RECYCLED WATER IN QUEENSLAND: BUILDING A MODEL FOR THE FULL COST OF RECYCLED CLASS A+WATER

A Thesis submitted by

Christina A James-Overheu, BA (Hons), GDipEd, FCCA, MFinMgt

For the award of

Doctor of Philosophy

2016

ABSTRACT

The fact that water is a critical resource in an increasingly urbanised population was highlighted in Queensland by the prolonged 1997-2010 drought, which in South East Queensland prompted investment in significant capital infrastructure in an attempt to increase the drought resilience of water supplies. The need to consider alternative water supply sources prompted interest in recycled water from waste water treatment both to supply industry and to replace potable water. This included using 'fit for purpose' recycled water rather than drinking water for non-potable uses, but also using high grade recycled water for indirect potable use. The question arises how to value such new water sources. The 'value' of a scarce natural resource such as water is not confined to traditional economic accounting models and undervaluation of the resource could encourage undesirable consumer behaviour in terms of increased volumes of use of a 'free' resource. Costs include direct costs, distribution and other capital assets, but these have not always been fully passed on to customers. Costs and benefits also include 'externalities' not captured in traditional accounting models such as environmental and social costs. Including full costs is crucial for informed policy decisions. This background is motivation for the research problem posed in this thesis:

How can a triple bottom line approach be used to provide a costing model for the full cost of Class A+ recycled water for use in South East Queensland?

This thesis provides a Triple Bottom Line (TBL) approach that reports economic, environmental and social costs and applies it to the case study of two advanced water treatment plants in South-East Queensland, each plant using different processing systems for the production of recycled water from treated waste water. Difficulties associated with producing such a model are highlighted via the case studies and externalities are identified. This thesis synthesises results from previous research from a number of disciplines, such as environmental management and engineering (Reungoat et al. 2010a; Halliday 2006), psychology (Menegaki et al. 2009) and economics (Frontier Economics 2011), and adds an accounting dimension. Realistic examples are provided via the case studies, and the thesis investigates the least-documented social aspect of a TBL approach via an extensive survey of perspectives

and motivations of recycled water customers, both actual and potential, at the same case study location.

The model suggests a broad range of interactions between stakeholders, assumptions made regarding the substitution of recycled water for marginal potable water supplies, environmental considerations such as greenhouse gas reporting, and the political and social costs of introducing a recycled water supply for potable and non-potable use.

The thesis demonstrates that on many levels management of key stakeholders is crucial and the social and political costs of decisions are high and suggests critical perceptions that have not previously been fully addressed well, such as stakeholder management in terms of media, information provision and awareness of and reasons for the polarisation of opinion on the subject of purified recycled water, particularly for indirect potable/drinking water use.

Certification of Thesis

I certify that the ideas, experimental work, results, analyses, software and conclusions reported in this dissertation are entirely my own effort, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award, except where otherwise acknowledged.

Signature of candidate

_10/7/2016_______________

Date

ENDORSEMENT

Signature of supervisor – Professor Marie Kavanagh

Signature of supervisor – Associate Professor Geoff Slaughter

ACKNOWLEDGEMENTS

I would like to acknowledge the help of my principal supervisor, Professor Marie Kavanagh and my associate supervisor Associate Professor Geoff Slaughter. I would also like to acknowledge the co-operation of the case study organisation's management and staff. I am similarly indebted to colleagues at USQ who took part in the pilot questionnaire and have offered advice and encouragement, and to Rachel King in the USQ Statistical Consulting Unit. I would also like to thank my family for their patience.

In memory of my brother Steve 1957-2015

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF KEY ABBREVIATIONS

ABS – Australian Bureau of Statistics
AWTP – Advanced Water treatment Plant
BAC - Biologically Activated Carbon
CSIRO – Commonwealth Scientific and Industrial Research Organisation
CSR – Corporate Social Responsibility
COAG – Council of Australian Governments
DOE – Department of Environment
EFA - Exploratory Factor Analysis
GRI – Global Reporting Initiative
IPCC – Intergovernmental Panel on Climate Change
LCA- Life Cycle Analysis
MDAWTP – Murrumba Downs Advanced Water Treatment Plant
NWC – National Water Commission
PAF – Principal Axis Factoring
PCA – Principal Components Analysis
PPRW – Potable Purified Recycled Water
PRW – Purified Recycled Water
QCA - Queensland Competition Authority
RO – Reverse Osmosis
RP – Research Problem
RQ – Research Question
RW – Recycled water
SCWRP – South Caboolture Water Reclamation Plant
SD – Standard Deviation
SE – South East; SEQ - South East Queensland
TBL – Triple Bottom Line
UNWCED – United Nations World Commission on Environment and Development
WASP – Water Accounting Standards Board
WBCSD - World Business Council for Sustainable Development
WCRWP – Western Corridor Recycled Water Project
WCRWS - Western Corridor Recycled Water Scheme
WRP – water Reclamation Plant

1. Introduction

1.1 Introduction

Water is a critical resource. The impact of the prolonged drought in Australia from 1997-2010 set in motion fundamental changes as to how water as a resource is to be managed, and opened debate about its scarcity value, particularly in South East Queensland (SEQ). Protracted drought followed by high rainfall intensified the flash floods and severe flooding in Queensland in 2010-2011 which caused widespread damage to infrastructure, in some of the most highly populated areas of SEQ. The fluctuation between drought and flood in Queensland is evidenced by the fact that by March 2014 nearly 80% of Queensland was again drought-declared, with the drought reaching 80% of the State by May 2015. This is the largest area ever officially recognised as being in drought, although in this instance mostly affecting inland rural western Queensland (Hough and Rogers 2014; McConchie 2015).

The focus of this project is the consequent attempts in SEQ to use recycled water in order to improve urban water supply, and the challenges this poses in tracking the cost of recycled water and in setting prices for consumers. Traditional economic-only based costing models are likely to be insufficient for reliable policy decisions regarding best use of water resources and supply, particularly with regard to recycled water. Water is part of a natural system, and a systems based view of its use is essential. Sustainability is grounded on a systems perspective drawn from the language of physical sciences (systems dynamics and stability). 'A system or a particular system state is "sustainable" if the system's inputs and outputs remain sufficiently balanced over time to avoid system collapse or disruptive change' (Peattie 2011 p. 21). In accounting terms this suggests accounting for flows rather than simply economics. The lack of an Australian national policy on drought is evidenced by the current differing treatment of farmers situated either side of the NSW/QLD border, despite the fact both are situated in the same natural system and drought area, with Walgett Shire in northern New South Wales experiencing its worst drought on record. Queensland has a policy of aid for 'drought declared' regions, but the NSW State Government has not declared any drought relief, as it affects a lesser area of that State (ABC 7.30 Report 2015).

Recycled water use has obvious environmental implications. These may be positive in terms of reducing the amount of water harvested from natural systems and reduction in effluent released into waterways and ocean outlets. Its use may reduce the need for major infrastructure storage such as dams, and defer the need for other means of water provision such as electricity intensive desalination. Benefits may also include improved waterways for recreational use (either by adding quality recycled water to water systems or avoiding the incidence of its removal), and provision of jobs if the additional water is used to service industry. There could also be potential negative implications for recycled water use. Depending on the particular process used to produce the water and its intended use, negative implications such as high electricity costs, increased salt concentration in output or health concerns regarding potable recycled water could arise. Social costs may include perceptions regarding health concerns and water pricing, with consequent political costs. Clearly the ‘value’ of water is not confined to traditional economic accounting models, and certainly not limited to market value economics (Hanemann 2006; Shatanawi & Naber 2011; Mooney & Tan 2012).

This thesis takes a Triple Bottom Line (TBL) approach to examine these questions and to build a model for the costing of recycled water that includes accounting for externalities. This looks beyond merely financial or economic performance to also take into account environmental/ecological and social performance (Elkington 1994). The thesis explores the social aspect of TBL via stakeholder analysis, this aspect of TBL being the least researched. It demonstrates how social cost is a critical success factor in moving towards the use of recycled water. Specifically two case studies of water treatment plants producing similar quality recycled water from secondary treated effluent, but using differing processes, are used to explore the issues.

The following section 1.2 gives some background to the development of sustainability as a reporting issue and to the development of a water recycling strategy by the Queensland Government. It outlines the movement towards a full cost approach to accounting for water, and provides motivation for this thesis and the research questions outlined in section 1.3.

1.2 Background research

The concept of sustainability

Recent years have witnessed a shift in thinking on corporate governance issues and the concept of corporate accountability. The concept of sustainable development was first clearly defined in the United Nations World Commission on Environment and Development's 1987 Brundtland Report '*Our Common Future'* as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (UNWCED 1987 Part 1.2.1). The definition was criticised for ambiguity but a 1991 joint publication by the International Union for the Conservation of Nature (IUCN), the United Nations Environment Programme (UNEP) and the World Wide Fund for Nature (WWF) asserted that**:** 'The confusion has been caused because "sustainable development", "sustainable growth" and "sustainable use" have been used interchangeably, as if their meanings were the same. They are not. "Sustainable growth" is a contradiction in terms: nothing physical can grow indefinitely. "Sustainable use" is applicable only to renewable resources: it means using them at rates within their capacity for renewal.' (IUCN, UNEP, WWF 1991 p.10).

The Australian Government Department of Environment website does not directly define sustainability but the 'Measuring Sustainability program' stated that 'Sustainability requires that the wellbeing of society – the combination of community liveability, environmental sustainability and economic prosperity – is maintained or improved over time' (DOE 2014b). The NSW Government Office of Environment & Heritage website commented that there are many different definitions but must include 'living within the limits of what the environment can provide, understanding the many interconnections between economy, society and the environment, and the equal distribution of resources and opportunities' (Environment & Heritage 2014).

Implications for corporate reporting

In terms of financial reporting, the expanded concept of accountability to stakeholders ('win, win, win') was captured by Elkington (Elkington 1994 ;1998) who coined the phrase Triple Bottom Line (TBL), also known as the 3Ps (People, Planet, Profits), and by Simon Zadek (Zadek 1998) at 'SustainAbility'. Increasingly research has explored the accountant's role in developing an accounting information system capable of providing reports on a TBL or Corporate Social Responsibility (CSR) basis. Business entities are viewed as accountable to a much broader stakeholder community and conventional financial accounting reporting is criticised for falling short in providing information that is useful for users, a process of change that Elkington (2004) describes as the 'seven sustainability revolutions'. These include movements towards transparency, life-cycle analysis in terms of function rather than product, a longer-term focus and inclusive corporate governance. In terms of products, this examines product acceptability 'from the extraction of raw materials right through to recycling or disposal' (Elkington 2004 p.5). He similarly talks of three pressure waves (i) acknowledgement of finite natural resources (largely compliance only) (ii) the need for more sustainable production processes (increasing competition) and (iii) significant changes in governance. All of these trends highlight the need for a holistic approach to accounting for such a scarce natural resource as water.

Organisations such as the Coalition for Environmentally Responsible Economies (CERES), the United Nations Environment Programme (UNEP) and the Global Reporting Initiative (GRI) (and its G4 Sustainability Reporting Guidelines), all promote the integration of sustainability issues and general purpose reporting, with such information being made available to capital markets. Reporting on sustainability is becoming mainstream, with all Fortune 500 countries in 2010 providing information on environmental and social issues on their websites (Junior, Best & Cotter 2013), with an increasing number providing a sustainability report, although with varied quality as far fewer offer independent assurance verification (Junior, Best & Cotter 2013; KPMG 2014). The growth in sustainability as a major issue is similarly witnessed by initiatives such as the United Nations' Clean Development Mechanism (CDM) which promotes the creation of projects that help Kyoto Protocol Annex 1 signatory countries reduce emissions to meet their targets and to promote sustainable development in developing (Annex B) countries. The benefits of CDM projects in 2012 included 'new investment, the transfer of climate-friendly technologies and knowledge, the improvement of livelihoods and skills, job creation and increased economic activity' (UNFCCC 2012 p.7), with an estimated USD 215.4 billion invested by 2012 (UNFCCC 2012 p.8), and the 6,000th project being registered in January 2013 (CDM 2013) with 7,678 registered projects as at 31 May 2015 (CDM 2015). The Chair of the CDM Executive Board, Peer Stiansen commented that 'the effects of climate change are already being seen, so increased action on climate change is inevitable.' (CDM 2013 p.1)

As is the case in Australia, sustainability reports are generally non-mandatory. Corporations need to be persuaded therefore as to the benefits of such reporting. The motivations for sustainability reporting, whether within an entity's financial statements, or as a separate report, fall within the research on voluntary disclosure, legitimacy theory and stakeholder theory

<u>The influence of climate change & its effect on water supply</u>

The huge shift in the last decade in the public perception of global climate change and the dramatic political 'volte-face' on this issue by a number of countries, including Australia, reflects the broader influence of stakeholders. Australia's change of heart regarding ratification of the Kyoto Protocol is an example (signed on 29th April 1998, ratified 12th December 2007) (UNFCCC 2012). The change of government was the impetus for Australian ratification, and that in itself was in part a reflection of the change in attitude towards climate change issues at that time in Australia. However this also serves to illustrate the precarious nature of climate change initiatives which require a long-term view and commitment, in a political arena often dominated in democracies by short-term party politics, and driven by economic concerns such as recovery from the Global Financial Crisis (GFC). The 2013 Australian federal election, by contrast, returned a party committed to the repeal of key climate initiatives such the carbon tax and subsequent emissions trading scheme. In response to the 2014 release of the 5th UN Intergovernmental Panel on Climate Change (IPCC) report, calling for urgent action on climate change, the effects of which are already being felt, Mr Abbott persisted in a 'business as usual' view. His comment 'Australia is a land of droughts and flooding rains. Always has been, always will be' (The Age 2014) was seen as dismissive and he rejected the idea of a link between climate change and 2014 drought conditions in eastern Australia (Hannam 2014). Lord Nicholas Stern, who headed the 2006 Stern Review on the Economics of climate change, cites political uncertainty as one of the key obstacles to private investment in mitigation technology and climate change action (Stern 2013). In relation to this project, changes in political will can also be seen to impact heavily on water policy and readiness to promote alternative water supplies.

With regard to sustainability reporting, according to The World Business Council for Sustainable Development (WBCSD) much of the debate globally is about how and what to report and the format of such a report. The report should contain specific targets and concentrate on what is material and relevant to users. Climate change and sustainability (an awareness of the need to conserve and appropriately value scarce resources) are increasingly important to stakeholders (WBCSD 2007). For Australia, water is increasingly viewed as a material resource. Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) responded in February 2007 to the Intergovernmental Panel on Climate Change's (IPCC) 4th Assessment Report on climate change, stating that it is 'very likely that most of the rise in global average temperatures since the mid-20th century has been caused by increased greenhouse gas concentrations in the atmosphere' with 'a greater than 90 per cent chance that temperatures are rising due to human activities' (CSIRO 2007). Dr Whetton from CSIRO continued that a decrease in rainfall was likely in most subtropical land regions, including southern Australia. Sustainable water management is a key issue and the WBCSD in 2006 published a range of future water crisis scenarios for businesses predicting that water costs will rise sharply (WBCSD 2006).

The 2012 IPCC 'Special report for managing risks of extreme events and disasters to advance climate change adaptation' noted it was likely that the Australian continent had already experienced a decrease in cold days and an increase in warm days and projected a significant increase in the number of days over extreme temperatures (35-40 degrees Celsius). Effects included increased duration of heatwaves; extreme rainfall events and an observed increase in droughts since the 1950s in south west and south eastern Australia (Department of Environment 2014a). A 2013 report on water security in the Asia-Pacific region by the Asian Development Bank (ADB) highlighted a general lack of water security in the region, particularly in developing countries, and a vulnerability to water-related disasters such as flooding exacerbated by a preponderance of habitation in coastal regions. The region also has a reliance on irrigation for food security, and an increasing demand for water connected to rising energy supply and increasing urbanisation with the latter also increasing environmental risk. The report called for improved water management and more efficient use of water resources, including waste water recycling. The report's first key message for national leaders was: 'Make the best use of already developed water resources by investing in and incentivizing "reduce, reuse, recycle" systems.' (Asian Development Bank 2013 p.80).

