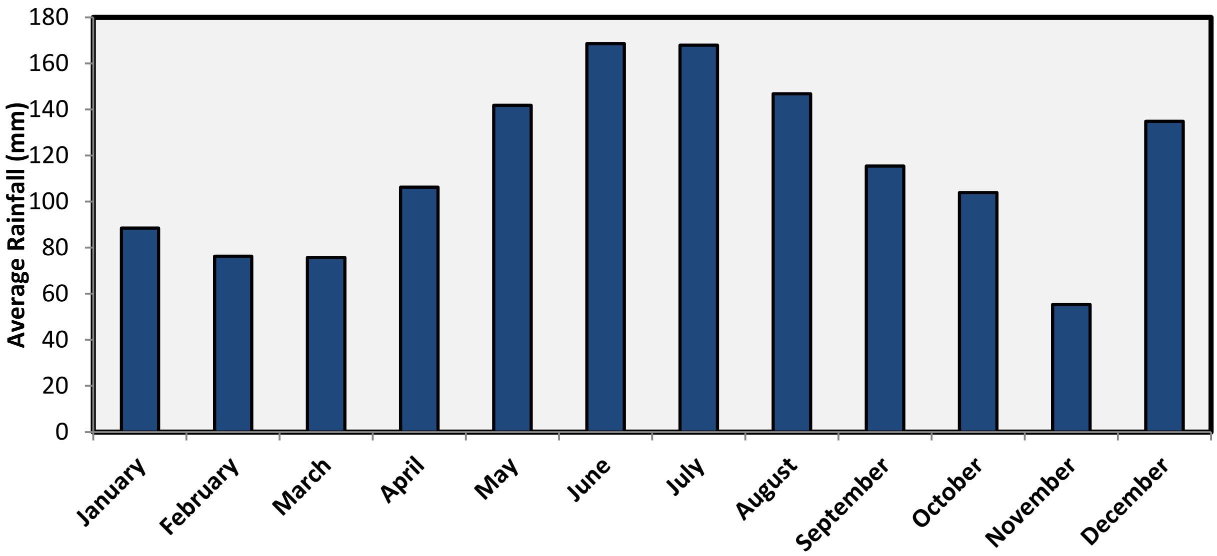
The mean temperature for each month averaged over the study period:



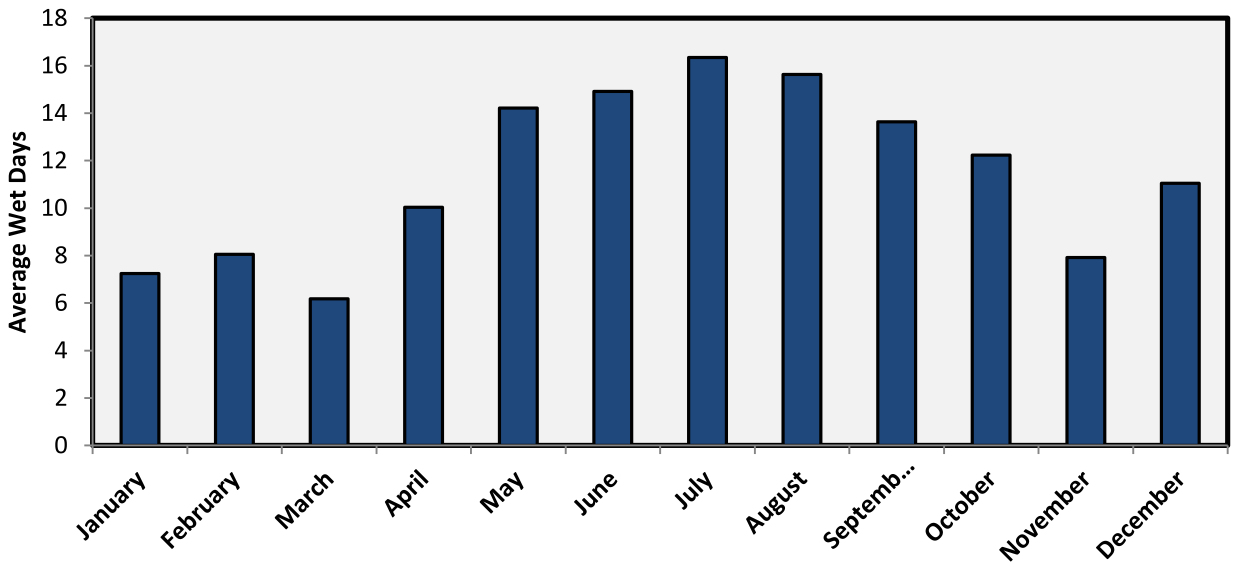
The mean highest temperature for each month averaged over the study period:



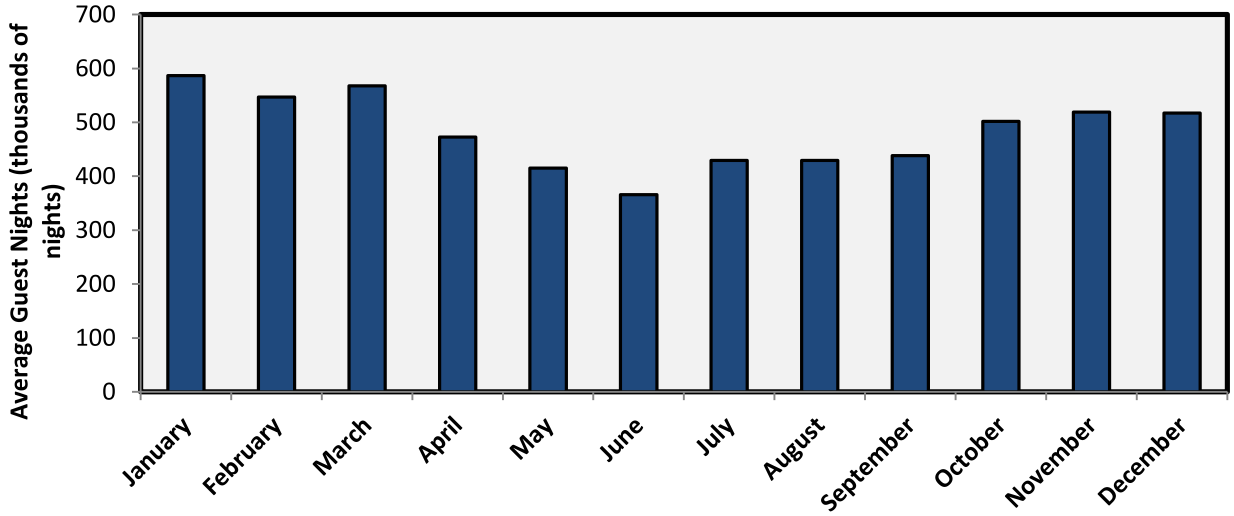
The average rainfall for each month averaged over the study period:



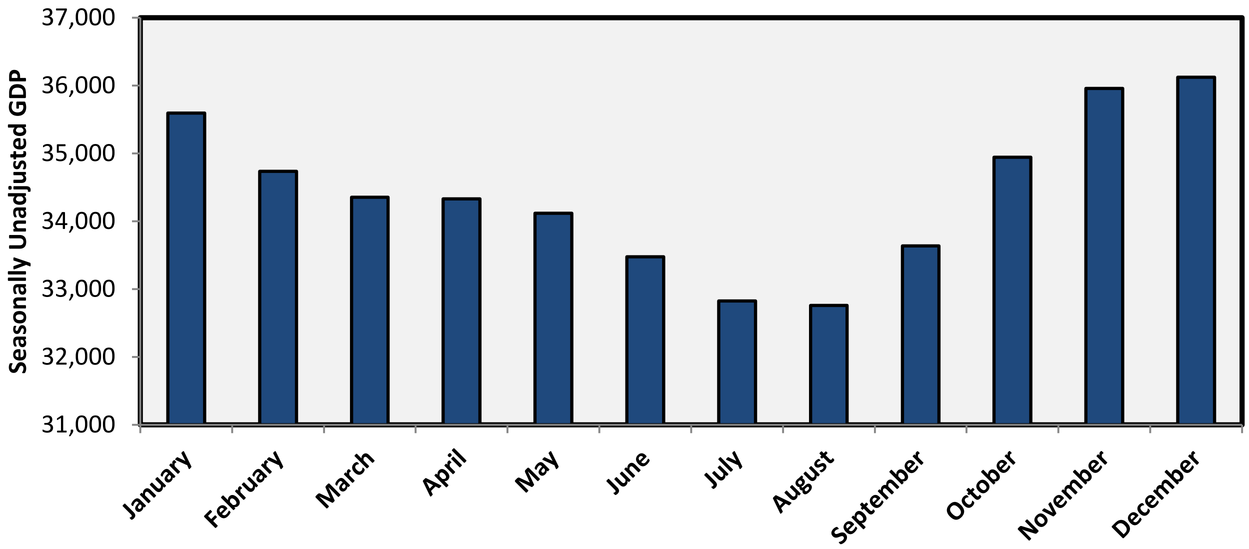
The mean Wet Days for each month averaged over the study period:



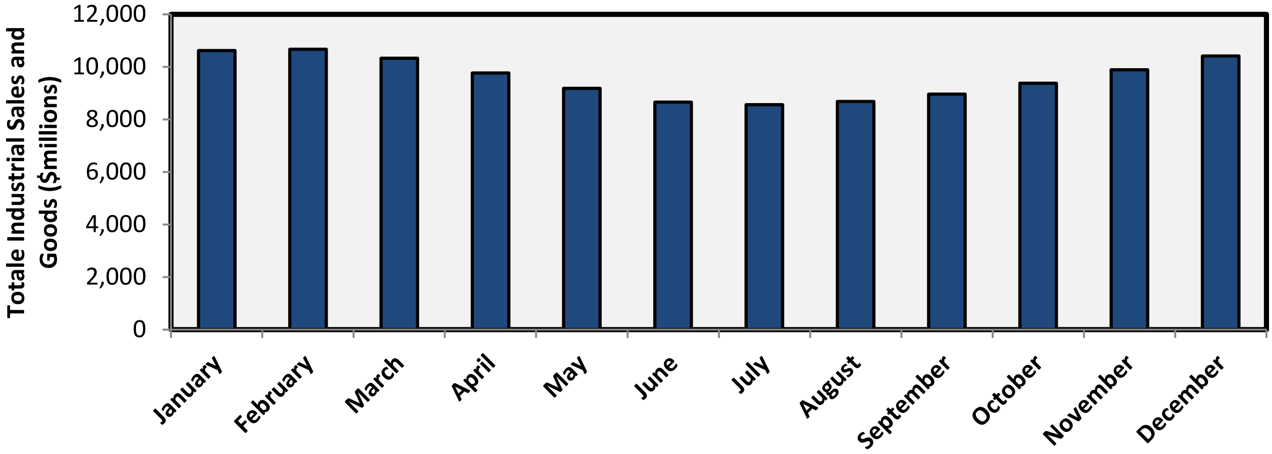
The mean Guest Nights for each month averaged over the study period:



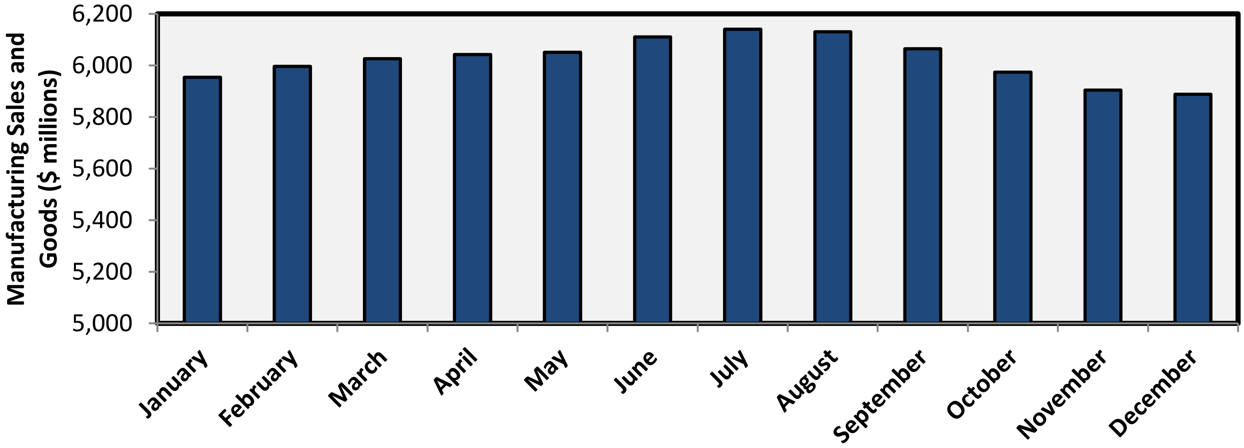
The mean GDP for each month averaged over the study period:



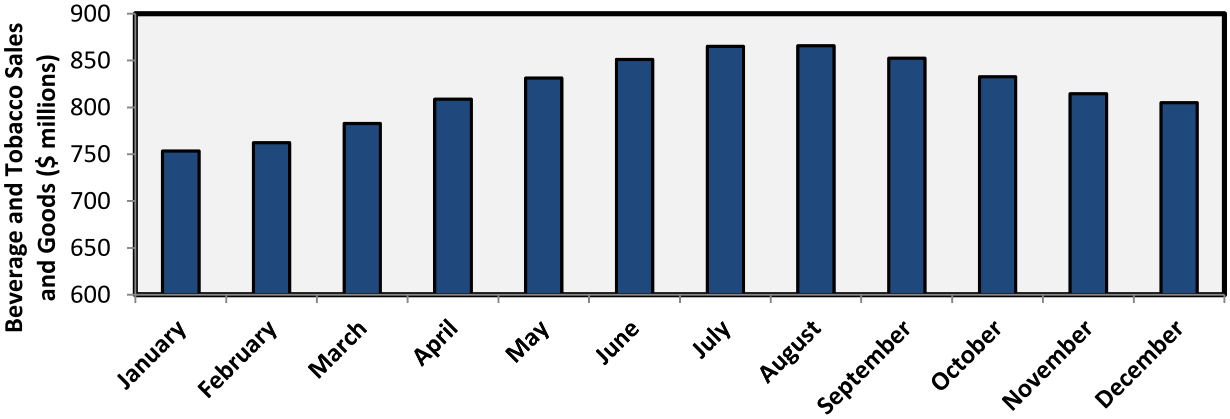
The mean Industrial Sales and Goods for each month averaged over the study period:



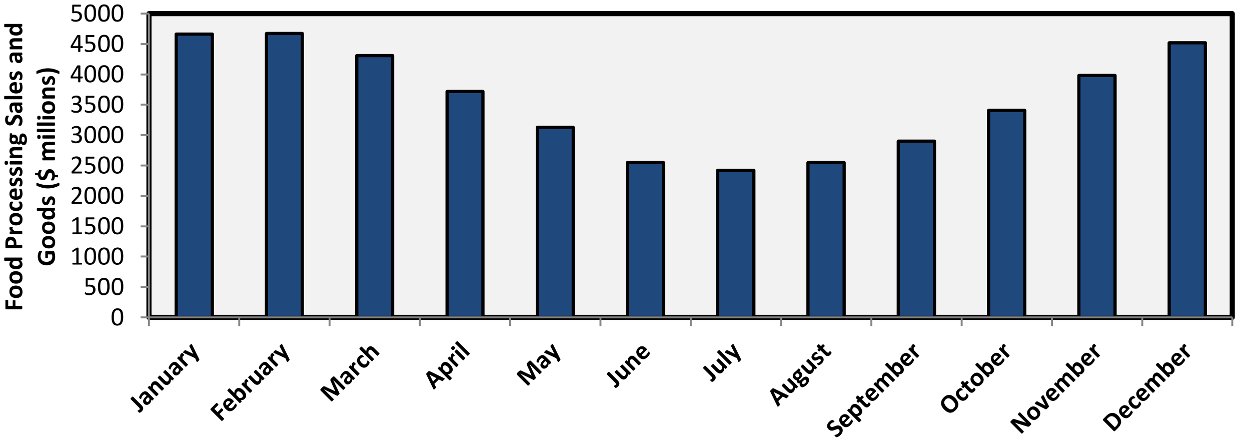
The mean Manufacturing Sales and Goods for each month averaged over the study period:



The mean Beverage and Tobacco Sales and Goods for each month averaged over the study period:



The mean Food Processing Sales and Goods for each month averaged over the study period:



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