The IPCC's 2014 5th Assessment Report with regards to freshwater resources stresses that there is robust evidence and high agreement that risk to freshwater supplies increases significantly with increasing greenhouse gas concentration and that:

> Climate change over the 21st century is projected to reduce renewable surface water and groundwater resources significantly in most dry subtropical regions (robust evidence, high agreement), intensifying competition for water among sectors (limited evidence, medium agreement). In presently dry regions, drought frequency will likely increase by the end of the 21st century under RCP8.5 (medium confidence). (IPCC 2014 AR5 Summary p.15).

In terms of sustainability reporting regarding water, the GRI G4 (2013) Reporting Guidelines in the Environmental category include the Aspect Water with one core indicator (EN8) – total water withdrawal by source and two additional indicators (EN9 and EN10 - water sources significantly affected by withdrawal of water and percentage and total volume of water recycled and used). The G4 Aspect Effluents and Waste also include G4-EN22 – Total water discharge by quality and destination (GRI 2013 p.60). This requires entities to:

a) Report the total volume of planned and unplanned water discharges by:
    - Destination
    - Quality of the water including treatment method
    - Whether it was reused by another organisation
b) Report standards, methodologies, and assumptions used.

Australian Responses to climate change and its political dimensions

Environment Australia (Department of the Environment and Heritage) issued a report in 2003 on Triple Bottom Line Reporting and this also included Environmental performance indicators for water – core Water 1 being total water use (m3), and additional 2 and 3 being total water reused (m3) and initiatives to decrease water consumption or increase water reuse (Environment Australia 2003 p.35). In July 2007 the then Prime Minister released 'Australia's Climate Change Policy – our economy, our environment'. This included the primary response of an introduction of a cap and trade emissions trading scheme (ETS) but noted that: 'Over time, the challenge of water security is likely to be exacerbated by climate change as parts of Australia are expected to become hotter and drier. This is expected to be Australia's most significant adaptation challenge.' (Department of the Prime Minister and Cabinet 2007 p.21). Subsequent Australian Governments have however failed to introduce an emissions trading scheme, although the Labor coalition government under Gillard did introduce a fixed price carbon scheme which was intended to convert into an ETS, but which was however repealed by the subsequent ALP government. The environment and water still remain important political issues with the Department of Environment asserting that 'The Australian Government is providing national leadership on the challenges of meeting future demand for water in a drying climate' (DOE 2014c). It is possible that the political atmosphere in Australia may again be changing towards greater action on climate change, with the 2015 appointment of a Prime Minister with a track record of favouring increased action.

Water scarcity and possible consequences for water policy and pricing

In Australia the Garnaut Climate Change Review's Final Report (September 2008) also highlighted the problems of urban Australia's stressed water supplies where continued investment in expensive new sources of water is likely to be a necessity. The Review was critical of the various systems of water regulation and pricing, particularly in rural areas, and pointed to inequities in allocation of property rights in water, in unfortunate price signalling (e.g. concepts of 'free' water) and a lack of overall co-ordination of water resources. Water markets should be 'transparent, broad and flexible, and based on clearly defined property rights' and 'should also value securing environmental flows' by allowing sufficient flows in waterways to maintain the ecosystem (Garnaut 2008 pp. 125, 373-4). If prices reflect the scarcity value of water (i.e. increase) then consumer demand will decrease.

Australia has the lowest rainfall of any habitable continent, the driest being Antarctica, and has the most variable rainfall and steam-flow (Department of Foreign Affairs and Trade (DFAT) 2008) with over eighty per cent of its population living in coastal areas, mostly in cities. Australian water use per capita is nevertheless one of the world's highest (Australian Bureau of Statistics (ABS) 2010). High evaporation rates, low rainfall, and high use of water from catchments such as rivers, lakes and underground aquifers is an unsustainable situation. Rainfall patterns in Australia have changed significantly since the 1950s and research suggests that it is strongly influenced by El Niño (drought) and El Niña (flood) events, with less rainfall in the highly populated areas of eastern Australia (Garnaut 2011a). This was evidenced by an unprecedented prolonged drought from 1997-2009 in south-east Australia, with disastrous results for Australian river systems such as the Murray Darling (De Blas 2003). The Murray River had flows to the sea for the first time in ten years in October 2010, yet the Murray-Darling Basin Authority's plan for the basin released in 2010 received a heated response from many communities. Finding the correct balance between sustaining natural ecosystems and providing water for agricultural use is proving difficult, though local opposition may in part be due to lack of information and poor introduction of the plan (Quiggin 2011). Drought conditions may also affect electricity supply, with coal and hydro power electricity plants requiring high water use (e.g. Victorian Snowy river scheme) (The Age 2007). The 1997-2010 drought was followed by equally devastating flood events in QLD, NSW and VIC. At the same time, south-west Australia had its lowest recorded rainfall in 2010, with water shortages and bush fires in Perth. Currently 80% of inland Queensland (not including SEQ) is drought declared, with early indicators of El Niño in the tropical Pacific making short term rain relief unlikely (McConchie 2015). Studies suggest that many of these changes are at least partly explained by anthropogenic climate change and are therefore unlikely to diminish (Garnaut 2011c p. 27).

Unpredictability of supply and increased urban populations have made water management a key issue. The evidence of the 2011 floods in Australia indicates ironically that water inundation can be as catastrophic to water quality and supply as drought, making water supply a vulnerable asset. Queensland Urban Utilities, for example, sustained significant infrastructure damage in the 2011 floods, including the Helidon water pump station being washed away; 21 of their 33 sewage pumping stations flooded or suffering loss of power; three major trunk mains fractured; significant damage to pipelines; and 9 out of 28 water reclamation plants inundated (including the advanced water treatment plant at Bundamba) (Lewis & Belz 2011). The Garnaut Climate Change Review 2011 Update points out that around 40% of the measurable market impacts of climate change are represented by infrastructure impacts, including water supply (Update 1 p.11). Garnaut also states in 2011 that later modelling suggests the IPCC (2007) underestimated the extent of sea level rise by 2100. The Department of Climate Change and Energy Efficiency updated their modelling to a level of 1.1 metres (from 70cm), with significant increase to the threat posed to Australian coastal regions, including water treatment plants (Garnaut 2011c p.25). Garnaut (2011) continues that the pressure on water supply is predicted to increase in the near future:

> Surface water availability is likely to be reduced across the entire Murray-Darling Basin, but more particularly in south-eastern Australia, where the median decline in runoff from 2008 levels may be as high as 13 per cent by 2030. Recent modelling has shown that the change in average stream flow under a median 2030 climate is a decline from 2008 levels of 10 per cent in Melbourne catchments, and 25 per cent in south-western Australia (CSIRO 2009; Post, Chiew et al. 2010). The warmer climate and increased evapo-transpiration will also increase demand for water in irrigated agriculture, cities and by water-dependent ecosystems, such as wetlands (Keenan and Cleugh 2011) (Garnaut 2011c p28).

The 5th IPCC report (2014) increased the prediction of global sea level rises for high emissions to 52-98cm by 2100 and a range of 28-61cm even with aggressive emissions reductions. This has been criticised by some scientific organisations as still being *conservative*, but in either scenario the vulnerability of coastal assets and water supply is clear (Rahmstorf 2013). A greater urgency is also reflected in the 2014 IPCC report with more frequent heatwaves and prolonged high temperatures putting a strain on water supply (McGregor & Sturmer 2014).

The effect of population growth

Australia also has one of the fastest-growing populations globally, estimated at almost 23.5 million as at April 2014 (ABS 2014a). The population grew at an annual rate of 2.1% compared to Canada (0.8%), USA (1.0%), China (0.5%) and Indonesia (1.1%), based on a SEQ population trends update in 2010 (Taylor 2010 p.3). The rate of growth was still at 1.8% in 2013, according to the Australian Bureau of Statistics (ABS 2014b). The Australian Government 2015 Intergenerational Report projects population to reach 39.7 million in 2054-55, up from an estimated current population of 23.9 million (The Treasury 2015). South East Queensland's (SEQ) 2008 population growth rate was 2.8%, above the national average, and the population growth in the Moreton Bay area (the geographical area examined in the case studies of this thesis) was one of the highest of the QLD Local Government Authorities (LGAs) (Taylor 2010 p.25). Between 2001-2011 the average annual growth rate was 2.5 per cent, with a 2011 population of 694,000 (BITRE 2013). 'At 30 June 2013, Brisbane (C), Gold Coast (C), Moreton Bay (R) and Sunshine Coast (R) were the largest LGAs by population size in both Queensland and Australia' (QGSO 2014 p.1, 'C' city & 'R' regional council). Current concern over population growth in Queensland, and in particular the pressure on SEQ, is reflected in Local Government Association of Queensland (LGAQ) plans to pursue incentives to attract growth to regional centres to ease the pressure (Local Government News 2013). Population growth alone puts pressure on urban water supplies, and climate change predictions anticipate increased migration from drought affected or inundated areas (Climate Action Network Australia 2006; Myers 1993). This link was emphasised in the Queensland Government's 2014 'Water Q' strategic document citing projected population growth from in 2011 4.5 million to 7-8/9 million in 2044, with expected growth in the greater Brisbane region from 2.1 million to a median estimate of 3.9 million in 2044 (DEWS 2014c).

Water pricing in the past and attitudes

Water is not 'free'. There have always been substantial costs, including distribution and other capital assets, but these have not always been fully passed on to customers, and water scarcity has also been undervalued, with a preference for urban water authorities, particularly council-controlled authorities, to opt for water restrictions rather than supply and demand pricing variations (Silby 2006; Hunt & Dunstan 2007; Hunt, Staunton & Dunstan 2013). This has encouraged customers' perceptions that water is, or ought to be, free of charge, an attitude still being expressed in Queensland media in 2010. According to one reporter for the Gold Coast News:

> Water is free. It falls from the sky - you don't have to manufacture it, or create it through some scientific wizardry, it's just there... Years ago, they used to give you 300kL a year for free. Then the council CEOs and bureaucrats realised there was money to made from the stuff that falls free from the sky and they banded together to see how they could squeeze more money from the ratepayer (Wuth 2010).

Charging appropriate rates for irrigation water, or trading in permits, is one way of encouraging irrigation efficiencies (De Blas 2003). Subsidised water has encouraged inefficiencies in water usage and allowed excessive reliance on catchment water rather than promoting the development of recycled water technology (WBCSD 2012). The Urban Ecology Australia website (UEA 2007), argued that 'subsidies for catchment water discourage water recycling' even though recycling 'if implemented widely, would do much to conserve often limited catchment water supplies.' The recommendation is for full cost pricing, including capital and maintenance costs and wastewater disposal. An imbalance between fixed fees and variable per unit charges also discourages conservative water usage. In rural Australia the legacy of not passing true costs on to customers, and subsidising water supply, may also have left regional facilities under resourced and incapable of maintaining satisfactory water quality standards, according to a 2010 report from Infrastructure Australia (IA). According to Rory Brennan, IA's executive director, 'without pricing reform, many of those water utilities are never going to achieve financial stability' (Hepworth 2010 p.6).

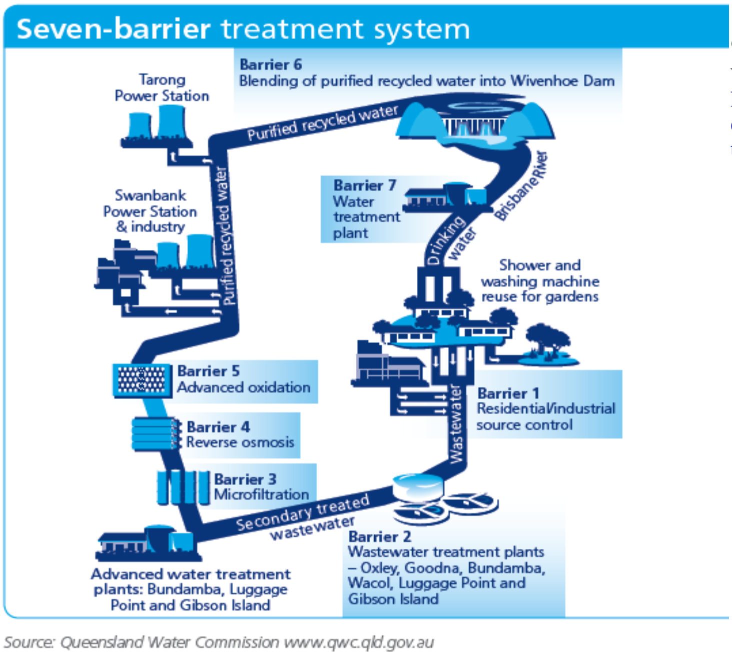
Full cost pricing of course implies an accurate assessment of costs and a debate over the boundaries of the 'full' definition. Historically, however, the political cost of charging full cost for water supplies has perhaps been too great for its successful implementation (Hunt & Dunstan 2007; Hunt, Staunton & Dunstan 2013; Pawsey and Crase 2013). Attempts to increase prices in SE QLD have resulted in widespread public protests in 2010/2011, described on the Gold Coast as a 'war' between ratepayers, the local council, the recently created water business (ALLconnex - replacing the local councils of Redland, Gold Coast and Logan regarding water supply and sewage treatment) and the State Government, with each accusing the other of profiteering from water price increases (Tuttiett & Killoran 2011).

The then (Labor) Australian Federal Government's view was encompassed in their 2008 'Water for the Future' policy. This advocated a national approach and recognised 'that water shortages are a serious threat to our economy and way of life' (Wong 2008, p.2). The policy was a $12.9 billion investment in strategic water priorities over a ten year period. The four key priorities included improving water efficiency to make better use of available water supplies and in ever-growing Australian cities (by 2050 population estimated to rise from 21 to 33 million) to seek 'new sources that rely less on rainfall given the clear threat climate change poses to traditional water sources' (Wong 2008, p.11). Brisbane in 2008 was cited as the urban centre with the most stressed water supply and this resulted in justifications for level 6 water restrictions as Brisbane was 'currently experiencing its worst drought in more than 100 years, with five consecutive low-rainfall years and water storages now at just 38 per cent of capacity' (Wong 2008, p.11).

Queensland response to water concerns

The Queensland State Government's response to the water crisis during the 2007-2010 drought was to invest heavily in new sources of water supply. The most notable investments were a desalination plant at Tugun, completed in 2010, and the Western Corridor Recycled Water Project, completed in 2008. A 2006 proposal for a dam at Traveston Crossing was delayed indefinitely in 2009 after failing to get federal Government approval on environmental and social grounds in 2009 (ABC News 2009), but construction of the Wyaralong Dam in SE QLD was completed sufficiently prior to the 2010-2011 floods to provide a flood mitigation role according to local government (Logan West Leader 2011) and was finally completed in 2011. A diagrammatic representation of the planned Western Corridor Recycled Water Project, as it was originally intended, is given in Figure 1.1 below. This shows that indirect potable use of recycled water was planned, as purified recycled water from the advanced water treatment plants was proposed to be added to the Wivenhoe Dam. The

Wivenhoe dam itself was built post the 1974 extensive flooding, intended as much for flood mitigation purposes as water supply (Gould 2014).



Source: QLD Water commission website factsheet, viewed 21 June 2010 http://www.westerncorridor.com.au/media/fact_sheets/Our_product_factsheet.pdf

Figure 1.1: Overview of the Western Corridor Recycled Water Project – as at 2010

As already mentioned, the socio-political background to water policy is often paramount. The break in the weather in 2010, and the economic downturn, also witnessed a break in the political resolve to implement the plans as intended. The Western Corridor Recycled Water Project potentially produces potable standard water and was originally intended to provide indirect potable water by supplementing water in the Wivenhoe Dam, as well as supplying the power stations at Swanbank and Tarong (as it currently does) - see the 2010 QLD Water Commission diagram in Figure 1.1. However public pressure regarding the safety of drinking recycled water from the scheme led the then Queensland Government to limit supply to industry and to shelve immediate plans for adding recycled potable water to Wivenhoe. The policy became only to supply Wivenhoe if dam levels fell below 40% (Edmistone et al. 2008). Plans for the Traveston dam were similarly shelved amid public pressure from residents and environmental groups and the $1.2 billion Tugun desalination plant was ‘mothballed’ only two months after the Queensland Government took receipt of it, in an attempt to reduce costs and bulk water charges to customers (Lion & AAP 2011). The Tugun plant was plagued by malfunctions and repair issues since hand over and these became the subject of a law suit with Lloyds of London (Stolz 2010, 2012). The QLD Government explained that it could be re-opened if the supplying dam levels drop below 60%. The Government was ‘reviewing its ten year price-path for bulk water sales to the council-owned retail water entities’ as a result and ‘called on local councils profiting from water retail businesses to pass on savings to struggling householders’ (AAP 2010).

This highlights the political dimension to water supply and water pricing, and the social cost to governments implementing reform. The then (2010) ALP Queensland opposition leader was quoted as saying that the desalination plant might be needed in times of water crisis, but the extra cost of running the desalination plant, at ‘21 times the electricity of traditional water storage’ was not justified (Barrett & Schliebs 2010). Paradoxically, during the drought, the same QLD Opposition party preferred a further desalination plant to be built (ABC TV News 2008). The position of the Gold Coast Desalination Plant at Tugun was reviewed by the Newman QLD State Government, (the Liberal National Party having defeated Labor in the March 2012 state election). A June 2012 media release acknowledged the difficulty of trying to save costs by putting the plant on ‘hot standby’ whilst balancing the increased problems with maintenance and asset degeneration as a result of running the plant at less than its designed capacity. The release also acknowledged that the desalination plant played an important role in supplying Brisbane with clean drinking water during the floods (Collins 2012). Controversy and local anger over the inflated cost of building and running the Tugun desalination plant continue, although its water security function was again acknowledged by Water Minister McArdle who noted that in January 2013 it supplied water to SEQ when water treatment plants were impacted by flooding (Killoran 2013).

The Tugun plant in 2015 remains at low operational levels of 25ML per week (compared to a maximum of approximately 125ML per day) and is described on the SEQWater website as ‘a climate-independent source of water that ensures South East Queensland’s water security in time of drought and extreme weather’ (SEQWater 2015). The tone of political comment has again changed in Queensland with the re-election of a State Labor government, and the Water Supply Minister Mark Bailey confirmed that Tugun will not be de-commissioned but is seen as a ‘$15 million dollar insurance policy' against drought, despite concerns regarding rising water prices (Houghton 2015). It should perhaps be noted that Victoria's desalination plant at Wonthaggi, built in 2012 but in standby since then, may be brought online in 2015 due to concerning levels of existing water supplies and a predicted hot summer. The Victorian State Environment Minister also described the plant as an insurance policy against drought (Edwards 2015). The fact remains, however, that emphasis of the debate post the last Queensland drought has been on costs, and whether all costs (including capital) should be passed on to customers in terms of increased consumer water prices, and also on the use of dams for flood mitigation. Management of the Wivenhoe dam during the 2011 floods has been the subject of an enquiry and criticised for waiting too long (in a reluctance to waste water) to release water as dam levels rose, until emergency release exacerbated the flooding (Thomas 2011). Following the Wivenhoe and Somerset Dam Optimisation study the Queensland Government was considering earlier release of dam waters in the event of pre-flood conditions to protect downstream communities (Newman & McArdle 2014). Flood concerns have also led to the QLD Government considering raising the level of the Wivenhoe dam and even building new dams for flood storage/mitigation (Vogler 2014; Gould 2014).

In view of the disputes over water pricing, accurate cost information seems both vital and lacking. There does not appear to be an integrated plan to develop a management information system capable of quantifying the full cost of supplying recycled water to the consumer. This leads to the research problem discussed in the next section.

1.3 Research Problem & Research Questions

The Council of Australian Governments (COAG) 'Intergovernmental Agreement on a National Water Initiative' (2004), commonly referred to as the National Water Initiative (NWI) and driven by the National Water Commission (NWC), states that a key element of the initiative is best practice water pricing. Pricing should promote sustainable use of resources and the principles of user-pays and transparency, and avoid 'perverse or unintended pricing outcomes' (COAG 2004 p.13). To avoid monopoly rents, such prices need to be based on accurate cost information, which the

NWI also notes does not exist in most States. In defining the upper bound of pricing, the NWI website outlined the costs that should be included:

> ..a water business should not recover more than the operational, maintenance and administrative costs, externalities, taxes or tax equivalent regimes (TERs), provision for the cost of asset consumption and cost of capital, the latter being calculated using a weighted average cost of capital (WACC) (National Water Commission 2011a, p.13).

Porter (2002) argues that economic policy failure occurs in two ways – hidden (inappropriate) subsidies and externalities, where only narrow private costs are considered. Both are common failures in the water system if water is priced for consumers at less than true cost (thus promoting waste of a scarce resource) and the costs of water supply are narrowly defined and exclude external and social costs. The definition of externalities in this thesis follows Porter (2002) where:

> the *marginal private cost* of something is what it costs the *producer* to produce it. Its *marginal social cost* is what it costs *society* to produce it. The difference between the two is the *marginal external cost* – costs to the society that are not costs to the producer. (Porter 2002, p.6)

A government may choose to limit the activity causing the external costs (such as environmental legislation) or convert it to a private or internal cost for business via taxation or legislation such as placing a price on carbon. However this will still limit the externalities that are 'caught', for example by focusing on environmental costs of Greenhouse gasses (GHGs) defined under the Kyoto Protocol. This thesis highlights the attribute of social cost as regards recycled water use and posits that it is a key cost often poorly understood and managed in public policy.

Sustainable development reporting (promoting sustainable use of resources and including externalities) cannot occur without a management information system sufficient to provide information on scarce resources and to link this information to the financial data. According to the World Business Council on Sustainable Development (WBCSD) recent research on sustainability reporting suggests that most reports lack rigour and linkages to mainstream economic reporting of the entity (WBCSD 2007). Environmental aspects are covered more fully than economic or social aspects. They also lack linkages across organisational boundaries, necessary for achieving sustainable strategies, and for analysis of the value chain and life cycle of scarce natural resources, and for managing risk [KPMG (2005; 2008); Baue (2006); Department of the Environment and Heritage (2005); European Commission (2009)]. Integration of CSR information with economic annual reports has long been considered desirable for a rounded picture of an entity's value, but the KPMG 2008 survey results indicated that progress is limited and that 'integration at both the G250 and N100 level remains the exception not the rule. Only a minority of N100 companies (nine per cent) and even fewer G250 companies (eight per cent) have taken up the practice to-date' (KPMG 2008, p.17). The 2013 KPMG reporting survey (KPMG 2014) did record a large increase in the incidence of Corporate Responsibility (CR) Reporting (including in Australia) and 51% of the reporting companies worldwide did include CR information in their annual reports but this did *not* reflect an increase in integrated reporting which 'can be the catalyst for integrated management'(KPMG 2014b p.11). Therefore it still appears to be a case of quantity rather than quality reporting, with European companies leading the way in terms of quality but a key area for improvement being reporting on suppliers and the value chain (KPMG 2014b p.14). The 2013 survey analysed areas of risk and opportunity and discussed the linkages between 'social and environmental megaforces' in which businesses operate, citing water scarcity as one of these 'ten sustainability megaforces' (KPMG 2014 pp.48-49). Of reporting businesses that mentioned these meagaforces, the top five most often seen as affecting the business were climate change, material resources scarcity, energy and fuel, water scarcity and population growth. Increasingly climate change risk and the lack (or surfeit) of water (drought/flood resilience) are becoming a major considerations for corporate investors looking for site locations, particularly in water intensive industries (Coffee 2014).

This thesis examines the scarce resource of water in the Australian context. In order to 'value' our water resources, the full cost of water supplies needs to be ascertained. This research takes a Full Cost or Triple Bottom Line (TBL) approach to the costing of recycled water. (This is further defined in section 2.1 below). If Australia is to reduce reliance on catchment water and take the pressure off ailing river and riparian systems, then alternative water sources, such as desalination and recycled water, need to be explored. It is hard to compare the viability of these without accurate costing information, and costing information from a system which is not based purely on economic considerations, but values social and environmental impacts as well.

Research Questions

This study concentrates on the costing of Class A+ recycled water, as produced by two alternative method advanced water treatment plants in South East Queensland, and asks the question:

Research Problem 1

How can a triple bottom line approach be used to provide a costing model for the full cost of Class A+ recycled water for use in South East Queensland?

Which gives rise to a set of further research questions (RQs) (Figure 1.2):

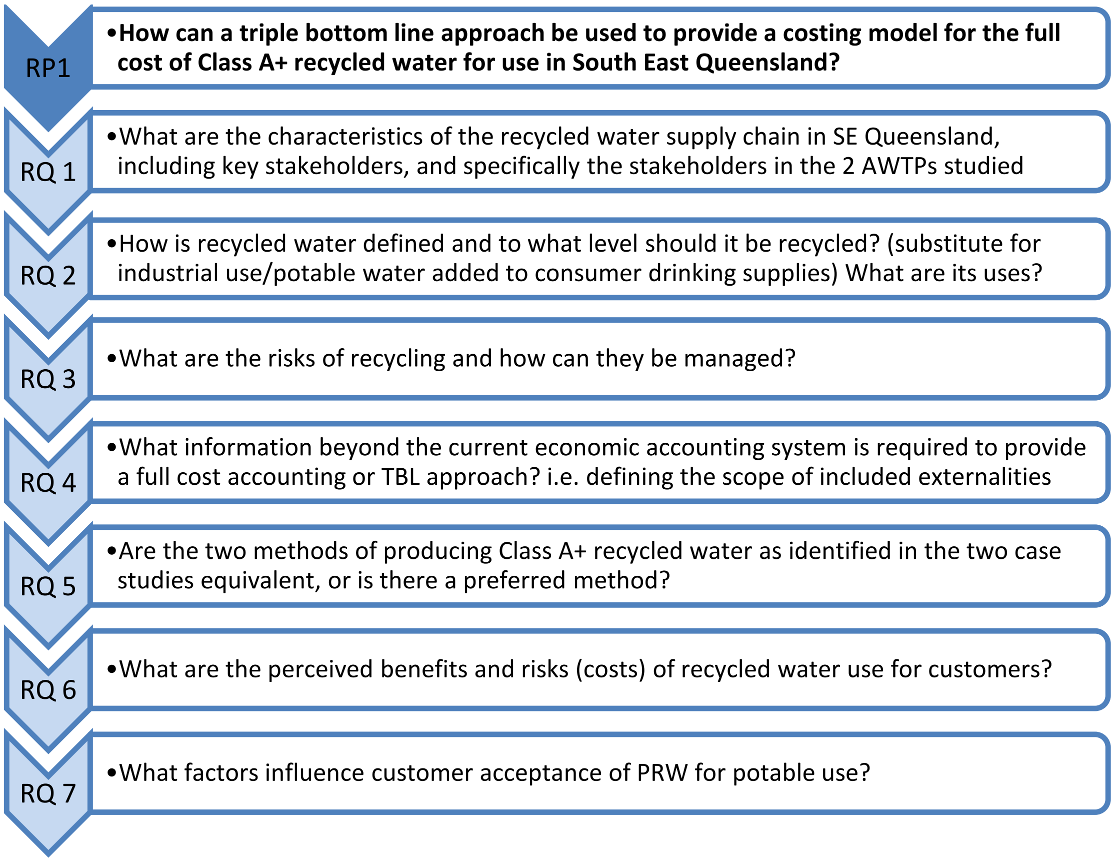


Figure 1.2: Research Problem and Questions

Links between the background research and the research problem and questions are shown in Table 1.1

1.4 Objectives of the thesis

The aim of this research is to develop a model for full costing of Class A + recycled water, which goes beyond traditional economic models, by using a triple bottom line (TBL) approach, including environmental and social aspects. The model includes materials flow information and may include externalities, for example any avoided or deferred costs, such as infrastructure costs, resulting from the adoption of water recycling as an alternative water source. Benefits might include mitigating the environmental costs of spilling waste water nutrients into the sea under the current system, or the deferral of expenditure on high capital cost alternatives such as new dams (with the associated high environmental cost of these) or desalination plants.

It would also include social costs such as those relating to changing value systems, usage habits and patterns of behaviour of consumers. It has been observed by previous research that there is often a lack of uptake of sustainable practices due to disconnect between the science of sustainability and the social science. Technologies exist but there may be a social brake on their use in terms of cultural values, emotions and lack of political courage or leadership (Agyemann 2011). Social/public and resulting political pressure in recent years in Queensland has caused the State Government to back away from using the newly-built recycled water facilities to provide water for potable domestic use. The government faced the task of persuading water customers to accept that the science of water processing is capable of reducing the perceived risks to an acceptable (minimal) level. Similarly water pricing reform requires public and industry acceptance of the idea of water as a valued commodity, and a willingness to pay appropriate amounts to protect water supplies in a sustainable model, and to promote altered consumer behaviour patterns. Given that the QLD drought was replaced by atypical incidence of rainfall in 2010/2011, SEQ dam levels were up to capacity by the start of 2011. In fact the necessity of releasing water from Wivenhoe dam, to ensure its structural integrity, possibly exacerbated the 2011 floods in SE QLD (Thomas 2011). In the face of this and a backlash of popular opinion after price increases, the QLD Government revised downwards the ‘ten year price path’ (Department of Energy & Water Supply 2014). In a sense this is a similar problem to that faced by governments in recent history attempting to introduce a price on carbon. Witness the lack of success for President Obama on emissions trading in the United

States, and the difficulties encountered regarding the Carbon Pollution Reduction Scheme by the former Labor Prime Minister Rudd, and former Opposition leader Malcolm Turnbull and the Gillard Labor Government's polling problems after the announcement of a carbon 'tax'. It has been argued that there exist strong vested interests in 'business as usual' that are fully capable of manipulating information to encourage a short term view of resource use, and that are capable of swaying popular beliefs even in the face of mainstream scientific evidence (Oreskes & Conway 2010; Stern 2013).

In the light of this it is important to develop methods for assessing policy that look at the broad picture, an objective of this study. Figure 1.3 sets the research questions into a TBL framework, allowing for considerable overlap and influence from one aspect to another. The perceived benefits and risks of recycled water, for example, could be both social/political and economic – benefit of improved supply reliability countered by perceived consumer risk and hence potential political/economic risk of introducing a policy or recycled treated wastewater which may lack acceptance.

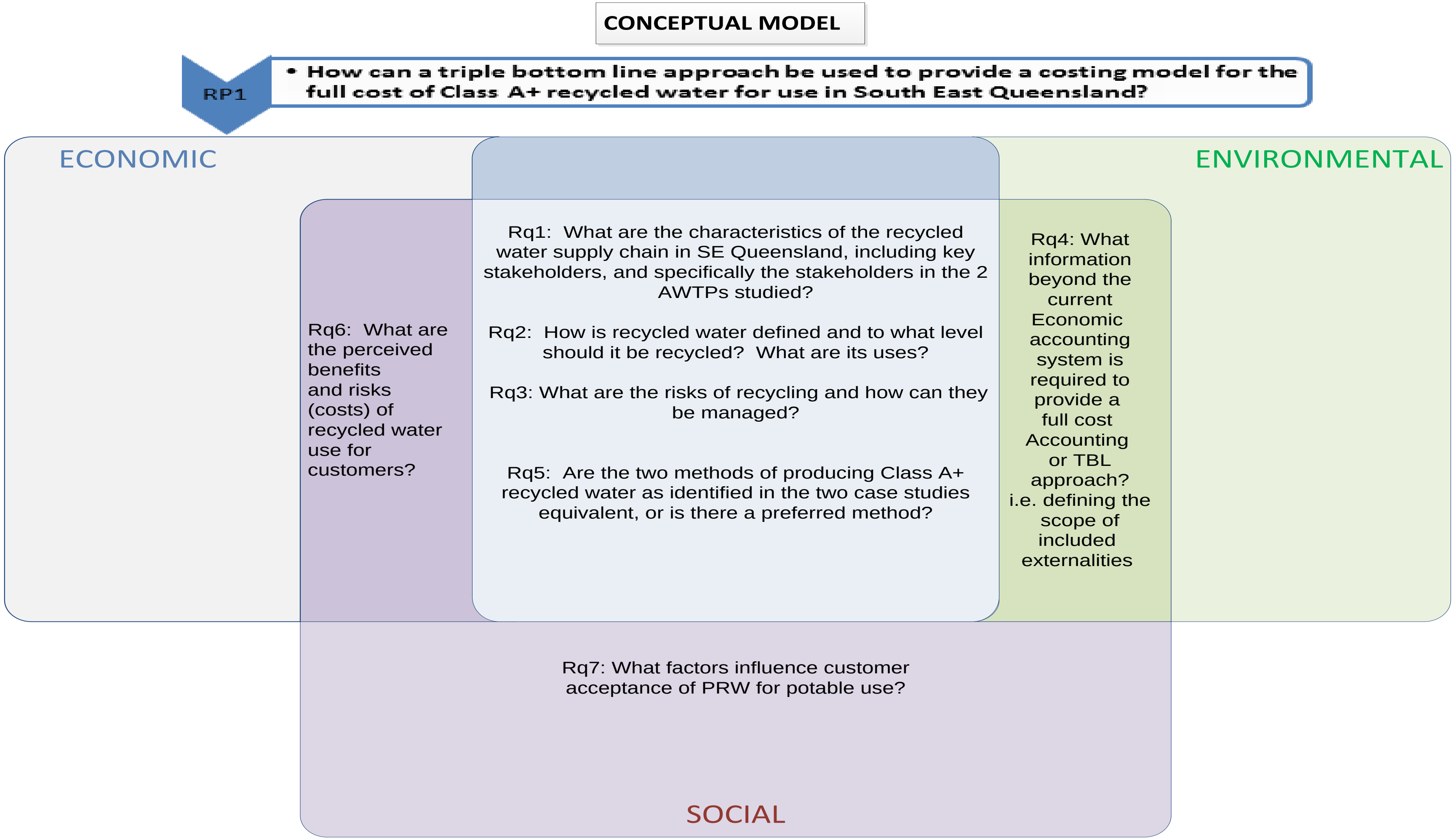


Figure 1.3: Application of the Research Problem and Questions to a Triple Bottom Line (TBL) model

Table 1.1: Research issues & motivation for Research Problem & Questions

Issues & Motivation	Research/Organisation	RP/RQ	TBL Aspects
Expanding concepts of stakeholders and reporting to TBL approach	Elkington 1994,1998; GRI 2013; WBCSD 2007	RP1 RQ1 RQ4	Eco, Env, Soc Eco, Env, Soc Env, Soc
Linking environmental risk to economics and reporting	Stern 2006, CERES	RQ1 RQ4	Eco, Env, Soc Env
Linking social risk to economics and reporting – aspect least reported	CERES, GRI 2013, KPMG 2013	RQ1 RQ4	Eco, Env, Soc Soc
Externalities should be considered	Porter 2002; Stern 2006; Garnaut 2013	RQ1 RQ4	Eco, Env, Soc Env, Soc
Concept of sustainability – but conflicting terminology	UNWCED 1987; IUCN 1991; DOE 2014b; Environment & Heritage 2014	RP1 RQ1	Eco, Env, Soc Eco, Env, Soc
Sustainability reporting mainstream but lacking integration & verification	WBCSD 2007; Junior, Best & Cotter 2013; KPMG 2013	RP1 RQ4	Eco, Env, Soc Env, Soc
Requires management accounting techniques e.g. LCA & long-term focus & cross-disciplinary approach	Elkington 2004: Baue 2006: Chalmers, Godfrey & Potter 2012	RQ1,3,5 RQ4	Eco, Env, Soc Env, Soc
Need for long-term strategy – an issue in socio-political context (government changes)	Stern 2013; UNFCCC 2012	RQ6 RQ7	Eco, Soc Soc
Climate change economic and social risk (& Australia)	Stern 2006, 2013; IPCC 2014; CDM 2013 (Garnaut 2008, 2011; CSIRO 2007);	RQ4	Eco, Env, Soc
Climate change risk – Water a vulnerable asset	WDCSD 2006; Garnaut 2011; KPMG 2013	RQ1,3 RQ4	Eco, Env, Soc Env, Soc
The value of water is not captured by economic accounting models; a systems view is preferable	Haneman 2006,Shatanawi & Naber 2009, Mooney & Tan 2012, NWC 2011a; Peattie 2011: WASB 2012	RQ1,3 RQ4	Eco, Env, Soc Env, Soc
Climate change & water as a critical resource – re-use	IPCC 2012, 2014; GR1 G4 2014; Garnaut 2011	RQ2 RQ4	Eco, Env, Soc Env, Soc
Australia & water – critical resource; climate variability; urbanisation & population growth	Department Prime Minister & Cabinet 2007;Garnaut 2011; DOE 2014c; ABS 2010: BITRE 2013	RQ2,3,5 RQ4	Eco, Env, Soc Env, Soc
Australia & water – need for new sources	Garnaut 2011, Wong 2008,	RQ2,3,5 RQ6	Eco, Env, Soc Eco, Soc
Australia & water pricing – politically difficult; social attitudes & media; pricing & use linked; lack of inclusion of externalities	Wuth 2011; Tuttiett & Killoran 2011; Quiggin 2011; COAG 2004; UEA 2007; Oreskes & Conway 2010; De Blas 2003; Hunt, Staunton & Dunstan 2013: Pawsey & Crase 2013;	RQ2,3,5 RQ4 RQ6 RQ7	Eco, Env, Soc Env, Soc Eco, Soc Soc
Lack of research on water use and sources from a customer perspective	Lane, de Haas & Lant 2012	RQ2,3,5 RQ6 RQ7	Eco, Env, Soc Eco, Soc Soc

1.5 Definitions and scope

Many terms in sustainability literature appear to be used interchangeably, without an agreed definition. It is useful therefore to provide some general definitions for the use of key terminology within this thesis.

Sustainability: The ongoing capacity to sustain and endure which requires 'living within the limits of what the environment can provide, understanding the many interconnections between economy, society and the environment, and the equal distribution of resources and opportunities' (Environment and Heritage 2014).

Triple Bottom Line (TBL): Following Elkington (1994;1998) a TBL approach to reporting includes economic, environmental and social performance.

Social: of or relating to society or its organization (Oxford University Press 2016, primary definition)

Full cost and full cost pricing: Full cost includes traditional economic costs (direct costs & capital costs) and environmental and social costs and full value would therefore be an assessment of economic, environmental and social costs and benefits. Full cost pricing is defined as per WBCSD 2012 p. 22: 'In relation to charging for water usage (and recovering costs for water services), this means setting a price that reflects both the financial costs and societal costs'.

Societal costs (as per WBCSD 2012, p. 22): The cost to society of an activity, which comprises resource (opportunity) costs and environmental damages.

Resource cost (as per WBCSD 2012, p. 22): The cost of foregone opportunities that other users suffer due to the depletion of the resource beyond its natural rate of recharge or recovery (e.g. linked to the over-abstraction of groundwater)

Environmental costs (as per WBCSD 2012 p. 22): The cost (or value) of damage imposed on the environment and ecosystems that affects human well-being (synonymous to societal and externality cost). In the context of water valuation, environmental costs may be water-related (e.g. related to water pollution) or non-water-related (e.g. the societal cost of greenhouse gas emissions).

Externality (as per WBCSD 2012 p. 22): A consequence of an action that affects someone other than the agent undertaking that action and for which the agent is neither compensated nor penalized through the markets. Externalities can be positive or negative.

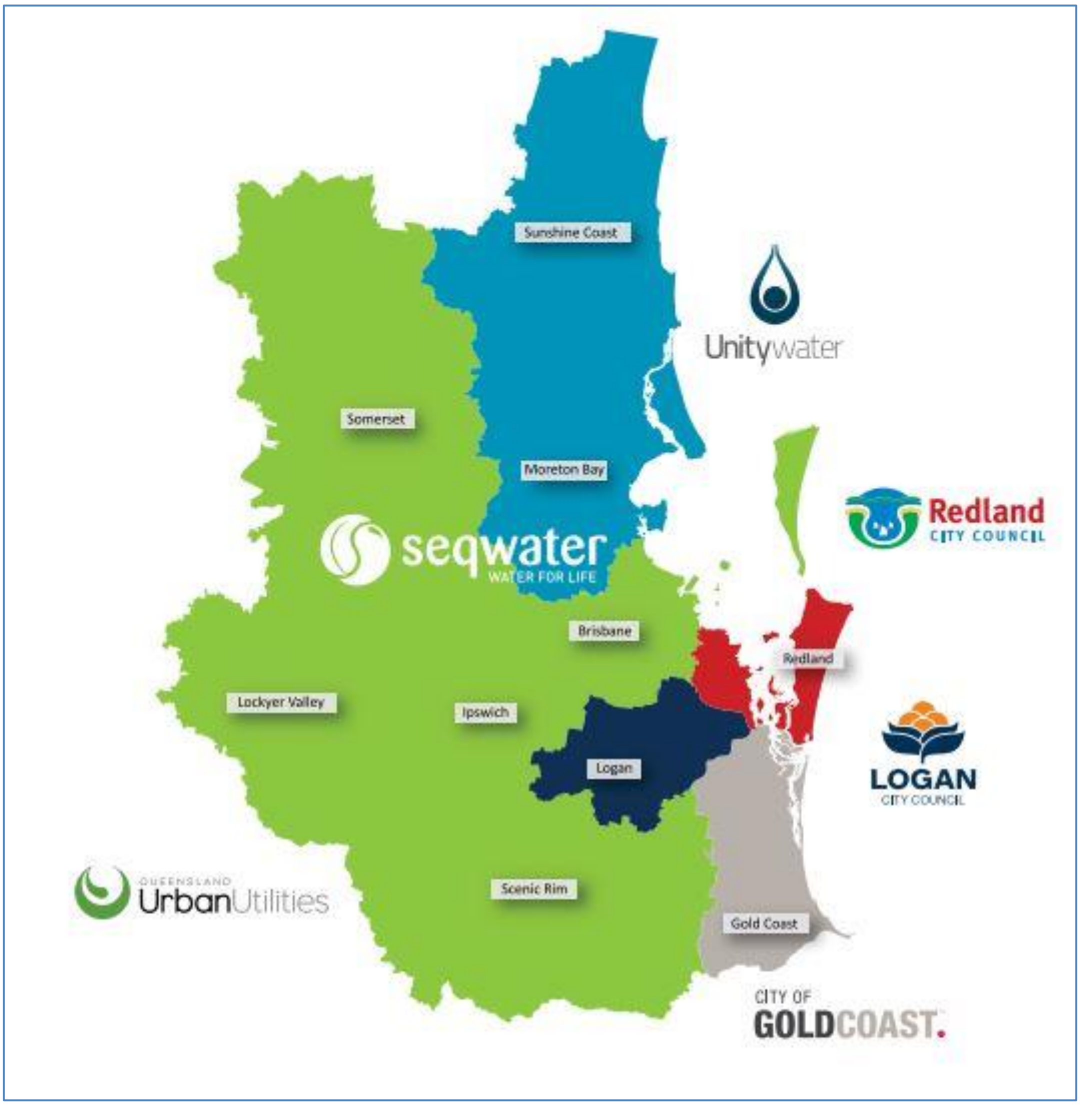
Non-use value (as per WBCSD 2012 p. 22): The value individuals derive from knowing that environmental features are maintained (e.g. pristine habitats and iconic species) even though they do not directly use them.

Stakeholder: Per Freeman (1984 p. 46) defined as: 'any group or individual who can affect or is affected by the achievement of the organization's objectives'.

SCOPE

In relation to describing a model for the full cost of class A+ recycled water for use in South East Queensland, using a TBL approach, *South East Queensland* (SEQ) is defined as the geographical boundaries covered by SEQWater (see Figure 1.4). This is relevant when discussing the relevant political/jurisdictional setting.

In relation to the two case study facilities, both are located in the area serviced by Unitywater. This then defined the area from which customer survey responses were drawn to examine customer perspectives (both users and non-users of non-potable recycled water) (see Figure 4.1). In terms of environmental impacts on the waterways adjacent to the two case study advanced water treatment plants, then the relevant areas are the Caboolture River catchment and estuary (Figure 4.6) and the Pine Rivers catchment and estuary (Figure 4.8). An overview of the SEQWater catchment areas is given in Figure 4.2.



Source: 'Water Outlook for South East Queensland' (SEQWater 2014b p. 3)

Figure 1.4: Area of the South East Queensland serviced by SEQWater

1.6 Contribution of the thesis

The aim of this thesis is to describe a method for building, and to suggest a model for the full costing of recycled water as applicable to two case study Advanced Water Treatment Plants (AWTPs) in South East Queensland (SEQ), which both recycle water to Class A+ (potential indirect potable use quality), a model which goes beyond traditional costing models by taking a Triple Bottom Line (TBL) approach. The TBL model was outlined in Figure 1.3 where the Research Questions (RQs) (Figure 1.2) were embedded in the TBL approach. The Research Questions underpin the model, but the research structure itself is part of the solution (RP1) of 'how' to go about building a model and to investigate the TBL dimensions, and these dimensions overlap. This means that same research questions e.g. RQ1 (What are the characteristics of the recycled water supply chain in SE Queensland, including key stakeholders, and specifically the stakeholders in the 2 AWTPs studied?) may provide information for several or all TBL aspects – economic, environmental and social. The model and the RQs are linked to the selected methods used to investigate the question in Figure 3.1. The results in Chapters 4 and 5 follow the methodology used to investigate the TBL aspects, but each section of Chapters 4 and 5 provides a summary of how these relate to the research questions. Finally Chapter 6 summarises the key findings embedded in the model with the RQs in Figure 6.1.

A significant part of the contribution of this thesis is therefore the synthesis of information from a variety of disciplines in order to create a TBL model. The need for a cross-disciplinary approach is a difficult aspect of sustainability research studies, and is one reason why such research is comparatively rare (Chalmers, Godfrey & Potter 2012). Single aspects of TBL e.g. an economic study or an environmental impact study (generally taking an engineering approach) are recent developments, but more frequently undertaken (e.g. Reungoat et al. 2012a). As far are the researcher is aware, there have been no previous TBL studies of recycled water from an accounting perspective and looking at all three aspects.

Further to this, the model in this thesis has added depth because it is applied to two case studies, and is unique in that both are located in the same water management system/authority and similar catchment areas, in the same time frame and the social aspect of the study looks at customers in the same geographical area, again in a matching time frame. This allows for some degree of comparison as it sets them in the same system for a systems-based view.

The inclusion of the third TBL aspect – the social aspect – is a key contribution as it also addresses a research gap and comprehension of the social dimension of recycled water use has implications for policy and planning in Queensland. A Queensland setting provides evidence of previous mismatches between planning/intended outcomes and results. A striking example is the Western Corridor Recycled Water Project in Southeast Queensland. As originally designed, it envisaged a closed loop supply chain, with greatest benefit in terms of maximisation of the water supply.

However public resistance to, and concerns about, the idea of recycled potable water prevented its full implementation, resulting in considerable political and economic costs. There is clearly a perception issue surrounding the use of recycled water. The social cost dimension of this report, and the management accounting perspective, differentiates it from previous research on technical life cycle analysis (Lane, de Has & Lant 2012).

Lane, de Has & Lant (2012) also noted a lack of data on the interaction between water sources (mains water and different sources of recycled water) from a customer perspective. How far does the use of recycled water replace mains water use and would Purified Recycled Wastewater (PRW) be a substitute for rainwater tanks? What are accepted uses from a customer perspective? The social aspect of this thesis throws some light on the first of these questions, and specifically addresses the second.

Similarly there has historically been resistance to the idea of 'user pays' with regard to water supply, with a continued erroneous perception that water is a cost-free or at least a low-cost commodity. There is consequently a strong resistance to any moves to increase prices, particularly in the current economic situation in Queensland and with dams at full capacity (Tuttiet & Killoran 2011; Wuth 2010). This has unfortunate consequences for the uptake of recycled water options, necessary long term for water provision in increasingly densely populated urban areas in a country likely to be adversely affected by ongoing climate change. The climate change debate, although making customers more aware of water scarcity as a global issue, does not seem to have directly translated into acceptance of new pricing regimes. Part of this problem is due to expectation and perception gaps between entities responsible for water supply and customers. This study seeks to investigate customer perceptions on climate change, water value and the need for new supplies. A transparent and comprehensive model for water costing may also help to breach perception gaps. A full cost model will assist in solving the issue of a pricing model for water that values it as a scarce resource.

In addition this research sits broadly in the area of sustainable supply chain or value chain management, an approach that has not previously been applied to water recycling.

The research is also significant in that it provides the opportunity to compare case studies of two advanced water treatment plants producing Class A+ recycled water, which use different multi-barrier recycling methods – reverse osmosis and biologically activated carbon (BAC). The study will therefore provide information that may help inform policy decisions on recycled water options.

Moreover the study is being carried out at a time when Australian standards on water measurement and accounting are in their infancy. Post the 2004 National Water initiative (NW1 2004) the Australian Federal Government introduced the Commonwealth Water Act (2007) to empower the Bureau of Meteorology (BOM) to develop and issue water information standards and to collect and publish water information, including an annual National Water Account (Palmer 2009). The Bureau established an independent advisory board - the Water Accounting Standards Board (WASB) - to develop and oversee water standards aimed at accounting for volumes and values of water traded across Australia in a consistent way (BOM 2014a). Australian Water Accounting Standard 1 for the preparation and presentation of general purpose water accounting reports was issued by the WASB in October 2012, complete with a set of four illustrative accounting reports, considered necessary for a wholly new area of accounting (BOM 2012). An assurance standard -Australian Water Accounting Standard 2 –for general purpose water accounting reports was issued by the WASB in February 2014. A Water Accounting Conceptual Framework (WACF) was released for comment in 2009 and Australia is the first country to develop water accounting reports (BOM 2009). The water accounting standard is purely volumetric in nature (volume is the quantification attribute measured in litres) (WASB 2012 p.9) and does not focus on water quality (fit for purpose) or value. However the notes to the water accounting report should disclose information that:

> assists users of a *general purpose water accounting report* to understand how *water assets* and *water liabilities* of the *water report entity* have been used during the *reporting period* in the pursuit of each of the following:
> a) environmental benefit;
> b) social and cultural benefit; and
> c) economic benefit.
> (WASB 2012 168, p.26)

In other words the accounting standard acknowledges that volumetric information is insufficient for users of the statements, and that broader considerations are important for decision-making. It is this broader view of water accounting that this paper seeks to contribute in terms of theory and practice by suggesting a triple bottom line approach in which volumetric accounting for water would form a part of the materials flow accounting of an entity.

2. Literature Review

2.1 Introduction

This section reviews the literature that relates to the research problem. It starts with the broader themes and background to the research and then narrows to focus on water recycling and Queensland in particular. The broader themes are the development of concepts of Corporate Social Responsibility (CSR) and Triple Bottom Line (TBL) and the reporting of these and the consequent need for management accounting systems capable of providing such information (2.2). The broader setting is the development of water policy to date in Queensland, and in particular South East Queensland (SEQ), as this is the setting for the case studies and community perceptions research (2.3). The focus on more specific water recycling research follows, starting with some background and examination of social attitudes (the social aspect of TBL) (2.4) looking at previous case study research, particularly in Queensland, and at research indicating that this social aspect has been neglected to date, despite its critical nature. Section 2.5 briefly looks at the context of current accounting standards and section 2.6 introduces literature on full cost accounting and TBL in the area of water recycling moving to focus on the environmental aspect (2.7) and systems thinking. The importance of a holistic approach leads to stakeholder theory and the value chain (2.8). Section 2.9 summarises key points from the literature review of relevance to the thesis and research problem and motivation for the thesis.

2.2 Background

<u>Impetus for CSR and extended reporting – links to legitimacy and stakeholder theory</u>

The push for improved environmental information, and an acknowledgement of the social implications of corporate actions can be traced partly to a reaction to environmental problems, and partly to the lengthy development of stakeholder theory and its implications for corporate strategy. An altered view of corporate accountability requires a matching change in the underlying accounting information systems if they are to be capable of providing the additional information required for financial reporting and for internal management of scarce resources such as water.

The drive towards Triple Bottom Line (TBL) or Corporate Social Responsibility (CSR), or Sustainability Reporting (largely interchangeable terms) reflects this accountability to a broad stakeholder community. As mentioned in Chapter 1, Triple Bottom Line extends the boundaries of the traditional accounting approach to report not only financial or economic performance, but to also take into account environmental/ecological and social performance (Elkington 1994). The repercussions of the Exxon Valdez oil spill disaster in 1989 included the creation of The Coalition for Environmentally Responsible Economies (CERES). A set of ten Principles were developed, the first three of which were: protection of the biosphere, sustainable use of natural resources and reduction and disposal of wastes (CERES 1989). CERES has a stated mission of ‘integrating sustainability into capital markets for the health of the planet and its people’ (CERES 2008).

CERES’ work in conjunction with the United Nations Environment Programme (UNEP) led to the launch of the Global Reporting Initiative (GRI), an independent international body based in Amsterdam, and the publication in 2002 of Sustainability Reporting Guidelines and Indicator Protocols along the lines of CSR the current version of which are encompassed in the G4 Sustainability Reporting Guidelines (GRI 2013).

Every company that volunteers to join CERES is obliged to produce sustainability or corporate responsibility reports and is encouraged to use the Global Reporting Initiative (GRI). The GRI Sustainability Reporting Guidelines quote the World Commission on Environment and Development ‘Our Common Future’ in defining that the goal of sustainable development is ‘to meet the needs of the present without compromising the ability of future generations to meet their own needs’ (UNWCED 1987 Overview 1.3.27).

Organisations such as GRI provide a suggested reporting framework, but have no legislative authority, and therefore corporations need to be persuaded of the benefits of non-mandatory reporting. The motivations for sustainability reporting, whether within an entity's financial statements, or as a separate report, falls within the research on voluntary disclosure, legitimacy theory and stakeholder theory.

Legitimacy theory is itself founded on the concept of a social contract where an entity operates within the norms of its society and is bound to the community via laws and codes of conduct the community creates. Stakeholder theory identifies key stakeholder groups and assesses their requirements and relative importance to the organisation and seeks to meet those needs proportionately (Freeman 1984). This is bound up with the idea of a dynamic (dialectic) global community constantly adapting its views on the world and expecting a consequent change in actions by business and governments.

The operation of such dynamic relationships between stakeholders is reflected in a huge shift in the last few years in the global public perception of climate change and the attitude of national governments and corporations alike, Australia being no exception. Worldwide attention on global warming was heightened by the publicity of public figures such as Al Gore and the 'Inconvenient Truth' and speeches made internationally after the election of US President Barack Obama. After a prolonged drought in Australia and the consequent high level water restrictions placed on consumers, and an increase in severe bush fires attributable to prolonged summers, the political arena in Australia underwent a sea change towards sustainability issues, most notable in the landslide election win of the Labor government in 2007.

Similarly the commercial world moved towards assessing the costs of climate change inaction after the 'wake-up call' of the Stern Review (2006), which arguably was the first persuasive report to use the language of business to catch the attention of the United States business community (Brown & Cornwell 2006) and was reflected in the 2008 Garnaut review and 2011 updates.

The Australian Government's Department of Environment and Water Resources referred to the GRI and the World Business Council for Sustainable Development (WBCSD) on its website on Corporate Sustainability Reporting (CSR) and noted drivers for this are seen as managing environmental risks and opportunities and improving accountability to stakeholders and meeting stakeholder expectations (DEWR 2007). A 2003 World Business Council for Sustainable Development report

(WBCSD 2003 p.15) listed ten perceived benefits for corporations choosing to include sustainable development reporting:

- Creating financial value
- Attracting long-term capital and favourable finance conditions
- Raising awareness, motivating and aligning staff and attracting talent
- improving management systems
- risk awareness
- Encouraging innovation
- Continuous improvement
- Enhancing reputation
- Transparency to stakeholders
- Maintaining licence to operate

Water as a key risk

According to WBCSD reports should contain specific targets and concentrate on what is material and relevant to users. Climate change and sustainability (an awareness of the need to conserve and appropriately value scarce resources) are increasingly important to stakeholders (WBCSD 2007). In 2012 the WBCSD argued the business case for water valuation (including case studies) in 'Water valuation: Building the Business case', arguing that a full cost approach improves sustainable decision-making and collaboration, may justify demand for products and infrastructure development and improve pricing (WBCSD 2012 p.6). It is clear that for Australia water supply is a key scarce resource and that management of water supply and water costs (and therefore demand) need urgent attention.

The global economic crisis of 2008, the end of the drought in 2010, and a change of national government, witnessed more recent changes in attitudes in the Australian Government regarding climate change, and on a domestic politics level sustainability retreated as an issue, particularly after the change of Australian Government in 2013 (Phillips 2013; Readfearn 2014). This was not necessarily reflective of the world stage however (Benyon 2015), where stakeholder interest in climate changehas been maintained. Climate change received attention in Queensland, for example, during the G20 summit held in Brisbane in 2014, with President Obama's focus on the issue

(Bourke 2014). His speech at the University of Queensland addressed climate change in Australia specifically:

> And here in the Asia Pacific, nobody has more at stake when it comes to thinking about and then acting on climate change. Here, a climate that increases in temperature will mean more extreme and frequent storms, more flooding, rising seas that submerge Pacific islands. Here in Australia, it means longer droughts, more wildfires.
>
> The incredible natural glory of the Great Barrier Reef is threatened. Worldwide, this past summer was the hottest on record. No nation is immune, and every nation has a responsibility to do its part. (The Sunday Mail (Qld), November 15 2014)

<u>Making sense of contradictions on the global stage from a theoretical perspective</u>

Oels & Zelli (2015) argue that political theory can be used to explain the apparent contradictions in action/inaction on climate change and sustainability issues, such as the US signing the Kyoto protocol and then not ratifying the agreement (Australia ratified belatedly in 2007). Taking a world view from neorealism this would be a rational decision based on the desire to maintain relative power. The Kyoto protocol with its concept of common but differentiated responsibility and respective capacity, places a higher economic burden on developed economies (in the interest of equity) than on emerging economies such as China, but from a power perspective China is an economic threat to the US.

Which begs the question, why did the US sign the protocol in the first place? From the theoretical standpoint of liberalism, political behaviour is still governed by rational interest but this is determined by domestic politics, interest groups and public opinion. The particular method of democratic elections in the US means that the executive and Congress may be out of sync -due to the timing of elections, and so reflect public opinion at different stages. This ‘time lag’ does not affect Australian politics, but the short three year term between elections (with all federal politicians elected simultaneously) can mean drastic shifts in policy, particularly if an issue does not have bi-partisan support. So these theories might explain the motivations of political actors, but if this is simply a reflection of public opinion, why has that changed?

Oels & Zelli (2015) further argue that this can be explained by the theory of social constructivism. This posits that motivation for action derives from accepted norms and these are created by a complex interaction between all stakeholders including science, politics, the media, interest groups etc. and actors desire to conform to the norm once it is shared by a critical mass of actors. Attempts to create norms may be deliberate, such as the IPCC seeking to express a scientific consensus on climate change, but change over time depends on the relative strengths of the interests, and the media has a significant role in this. Using constructivism Oels & Zelli (2015) argue that key factors determining that action on climate change was a leading ‘norm’ in the US during the period 1986-1992 was an extreme drought in 1988 and a convincing testimony given to Congress by a NAASA scientist. However the end of the drought and the emergence of an economic crisis lowered public concern- and replaced climate change with more urgent norms in public perception. This was exacerbated by media coverage on climate change which eroded the sense of scientific consensus.

Water policy is inevitably linked to attitudes on climate change, given that climate change science suggests that weather patterns in Australia will become more extreme and future droughts more prolonged. Social constructivism and the creation of ‘norms’ may help explain perceptions of stakeholders regarding the use of recycled water. This justifies developing a costing model that is expanded to take into account social and political dimensions, and in its environmental setting (PR1). RQ1 seeks to identify key stakeholders. RQ4 examines a TBL approach and identifies externalities. RQs 6 and 7 specifically look at customer perceptions and influences.

2.3 The water crisis in Australia & Queensland water policy

<u>Co-ordinating water policy at a national level: a systems approach and tension between long term goals and short term decisions</u>

It is a truism that you cannot report what has not been measured. This means the development of management information systems for water measurement (volumetric/quality etc.) and accurate costing of water supplies. This in turn enables the pricing of the supply to better reflect its true scarcity value which will encourage conservation measures and efficiency in water management. The European Union is one international body pursuing a ‘user pays’ policy to promote efficient water use and sees water resource mismanagement ‘often a result of ineffective water pricing policies which generally do not reflect the level of sensitivity of water resources at local level' (European Union 2007, Section 1). Australia's Commonwealth, State and Territory governments commissioned the Garnaut Climate Change Review to examine the impacts, challenges and opportunities of climate change for Australia. The final Report was issued in September 2008. The report was critical of the lack of a national, unified approach to water management and also of past unfortunate price signalling (by subsidising prices) which encouraged concepts of 'free' water supply. In the absence of effective global mitigation, continued investment in expensive new sources of water is likely to be a necessity (Garnaut 2008 6.2, p.125).

In Australia the history of water management has been plagued by tensions between state and federal lines of responsibility. The Federal and State governments were unable to come to an agreement over the division of responsibility for rural water usage and river management, with Victoria opting out of the National Plan for Water Security proposed by the Howard government in January 2007. The Federal Government has been attempting to achieve a 'more cohesive national approach to the way Australia manages, measures, plans for, prices, and trades water.' Its overall objective was 'to achieve a nationally compatible market, regulatory and planning based system of managing surface and groundwater resources for rural and urban use that optimises economic, social and environmental outcomes' (NWC 2011b). PR1 seeks to develop just such a TBL model. The key Australian Government Agency for this national approach has been the National Water Commission (NWC), an independent statutory body, set up under the 2004 National Water Initiative via the Council of Australian Governments (COAG) with the aim to 'promote improved management of Australia's water resources' (NWC 2013 p. 2). All Australian States/Territories have had implementation plans accredited. In its meeting on 26th March 2008 The Council of Australian Governments (COAG) acknowledged that 'Cooperative partnerships between the Commonwealth and all States and Territories is the key to addressing the water challenge across the country' (COAG 2008, p. 1).

This demonstrates the need for a stakeholder approach to water issues, as decisions have social and political costs. An acknowledgement of the interconnected nature of water use and planning is evident too in the NWC 2013 strategic plan for 2013-16 which has to take into account 'the increasingly important interface between water and related sectors and policy domains such as resources, energy, food security and urban planning' (NWC 2013, p.3). This interconnectedness favours a systems and stakeholder approach to research (RQ1). There is a change of emphasis moving on from the NWI, and this reflects the socio-political dimensions of water policy as the environmental conditions have changed (with the end of the drought in 2010) as well as increased fiscal constraints for Australian governments leading to a new 'focus on delivering more efficient approaches to water management—approaches that will address community affordability concerns and support economic aspirations' (NWC 2013, p.3) (customer perceptions examined in RQs 6 and 7) . Sustainable water supply it seems is a long-term aspiration operating in short-term political arena. Among the government agency cuts announced on the 13th May in the 2014 Australian budget, the NWC was disbanded (effective 21 September 2015), with responsibilities for auditing and monitoring water policy reform transferred to the Department of Agriculture and Water Resources (Vidot 2014a; DOE 2015). There are concerns that this will leave a gap in national leadership and advice on water reform, independent of government, and reduce the ability to respond to water reform issues in a co-ordinated fashion between the States and federal government as the NWC reports to the Council of Australian Governments (COAG) (Vidot 2014b; Smith 2014). Again, a recurring theme regarding the difficulty of long-term planning and co-ordination (and a systems approach to solutions) for water and other long-term sustainability issues, is that stable planning is hard to achieve in the face of repeated structural changes.

Developments in water policy in Queensland – managing the risks of drought and flood

In terms of water policy in Queensland, fluctuations in policy have been exacerbated by fluctuations in the natural cycle. Queensland is a sub-tropical/tropical State. As such, the *normal* weather pattern for the region, based on recorded history, is fluctuation between drought and flood, influenced by El Niño and La Niña effects (Garnaut 2011a). El Niño events are often associated with drier than average conditions (potential drought) and La Niña events with wetter conditions (potential flood) (BOM 2014b). Even within one year there is significant (and predictable) variation in the seasonal levels of rainfall. This variation is likely to increase as the result of climate change (Garnaut 2011c; Mcgregor & Sturmer 2014). The scientific evidence would suggest therefore that drought conditions will recur in Queensland in the near future, particularly as El Niño conditions are forecast to return in 2014 (News.com.au 2014). This weather pattern poses unique challenges for the management of water supply to an increasingly urbanised population, as acknowledged by SEQwater's 2014 'Water Outlook for South East Queensland':

> Whatever challenges our climate throws at us - drought, storms or high rainfall - we all need to be ready to adapt to changes in our catchments and water supply. (SEQWater 2014b 2014, p.2)

Prior to 2010-2011, Southern Queensland has had severe flooding in 1893, 1927, 1947 (following a drought and concurrently with droughts in western Queensland) and 1974 (Carbone & Hanson 2012; Sydney Morning Herald 1947). Floods seriously affecting Brisbane were in 1893, 1974 and 2010/11. The widespread damage caused in 1974 in South East Queensland was a significant part of the motivation for major infrastructure developments such as Wivenhoe dam, located on the Brisbane river 80 km from the centre of Brisbane. It was designed with the combined purpose of acting as water storage for South East Queensland, and also as flood mitigation, with additional hydro-electric generation at Wivenhoe Power station (Gould 2014). It served to mitigate a potentially severe flood in 1983, though not fully completed until 1985. It also supplies water for energy generation for the Tarong Power stations. It has been policy to split the dam capacity between water storage and spare capacity for flood mitigation, with an additional policy of releasing water from the dam within 7 days of reaching its 100% storage capacity (with a theoretical capacity of 225% capacity for flood mitigation) (Andersen 2011; Fraser 2011; Wikipedia 2011). The dam is an embankment design which cannot permit overspilling due to potential loss of integrity or failure, and therefore has substantial spillways. January 2011 witnessed record levels at Wivenhoe of over 188.5% (SEQWater 2011), and releases from spillways and the timing of these is one aspect of a Commission of Enquiry regarding the lead-up to, response to and the effects of the severe 2011 Queensland flooding (Hatzakis 2011; Hatzakis et al. 2011).

At the other extreme, Australia in the period 1997-2010 faced unprecedented levels of drought. Despite this, there has been a reluctance historically to introduce monetary sanctions to promote efficient water management. Research suggests that there is a political dimension to water pricing (Hunt & Dunstan 2007; Hunt, Staunton & Dunstan 2013), making water authorities reluctant to voluntarily introduce a full user pays system. As mentioned, the Queensland Government's initial approach was to try to manage volumetric supply directly via water use restrictions rather than via pricing mechanisms, introducing level 5 restrictions in 2007 to twelve council areas, including Brisbane. At the same time the government was criticised for not building water assets, such as recycling facilities, in time to avert such restrictions (McCutcheon 2007). The Business Water Efficiency Program (BWEP), co-ordinated by SEQWater, aimed to reduce water consumption by up to 20ML per day in Queensland (SEQWater 2009a). There was a 'three tier' approach:

1. targeting top 1200 companies by water usage and conducting local council reviews of their water usage;
2. working with industry bodies in business sectors with high water use;
3. encouraging other businesses to take part voluntarily in water reduction management.

The prime tool used was the requirement for businesses to prepare Water Efficiency Management Plans (WEMPs) with the aim for each business to reduce water consumption 'by a minimum of 25% or best industry practice' (QWC 2008a). The BWEP was an incentive scheme with $40m of Queensland Government limited funding that was fully allocated in early 2008.

The prolonged 1997-2010 drought years prompted high level water restrictions in Queensland and other States. South East Queensland's restrictions increased in severity from May 2005, when Level 1 restrictions were imposed, reaching level 4 by November 2006 and level 6 by November 2007 (QWC 2010)

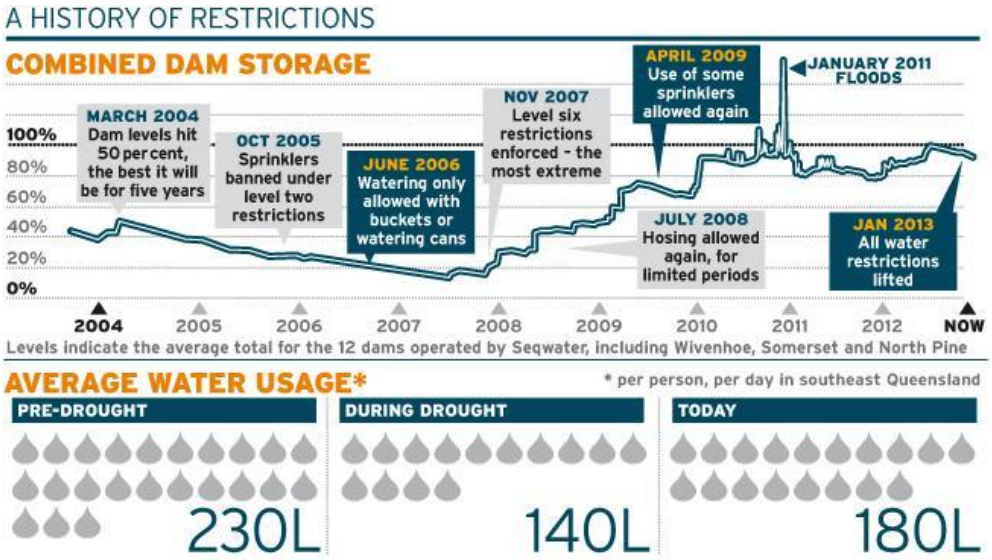
Restrictions were directly related to water levels in the region's dams. These levels were re-categorised as Target 200 restrictions (medium level – average per person daily use 200L) and Target 170 restrictions (high level). As dam levels reached 50% in 2009 the restrictions were set at Target 200 (the 'voluntary residential water use target'), aimed at permanent water conservation (contrasted to 300L per person prior to the drought restrictions) (QWC 2010). Water restrictions were not lifted until

January 2013 when target 200 was no longer considered necessary with average water use at 180 litres per day per person (Withey 2013). Research suggests that the restrictions have been effective in reducing average household water consumption, and despite the easing of restrictions, there has been no 'bounce back' effect in terms of a marked increase in water use (Beal, Stewart & Huang 2010; Beal & Stewart 2011). According to the Queensland Water Commission (QWC) there was a per capita average of 155.8 litres/person/day over the five week period 11th March – 8th April 2011 (QWC 2011c) compared to a figure of over 300 litres/per person/day prior to restrictions and under 140 litres/per person/day at the height of drought restrictions, although this would be higher in early 2011 due to continued flood clean-up efforts (AAP 2009). Average actual usage has remained below that recorded prior to the imposition or restrictions, with recent figures from SEQWater showing SE Queensland average daily per person residential water consumption at 152 litres (14 days to 7 May 2014: SEQWater 2014). Later attitudes to water use may be coloured by an increase in water prices, although these increases relate primarily to fixed component charges rather than usage charges, and are therefore not volume related, and came into effect post-drought. Both the climate variability and the historical attitudes of consumers towards water pricing are risks requiring consideration for policy makers wishing to encourage recycled water as an additional sources (RQ3). Consumer attitudes towards consumption and pricing are two aspects examined in this thesis, particularly relevant to Research Question 7: What factors influence customer acceptance of PRW for potable use?

Previous research suggests that this reduced demand may be a long-lasting effect, particularly with permanent household changes taking place, such as installation of rainwater tanks, low water consumption front-loader washing machines, efficient shower heads etc. (Beal, Stewart & Huang 2010) many of which were retro-fitted with financial assistance from local government (Beal & Stewart 2011). Both water efficient front-loading washing machines and more efficient shower heads appeared to make significant reductions in water use, as did the use of rainwater tanks, particularly on the Sunshine Coast and Ipswich, (but mindful that irrigation use was still low compared to other uses) (Beal & Stewart 2011). Beal, Stewart and Huang (2010) studied 252 households in the Brisbane/Gold Coast, Sunshine Coat and Ipswich regions and the research 'confirms the anecdotal and government reporting of a shift in general water consumption post drought in SEQ. This may be partly a result of the prolonged water restrictions that have created a behavioural shift in SEQ consumers,' (Beal, Stewart and Huang 2010, p. 44). Households in the study located on the Sunshine Coast on average used slightly higher levels of water per person (171 l/p/d) and per household (472 l/hh/d) than the other areas of SE Queensland studied (Gold Coast, Brisbane and Ipswich) and also the lowest average occupancy at 2.5 people per household (Beal & Stewart 2011 pp. 38 & 25). Given that customer attitudes play a significant part in acceptance of new water uses such as recycled water, the ability to alter customer attitudes and habits in the short term is of significant interest. Social constructivism theory would see this as the creation of a new 'norm' that water is a resource to be conserved.

Other observations of the Beal et al study were that younger households tended to use less water per capita (particularly shower use in households with teenagers (Beal & Stewart 2011 p.105)) and that toilet flushing and tap use of water was a greater percentage use than garden use, although this result may be atypical given the higher than usual levels of rainfall in 2010/2011. The Sunshine Coast had both the highest level of water use and oldest average age for children and highest level of retired/pensioned residents (Beal et al 2011 p.43). The continuation of the study into 2011 confirmed that highest water use was for shower, tap, clothes washer and toilet use, with irrigation only between 4-5% of use, even in summer, and average consumption was in line with QWC reported figures (Beal & Stewart 2011).The study also highlighted the difference between perceived use and actual water use behaviours. There was also some concern that the current policy of permanent water conservation measures may induce lethargy towards conservation measures, and it may be preferable to remove water restrictions when there is adequate supply to ensure an equally enthusiastic response to enforcing restrictions in future drought periods (Greenfield et al. 2011; Quiggin 2011).

Permanent restrictions were in fact lifted in South East Queensland on 1 January 2013 (UrbanUtilities 2014; Vogler 2013), although other areas of Queensland may face restrictions in 2014 (Arthur & Moore 2014). It does appear that average water use is not returning to pre-drought levels, being 180L per person in 2013 as shown in Figure 2.1 (Vogler 2013). As environmental psychology literature indicates that attitudes and social norms, and past water use habits, play a significant role in determining attitudes to water conservation (Russell & Fielding 2010), this suggests that it is possible to change attitudes and behaviour in a relatively short time frame. A fall in demand as a result of such household changes (appliances and attitudes) and as a result of the end of drought conditions in coastal SE Queensland, may also put pressure on the economic viability of recycled water schemes (Marsden Jacob Associates (MJA) 2013). Again, customer attitudes towards recycled water post drought are of particular interest (RQs 5-7).



Source: Vogler 2013 p.1

Figure 2.1 Southeast Queensland water restrictions and average water use

Ironically the drought-breaking rains and subsequent flooding also created water supply problems. Although residents and business affected by the 2011 floods were not subject to restrictions, other users were encouraged to minimise water use to allow for water being used for clean-up purposes, and because flooding had caused problems with inundation of water treatment facilities, and contaminants in the waterways (Hanna & Waters 2011; Brisbane City Council 2011).

<u>Developments in water policy in Queensland – structural stakeholder changes</u>

An issue with water planning, and a factor in the difficulty of this research, has been the frequent changes in the political structural landscape over recent years in

Queensland. Major local government restructuring took place in Queensland in 2007-2008 with water and catchment assets being transferred in July 2008 to a State authority under a new water service provider in South East Queensland - the Queensland Bulk Water Supply Authority, trading as SEQwater (SEQWater 2009b). ‘Water for Life is our promise to the community to deliver secure and reliable water sources both now and into the future... The SEQ Water Grid is now in operation, connecting a network of water treatment plants and two-way pipes that move water from new and existing sources across the region’ (SEQWater 2010). The Queensland Government published its vision for water supply in SE Queensland in a 2008 draft water strategy, and this included a major water recycling project – the Western Corridor Recycled Water Project- (completed in 2008 but never brought fully online as anticipated).

A stated aim of the restructuring of water management in Southeast Queensland was ‘to ensure that in the face of climate change and massive population growth, water supplies and wastewater services are sustainable and efficient’ (Queensland Water Commission (QWC) 2008b p.42). The new structure for south-east Queensland water supply was outlined in The SEQ Water Strategy Draft 2008 p.42 (see Figure 2.2). The key bodies were established in November 2007 under the *South East Queensland Water (Restructuring) Act 2007* and the resulting key stakeholders in the following areas of the supply chain became:

- BULK WATER

The Queensland Bulk Water Supply Authority – (trading as LinkWater): Queensland Government Statutory Authority responsible for the management, operation and maintenance of potable bulk water pipelines and related infrastructure throughout South East Queensland (SEQ). LinkWater to move water through the bulk water pipelines from dams and other sources. (Note: Linkwater was merged with SEQWater at end of 2012)

- MANUFACTURED WATER

Queensland Manufactured Water Authority (trading as SEQWater): The Authority to own all dams, groundwater infrastructure and water treatment plants in SEQ. This included the Gold Coast desalination plant (managed originally by WaterSecure) and the Western Corridor Recycled Water Project. It was to manage catchments, storage and water treatment plants.

 MANAGEMENT OF THE SYSTEM

SEQ Water Grid Manager (WGM) to:

–– Manage water sharing across the region (physical operation) of the Water Grid per the Regional Water Security Program and the System Operating Plan

–– Provide a mechanism to share the costs of the Water Grid, by acting as the single buyer of bulk water services and the single seller of bulk water for urban and industrial purposes.

The SEQ Water Grid Manager (WGM) to co-ordinate this (but hold no physical assets). The WGM Will to manage the ‘Price Path’ going forward with the ultimate aim to move towards a user pays model and therefore increased consumer water prices. (Note: Management reverted to SEQWater in January 2013)

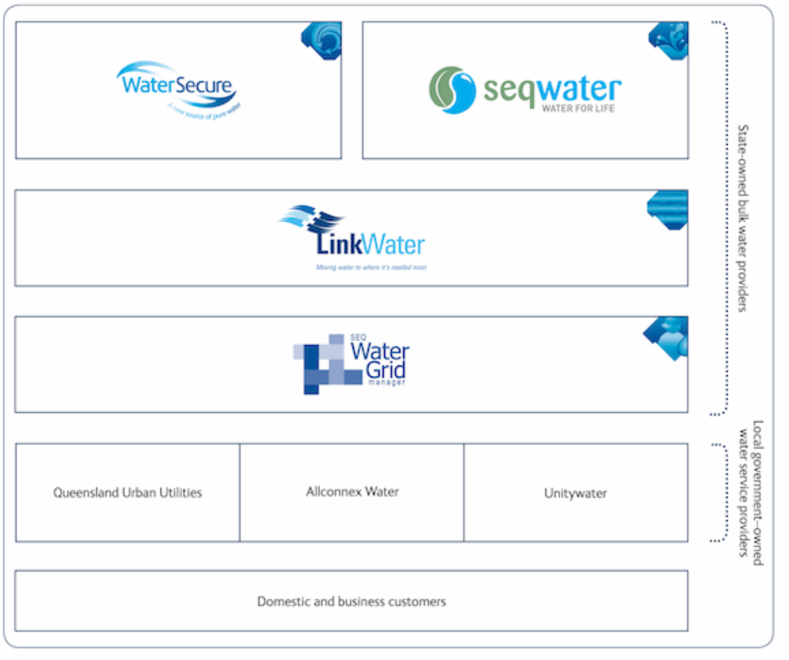
 RETAIL DISTRIBUTION

Local councils as the ‘retail businesses’ were reduced in number by the restructuring from 17 to 3. These were distribution businesses owned by local government – to own water reticulation, service pipes, meters and sewerage reticulation in the region.

The three businesses were:

- Queensland Urban Utilities (Brisbane, Ipswich, Scenic Rim, Somerset and Lockyer Valley)
- Allconnex Water (Gold Coast, Logan and Redland)
- Unitywater -(Sunshine Coast and Moreton Bay)

→ ULTIMATE CONSUMER (residential and business consumers)



Source: Queensland Water Commission 2010b, *SEQ Water Reform*, QWC website

Notes: SEQWater and Watersecure were merged following the decision to 'mothball' the Tugun desalination plant in 2010

QWC ceased operations on 1 Jan 2013 & Linkwater and management of the SEQ Grid also reverted to SEQWater

Figure 2.2 Overview of the SE Queensland water supply chain after restructuring 2007/8

<u>Developments in water policy in Queensland – managing prices</u>

The Queensland Government announced the ten year price path in May 2008, following recommendations by the QWC, aimed at gradually increasing bulk water prices over a ten year period This path implemented price increases and reflected 'not only existing bulk water assets but also significantly improved water security for South East Queensland by the $7m water grid, including desalination, purified recycled water, new storages and the regional pipeline network' (QWC 2011b). The review of the pricing by the QWC was, however, brought forward, and the increases were reduced subsequent to the mothballing of the Tugun desalination plant and other savings, described as 'passing on the benefits of the efficient operation of the Water Grid. This is possible as all SEQ dams are close to full' (QWC 2011b). The new approach to efficient management included 'keeping climate-resilient sources on standby so we can take more from our dams in times of plenty, knowing back-up supplies are available when needed' (QWC 2011a).

The cost of the capital investments and the costs of restructuring the water grid and retail supply entities needed to be recouped in the water pricing mechanism. It meant an increase in bulk water prices charged initially to councils, and then indirectly by the restructured water providers – Queensland Urban Utilities, Allconnex Water and Unity Water. This in turn has led to increases in water prices to retail customers. The consumer backlash caused the State Government to blame councils for profiteering and councils to accuse the State of passing on the capital costs to councils, an accusation all the more heated as a result of the perceived 'waste' regarding the underutilised water grid assets, given the end of the drought period in 2010.

The Queensland Premier Anna Bligh announced on 7th April 2011 that the Queensland Government intended to repeal part of the restructuring legislation (South-East Queensland Water (Distribution and Retail Restructuring) Act 2009), in order to permit local councils to separate from the retail water utilities if they wished and take back control for retail water pricing to customers, a decision to be made by each council by the 1st July 2011. The Queensland government would retain control of bulk water production and treatment. This was to be accompanied by a cap on water prices (pegged to inflation) for the following two years. The stated objective was to control rising water for householders and stop council 'profiteering' as they would now be accountable for the pricing decisions.

This extraordinary turn of events has been seen by many as another expensive 'u-turn' or 'back-flip' on water policy and a political stunt, perhaps as a reaction to the former Lord Mayor of Brisbane Campbell Newman taking up a position as State Opposition leader (Barrett 2011; Hurst 2011; Hurst & AAP 2011). The 2011 Queensland State elections in fact saw the replacement of the Labor government with a landslide victory by the Newman led coalition. The Local Government Association of Queensland had put forward a plan to merge the three utilities in order to save money, and blamed the price increases on mounting bulk water costs (Barrett 2011; Foley 2011; Hurst & AAP 2011).

Reaction from councils was mixed. Brisbane City Council (BCC) initially stated that it would opt out from Queensland Urban Utilities (QUU) and resume billing by council, but called for a longer depreciation period for the write-off of water grid capitalisation debts (40 years rather than 20) (Moore 2011; Hurst & AAP 2011). However by June BCC reversed that decision and announced it would stay with QUU as otherwise it would be forced to pay excessively high compensation (Brisbane Times 2011). Ipswich council similarly took the view that it was too costly to take back control of water, again as a result of infrastructure debt and according to Councillor Nardi 'water will become more expensive no matter who runs it' (Foley 2011). Allconnex Water supplied the Gold Coast, Logan and Redland city council areas under the new structure. Both the Gold Coast Council and Redland City Council voted in 2011 to opt-out and return water operations to the councils, with only Logan initially voting to stay with Allconnex. This led to the costly disestablishment of Allconnex and return of water responsibilities to all three councils in 2012 (Capati 2013). According to Baumfield, 'Allconnex's failure was specifically a result of widespread anger over its pricing' (Baumfield 2012, p.62) and excessive pricing was the result of a lack of adequate governance structure (internally and externally). An effective regulator with the ability to check price increases was needed, but rather the Queensland Government did not instruct Allconnex to keep prices low and delayed too long in intervening to set a price cap (Baumfield 2012). The Sunshine Coast Council and Moreton Bay opted to stay with Unitywater.

The then Queensland Government assured water customers in 2011 that the price cap would reduce the proposed amount of annual increase in water prices for Unitywater retailers by $102 for an average household (Holznagel 2011). The move was seen as a victory for Gold Coast water protesters (Lappeman 2011). However debate over water prices, and the disparity of charges between locations in South-east Queensland, has continued with Moreton Bay being one of the areas with the highest charges due largely to infrastructure costs per capita and State Government charges according to Unitywater (Killoran 2014a). This was evidenced in a 'feisty' water forum in Bribie in March 2014 (Branco 2014). This is despite assertions from councils that restructuring would be excessively expensive and that return to council control would not mean a return to former prices, as bulk water remains in state control and the previous state government 40% subsidy for sewage infrastructure no longer exists (Branco 2014; Unitywater 2014). A draft report released by the Queensland Competition Authority in December 2014, making recommendations regarding bulk water prices for 2015-18, expects bulk water prices to be reduced in the Moreton Bay area, with some increases in other areas, aimed at a single common price across south east Queensland by the end of the decade, driven partly by efficiency savings at Seqwater (Queensland Competition Authority 2014; Remeikis 2014).

The dispute over water prices in South East Queensland highlights the political and social dimensions of water policy, and the need to take a stakeholder approach (RQ1). It shows, with politically embarrassing changes of policy direction and events such as the disestablishment of Allconnex, that misjudging public reaction can have costly consequences, both in terms of political survival in a democracy and in terms of wasted investment (RQ3). The need to adequately gauge stakeholder concerns and address them is evident (RQs 5-7). It also emphasises the link between the end price of water and the cost of water provision, and the accounting policies taken regarding these costs, and demonstrates the need for improved information about such costs. It also highlights the fragility of long-term policies in a system focused on three year election terms, and the difficulty of consensus in a party-politics environment. Policy should be forward-looking and consistent, rather than reactive, and decisions made regarding water solutions in times of water crisis may not be optimal (Khan 2014). Of course this also conforms with social constructivism theory where there are competing norms which replace each other as they gain or lose critical mass of actors supporting it as a priority.

The South East Queensland Water Strategy (July 2010) was replaced in July 2015, with Seqwater releasing a new Water Security Program for SEQ to meet mandatory level of service (LOS) objectives for SEQ. SEQ was identified as a critical water supply area and is the only Queensland region with mandatory LOS objectives ‘due to the bulk water supply system being owned by the State Government, and .. the potential for very high concentrated economic impact if the region runs out of water’ (DEWS 2015a). LOS cover the operation of the bulk water supply system, future infrastructure needs and any drought response (DEWS 2015b).

2.4 Water recycling background and social attitudes

One definition of recycled water is the use of reclaimed stormwater, greywater or wastewater/effluent at a variety of levels – end (household) consumers (potable and non-potable uses), industry and agriculture. Another possible use is environmental allocation, or returning recycled water to augment the natural water cycle or flows (Recycled Water in Australia 2014). Seawater desalination is also an alternative water source, as is rainwater capture (although this is sometimes included in the definition of stormwater). A more recent possible supply of recycled water is from coal seam gas (Department of Energy and Water Supply 2013).

All these sources also require the storage of recycled water. Urban Ecology Australia (UEA) points out that a comprehensive approach to the problem would need to consider a variety of types of water systems and scales (RQ2). Smaller scale projects for recycling may prove more efficient in the long term, using a life cycle approach, particularly if costs include all environmental impacts. They refer to a CSIRO report on Life Cycle Costing in urban Water Systems which argued that traditional costing systems based solely on operating costs or capital are inadequate (RQ4). A life cycle approach should include looking at ‘capital, maintenance, operating and replacement costs over the whole life of an infrastructure facility’ (Urban Ecology Australia 2006). They too are critical of pricing policies that keep water prices artificially low so that alternative supplies appear uncompetitive compared to subsidised catchment water, which effectively discourages recycling (RQ7).

2.4.1 Recycling Cases Studies and Social Attitudes towards its use

Recycling a desirable strategy but underutilised for potable replacement despite investment

A characteristic of recycled water use in Australia has been that it is seen as desirable at the planning/strategic level, but this has not been translated into widespread ‘grass roots’ use. Investigation of stakeholder attitudes is therefore critical (RQs 6 & 7).

The National Water Initiative (NWI) and the individual Australian States have all had strategies to reduce potable water usage. Most Australian jurisdictions have expressed targets for wastewater recycling, the national target being 30% by 2015. A 2012 report sponsored by the Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) to assess progress against the 30% recycled wastewater national target noted that in terms of volume the majority of wastewater recycling occurred in metropolitan areas, but as a proportion of all wastewater, a higher proportion was recycled in rural areas (Whiteoak, Jones & Pickering 2012).

The DSEWPaC report further expected the national percentage of wastewater recycled to be only 18.7% in 2015. It was noted that this was partly due to a change in political and climatic conditions following the end of drought conditions in capital cities in 2010, and a consequent underutilisation of assets such as SE Queensland's Western Corridor Recycled Water Project (WCRWP) (Whiteoak, Jones & Pickering 2012 p.3). A shift in recycled water towards sources capable of substitution for potable water had not been matched by uptake of this use, which combined with a changeable weather pattern, has resulted in some areas having excess recycled water capacity (a risk for policy makers – RQ3). In other words States had developed a capacity for high-end quality recycled water, but this water was not being used for higher quality uses, particularly not as drinking water. The WCRWP had a substantial planned indirect potable use component, but this did not eventuate. The only other current project is the Groundwater Replenishment scheme being trialled in Perth, involving an indirect potable use via recovery from an aquifer (Whiteoak, Jones & Pickering 2012 pp.5-6). Stormwater harvesting has been increasing, possibly as an alternative recycled water source with less 'yuk' factor, but has the disadvantage of being drought susceptible. It can also require use of limited public land in urban areas for storage, but does have some potential for treatment to potable use level (McArdle et al. 2011). Brisbane City Council has a current project for stormwater harvesting and reuse, primarily as a resource to replace potable water for irrigation of parks and sports fields (BCC 2015) (RQ2).

Non- potable residential use

Australia has some notable examples of water recycling initiatives for *non-potable* residential use, including the Sydney Water developments at Sydney Olympic Park Authority (SOPA), Newington and Australia's largest dual-pipe residential scheme at Rouse Hill (north west Sydney), with two new residential projects under construction at Hoxton Park and Ropes Crossing. The Rouse Hill residential recycled water scheme commenced in 2010 and by 2013 supplied 'about 2.2Mm^3/yr to 19,000 homes for toilet flushing and watering gardens' (Anderson 2013 p.31). The homes have dual reticulation and treated water is not used for potable (drinking) water or for filling swimming pools. In Queensland the Gold Coast had residential dual reticulation of recycled wastewater in Pimpama, Coomera and Upper Coomera to class A+ recycled water standard introduced in 2004 under council control, extended to all new properties in the Pimpama Coomera area from late 2008 as ‘part of a plan to reduce Pimpama Coomera’s reliance on precious drinking water supplies by up to 84 per cent’ (Gold Coast Water 2007, p.1). The categories of recycled water in Queensland are shown in Figure 2.3 below.

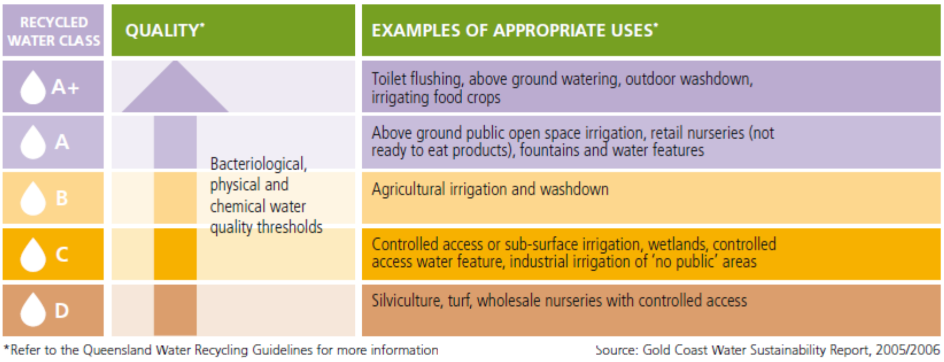


Figure 2.3 Queensland recycled water classes and appropriate uses
(Gold Coast Water 2007 p. 4)

However the Gold Coast City Council announced in February 2014 that the class A+ scheme will be decommissioned over three years as ‘the high cost of the scheme for the Gold Coast community and the City outweighs the value to the city’ (City of Gold Coast 2014). Lower grade class C recycled water will still be delivered to industry/commercial customers. The Council announced the change as part of their action to tackle water prices and stated that the scheme was introduced originally as a response to ‘worsening drought conditions’ and cited the need to save costs in response to bulk water price increases and resident feedback over increasing prices (Water Services Association of Australia (WSAA) 2014) (RQ7). The policy appears to lack consistency and long-term vision, if it is to be assumed that drought conditions will return, but is understandable in terms of an elected body responding to community concerns over cost. However, it does suggest that far from recycled water being charged at full cost, returns must be less even than marginal costing if stopping supply provides a saving.

At the time of this study the Sunshine Coast and Moreton Bay region also has a limited dual reticulation class A+ recycled wastewater system from South Caboolture introduced by Moreton Bay regional council and then operated by Unitywater, but it currently supplies potable water (permitted only for recycled water purposes) through the 'purple pipe' dual reticulation system. South Australia has developed a residential artificial wetlands based class A recycled water scheme at Mawson Lakes in North Adelaide. The South Australian water policy, whilst being consistent with NWI Pricing Principles, 'sets prices that will recover the cost of providing the service and meet its strategic priorities, including:

- Customer impacts and affordability
- Ensuring the ongoing viability of SA Water;
- Compliance with service standards and regulatory requirements; and
- Sending appropriate pricing signals that encourage the most efficient use of resources.'

Charges may include capital contribution, annual access charge & water usage charge) (SA Water 2013). However in December 2012 the Minister for Water and the River Murray announced a reduction in the price of recycled water for dual reticulation residential customers to 90% of the price of mains 1st tier drinking water, acknowledging that price may have deterred people from using it. 'Following this price change, recycled water will become the cheapest form of water supplied by SA Water' (Caica 2012). Consumer acceptance of non-potable recycled water, particularly in the absence of drought conditions seems closely related to price. This is investigated in this thesis as part of RQ7. Willingness to pay and funding of required infrastructure capital costs are important components of the social aspect of water costing.

<u>Social aspects: Non- potable residential use</u>

The social aspects of water recycling in residential areas have been investigated via survey and case study research for non-potable recycled water at Mawson Lakes (Hurlimann & McKay 2006; Higgins et al. 2002) and in a recent case study in Sydney including Rouse Hill (Marsden Jacob Associates 2014a) and more generally by Po, Kaercher and Nancarrow (2003). These studies strongly suggest that there is a social cost to the introduction of recycling schemes that should not be ignored, which supports a TBL approach (RP1; RQ4)

The case studies were centred on grey water/treated wastewater recycling for non-potable uses only. Acceptance of the use of recycled water appears to decrease as the use becomes more personal, and is also influenced by the source of the recycled water, with a preference for storm water or grey water harvesting over recycled waste water (Hurlimann 2007; Marks, Martin & Zadoroznyj 2006; 2008). Marks et al examined consumer attitudes to recycled water with reference to sociological approaches to risk perception:

- the epistemologically ‘realist’ position, (risk as identified and scientifically measured for decisions);
- a ‘risk society’ perspective and a socio-cultural perspective, placing the decision in a specific cultural background with accepted views on the concept of ‘purity’ and whether products are viewed as being ‘out of place’, and
- the ‘divide between ‘expert’ assessments of risk and public perceptions of it’(p.86), as explored by Beck (1995)

The social aspect of recycling schemes for drinking water is likely to be most prominent, including a ‘yuk factor’ or strong reaction to the suggestion of recycled effluent (Po, Kaercher & Nancarrow 2003; Marks, Martin & Zadoroznyj 2008). This reaction to recycled water is influenced by culture (social conditioning) where origin of the water and the name given to the water source (‘recycled water’ not ‘treated wastewater’ (Menegaki et al. 2009) strongly determine reactions, and by the psychology of ‘disgust’ provoking irrational responses (Prevos 2013; Russell & Lux 2009). This research suggests that there is a social acceptance hurdle for treated wastewater, based on perceptions rather than science, and social norms, that needs to be addressed before acceptance is likely (RQs 5-7).

Water recycling is not widespread in Australia. A Government funded research study (Dimitriadis 2005) noted that recycling was under-used as a water management option and estimated that only 9-14 per cent of urban stormwater or effluent is recycled. As previously noted, Whiteoak, Jones & Pickering (2012) expected the national percentage of wastewater recycled to be 18.7% in 2015. Dimitriadis (2005) quotes Dr

Peter Dillon (CSIRO) that the main barriers to recycling are 'issues of public confidence, health, the environment, reliable treatment, storage, economics, the lack of relevant regulation, poor integration in water resource management, and the lack of awareness' (Dimitriadis 2005, p.10). Stakeholder preferences need to be considered therefore in an attempt to allay concerns and 'perceived risks need to be seen as a social as well physical issues' (p.35)(RQ6).

Dimitriadis further argues that although urban water use is only estimated at 30 per cent of total use, the geographical position of Australian cities with regards to waterways, rivers and oceans magnified their catchment and environmental impact. She advocates greater use of integrated water cycle management considering 'water supply, stormwater and wastewater concurrently as components of the total urban water cycle' (Dimitriadis 2005, p.20). This study also noted the issue of likely price imbalance between traditional, existing water sources (often currently at a low price) and newer recycled water sources, if the cost of these were passed on to customers. It was suggested that potable water prices may need to be increased to allow recycled water to be more competitive, with the possibility of using surplus revenue from these more general price increases to invest in recycled water and keep costs reasonable in the eyes of consumers in order to pre-empt political problems with perceived over-charging for recycled water. In other words the environmental benefits and other externalities should be included in the decision to promote recycled water as part of a wider perspective on the water system, and if considered desirable, the system should be designed to support this (Dimitriadis 2005, p.35) (RQ4).

In terms of willingness to pay, for a non-potable use supply it seems reasonable to assume that its restricted use would mean that the upper pricing bound would be the price of the alternative potable water. However this presumes that there is an alternative supply, which might not be the case in times of drought and water restrictions for some uses e.g. garden watering. 'Drought proofing' and some of the properties of the water itself when recycled from treated wastewater may be attractive to garden and agricultural users. There is some evidence from the Rouse Hill survey (conducted *after* the survey in this thesis) that customers value the availability of a recycled water supply with householders willing to pay a premium of around $5,000 for properties with such a connection compared to similar properties without (Marsden

Jacob Associates 2014a). Moreover 90% of respondents in Sydney seemed potentially willing to accept marginally higher water pricing in order to subsidise/promote the uptake of recycled water, particularly if the water were used for business/industrial purposes, but also to reduce discharge into the ocean. Suggested factors influencing increased willingness to pay were higher income and age, gender (female), existing use of recycled water, and recreational use of waterways (MJA 2014b). In other words there is possibly a perceived 'non-use' or societal value for recycled water which suggests some justification for holistic pricing of water supply or a systems approach, rather than one based entirely on 'user pays' for recycled water. Customer perceptions on willingness to pay and benefits of recycled water, and the influence of demographics, were examined via responses to the survey instrument in relation to RQs 6 and 7.

Social aspects: Recycled water in Queensland – customer perceptions and media influence

In Queensland plans for recycling water for drinking purposes were rejected in Noosa and Toowoomba. The attempt to introduce recycled water was made in Toowoomba in 2006, with one of the proposed initiatives being the construction of an advanced water treatment plant for the provision of additional potable water. This proposal was being made at the height of the drought. Moreover growth in population of the city and its elevated location makes potable water supply an ongoing concern in Toowoomba. Nevertheless, Toowoomba residents voted in a referendum against the proposal after heated campaigns on both sides.

Hurliman & Dolnicar (2010) examined public participation and the reasons behind the defeat of the Toowoomba proposal. They found that factors included politics, vested interests and information manipulation. Concerns voiced by residents and business included losing their wholesome green 'garden city' image, and adverse marketing, for example an ice cream manufacturer was reluctant to use recycled town water in production. There was distrust of the science behind the process, and concern that the percentage of recycled water to be added to the water (25%) would be higher than that of overseas recycled water schemes, and that Toowoomba was being used as an experiment. However many voters did not seem to have adequate information to make an informed decision, making a referendum an unsatisfactory decision-making mechanism (Miller & Buys 2008). An information/consulting process may be preferred. This last study also suggests that attitudes had changed within two years after the referendum, perhaps in light of the construction of the Western Corridor Recycled Water Project (WCRWP) (2008). Nevertheless in a media debate five years on from the Toowoomba referendum, the main protagonists in the conflict did not seem to have changed their views, with the ‘no’ lobby standing by the decision to fight primarily on ‘perception’ i.e. on ‘the “yuck” factor, the “fear” factor and the worry that Toowoomba was going to become a “guinea pig” for the rest of Australia’ (The Chronicle 2011, p.2). However another aspect of the debate was cost, with the ‘yes’ campaigners arguing recycled wastewater was the cheapest option, and indeed the alternative water strategy of building a pipeline from the Wivenhoe dam proved costly and has been criticised for this even by leading ‘no’ campaigners.

A study by Browne et al. (2008) using ‘Q-Methos sampling’ with small sample sizes, researched professional (technical) perception of risk and community perspective on risks of the purified recycle water (PRW) scheme in south-east Queensland (WCRWP), using small workshops across Brisbane, Ipswich, Gold Coast and the Sunshine Coast. This method was not intended to support generalised results, but is helpful in comparison with the analysis of the questionnaire data in the social aspect of this thesis. The study found broad community acceptance of the WCRWP, although this was partly attributable to a feeling that such a scheme was inevitable, and was less certain when offered with alternative sources for PRW. Trust or otherwise in the science, in the local authority, and in any company running the scheme, was a clear factor in acceptance. However the overall results were dichotomous, with a sizeable proportion still not accepting and concerned about health risks, human errors, source control and treatment. Participants indicated that system risk and health risk were of most concern, and most participants considered themselves to be more accepting of the scheme than others. Gender did not seem to influence acceptance/non-acceptance.

Comments made by the technical focus groups including the need to reduce hospital and industrial waste; that they thought it hard to convince others to accept PRW; and that they thought that the government was seeking the safest (rather than the cheapest) solution for water supply. They were non-committal on the idea that all SEQ water users should be helping to pay for the scheme. They thought generally that the biggest community concern was health risk. Participants were also asked to identify 'missing' areas from the study questions and identified education/public information; fit for purpose; fluoride; community involvement in scheme oversight; role of media; more conservation of water; preventing people putting contaminants in deliberately; concern over independence of experts; longitudinal studies; use of bottled water; and council role.

Community perceptions, therefore, seem to cover a complex range of issues, but characterised by majority acceptance (albeit conditional) of the scheme, but with a sizeable section of non-accepters, concerned mostly on health grounds. The timing of the Browne et al. (2008) study (during the prolonged drought) may be a strong influence on the rate of acceptance The suggestion that attitudes may change over time make the social aspect of this thesis particularly interesting, as it comes after a period of intense drought, which included public attempts to curb water use and change attitudes towards the value of water, but was also undertaken after the 2007-2010 drought had ended in SE Queensland. It was therefore possible to offer some insight on how far have public perceptions may have changed (RQs 6 & 7).

Research in psychology has examined the phenomenon of persistent belief in a point of view in the face of widespread contrary evidence, such as scientific evidence. The 'yuk factor' in the debate regarding the scientific evidence for the safety of indirect potable use for recycled water is an example. The 'denial' of climate change in spite of repeated IPCC and mainstream political consensus is another. It can be argued that such entrenched beliefs can severely hamper the consideration of sustainability issues compared to 'business as usual' (University of Queensland 2014a; Oreskes & Conway 2010). This can partly be explained by a 'confirmation bias' – concentrating on the evidence that supports your particular point of view and not considering the full range of evidence (Nickerson 1998). People also tend to over-estimate the percentage of people who will agree with their own point of view (a false consensus effect) (Marks & Miller 1987). This reinforces an 'availability bias' (Tversky & Kahneman 1974) as the decision-maker is only exposed to certain types of information. This is even more prevalent in an advanced information age where media can be effectively manipulated and where many social media self-select news streams that match the user's existing preferences – in other words a user sees mostly posts from those who have 'liked' similar content, and are more likely to hold similar points of view (e.g. Facebook) (University of Queensland 2014b). Even mainstream media often presents information in a biased manner, for example by making sure that 'both sides' of a debate are represented. Most people make sense of the conflicting points of view by using the 'it must be in the middle heuristic' in that they assume that there must be some, or even an implied equal, truth in both sides of the argument, as both sides in the debate appear evenly represented (Oels & Zelli 2015). This potentially skewed view may also be reinforced by media programmes where speakers are invited to debate a topic – often one from either 'side' of the argument in an attempt to 'be fair to both sides' which ironically may create its own bias. In fact such coverage reinforces the 'in the middle' interpretation. In the case of the climate change debate this approach has been much criticised as it does not reflect the fact that the vast majority of scientists support only one side of the 'debate' (University of Queensland 2014b)! This situation can be exacerbated by a mistrust of government or authority. In terms of policy this can mean that a relatively small group (such as a lobby group) can have a disproportionate influence over an issue that can be hard to counter (Oreskes & Conway 2010; Stern 2013; Lewandowsky, Gignac & Vaughan 2013 & Lewandowsky, Oberauer & Gignac 2013), and successful handling of the social aspects (and the media) can be critical to a project (Lim & Seah 2013). Respondent perceptions on the influence of the media were specifically investigated as part of the survey in order to answer RQ7.

Australian and Queensland water policy approaches

In Australia the National Water Initiative (NWI) increased the emphasis on new sources of urban water supply and the use of recycling. The NWI required annual water utility performance reporting for all States. The National Performance Framework Handbook for 2009 required States to outline their sources of water, including recycled water and the uses of recycled water and details of recycled water treatment plants. Reporting is also required under customer, environmental, pricing and public health indicators.

The Queensland Government via 'Total water cycle planning' was attempting to take an integrated approach to water management, and this was part of the impetus behind the local government restructuring and the transfer of water assets to the Queensland Bulk Water Supply Authority (SEQwater). The South East Queensland Water Strategy – Draft was issued in March 2008. The key elements of this long-term plan were outlined as:

- Target 230 – our permanent residential water-usage target [later target 200]
- Businesses striving for best practice water use
- New climate resilient water supplies like purified recycled water and desalination schemes
- Drought response plans so medium level restrictions occur no more than once every 25 years on average
- Power stations and major industrial customers using recycled water where available
- Additional water supplies for rural production. (QWC 2011d)

Total water cycle planning was outlined in pages 42-43 of the Strategy. It 'recognises the finite limit to the region's surface and ground water resources, and the inter-relationships between the human uses of water and the health of the natural environment. It involves integrated assessment of water management issues across the entire community. A component of total water cycle planning is Water Sensitive Urban Design (WSUD).' One of the key features was 'enhanced recycling'. The Queensland State Government undertook a number of major infrastructure projects. These included interconnectors (Southern Regional Water Pipeline, Eastern pipeline inter-connector and Northern pipeline inter-connector), manufactured water (Western Corridor Recycled Water Project (WCRWP), Desalination facility, Brisbane & Caboolture groundwater) and River interceptions (AQUA Projects 2007). This public policy recognises a systems approach and the environmental setting of water (RP1 & RQ4). The policy has been to encourage water recycling and this leads to questions about the type of supply (RQ2), the risks involved for implementing it (RQ3) and the need to take into account stakeholder perceptions (RQ1, RQs 5-7).<u>Water policy, public perception and politics in Queensland</u>

The introduction of the Western Corridor Recycled Water Project/Scheme (WCRWP) in South East Queensland, which is capable of producing recycled water to a drinkable standard, was a first for Australia, and is potentially one of the largest such schemes worldwide. It also provides a good demonstration of the way social costs of such a project may be critical, and of the need to manage public perceptions. Reaction to intense public pressure was evident in the Queensland government's abrupt change of stance in 2008 on the use of recycled water for potable supply. As the Courier Mail highlighted in a front page article 'Gone to Water' on November 26th 2008, the then Queensland Premier is quoted as saying: 'There is no choice but to go ahead' with recycled water being pumped into the Wivenhoe Dam (for indirect potable use) (Nov 22 2008) and then reversed the policy days later: 'It is...clear that people are uneasy about recycled water as a constant part of our water system' (Nov 25 2008) (Courier Mail 2008). It also demonstrates the political dimension of planning, with accusations that planning for the best interests of Queensland and its long-term water security took a back seat to party politics as popular opposition to the WCRWP was encouraged by the opposition party in QLD in order to discredit the Premier (Johnstone 2008).

As mentioned, the political emphasis changed in Queensland after the end of the drought and a change in State Government. Focus moved towards cost savings over recycled water facilities, limiting water price increases, and flood mitigation. The Queensland Water Commission (QWC) was disbanded on 1 January 2013, with policy functions transferred to the Department of Energy and Water Supply (DEWS) and other functions to SEQWater, with remaining water restrictions lifted on the same date (DEWS 2014b). A change in the commonwealth Australian government also saw a de-emphasis of sustainability issues and climate change response. The 2014-15 Budget confirmed the closure of the National Water Commission at the end of 2014, with some function transferred to other agencies, and the NWC concentrating in 2014 on completing the third assessment of Commonwealth, State and Territory commitments under the NWI (Maywald 2014). A large number of Government agencies have been abolished under the current Australian government's cost-cutting policy including: Climate Commission; Climate Change Authority; National Sustainability Council; National Council for Education for Sustainability; Energy Security Council; Clean Energy Finance Corporation; Australian Renewable Energy Agency (Anderson 2014). Again, political stability and consistency are problematic in sustainability planning. This may hamper efforts to change public perceptions about such policies and exacerbate issues of trust. Trust in the regulatory environment regarding recycled water was specifically addressed in the survey instrument (RQ3 & RQ6).

It is clear that a major aspect regarding the use of recycled water is public perception, and this perception appears to be changing over time. This study presented an opportunity to investigate current attitudes to the use of recycled water for a number of purposes, and to examine which uses are considered acceptable. Dual reticulation customers of the South Caboolture plant have been using recycled water for non-drinking purposes for a number of years. No research has been done to ascertain how successful this has been at South Caboolture from a customer perspective. Longitudinal research at Mawson Lakes suggested that support for using (and drinking) recycled water increases with positive experience of using recycled water for non-drinking purposes (Hurlimann & McKay 2006).

The South Caboolture Water Reclamation Plant (SCWRP) was built in 1999 and commissioned in 2000, with the original dual intention of rectifying poor quality effluent discharges into the Caboolture river and of securing local water supply by producing quality recycled water that could be added to Caboolture weir and retreated for indirect potable use. Subsequent research suggests that the water produced by this BAC system is of high quality (Reungoat et al. 2010a & 2012a). However, public opinion backlash at the time (1996-1999) prevented indirect potable use (Halliday 2006; Uhlmann & Head 2011), and was the main reason for the local mayor failing to achieve re-election in 1997. The council did run a community education programme after the decision had been taken, but did not allow for community consultation and participation in the planning stage, which exacerbated the lack of trust between the community and the Shire Council (Uhlmann & Head 2011). However the Caboolture plant did provide recycled water for non-potable use via a dual reticulation system. The 2011 Australian Government Productivity Commission report on the urban water sector noted that all Australian attempts to use recycled water for indirect potable use have failed as a result of government response to ‘opposition by communities’ regardless of evidence from health experts, the National Water Commission and overseas examples such as Singapore and the United States. Community views are essential to planning and costs of misjudging them are high. It is therefore ‘important that the community and decision makers are properly informed about the costs, benefits and risks to water consumers, so that the best choices can be made. Community consultation needs to be a component of decisions on supply augmentation. Although it is difficult to estimate the costs of inefficient investment with precision, they appear to be large' (Productivity Commission Inquiry 2011, Overview p. XXIV).

Certainly the Singapore example provides clues to the problems encountered in Australia. In a list of 'keys to success' (Lim & Seah 2013) NEWater Singapore cites having a single agency managing wastewater and drinking water, strong government support and effective public education and communication. From a social constructivism view this could be seen as a deliberate policy to create a new social norm in favour of water recycling. NEWater followed a lengthy and comprehensive public communication strategy which involved close liaison with media, political and community leaders, including a funded 'study trip for the journalists to visit water reuse facilities in the United States' in 2002 (Lim & Seah 2013, p.60). This was designed to manage non-acceptance risk (RQ3) and public perceptions (RQ7). Recent research in Australia suggests that that support for potable recycled water is increased with the release of detailed information, and that information is better processed when the topic – recycled water – is a relevant issue (e.g. during or immediately post a drought event) and detailed risk information seemed more inclined to promote acceptance (Price et al. 2012, p.1). Questions regarding respondent views on the media and available information were included in the survey instrument (RQs 6-7).

There is some evidence that attitudes in Australia are also evolving. Recent research has suggested that if users are made aware that treated wastewater is effectively already recycled via introduction to river systems and then re-treated further downstream for potable use, as in the Hawesbury-Neapean River near Sydney (and many parts of Europe) with residents in Richmond and Windsor already drinking this, then consumers may be more willing to accept recycled wastewater (Hasham 2012; Macpherson & Snyder 2012). The renewed interest in recycled potable wastewater stems from its presumed lower cost compared to desalination in Sydney. Plans to introduce indirect potable recycled treated wastewater via the Gnangara-Mound aquifer may have some support according to one WA Water Corporation survey (Trenwith 2012). However, the proof of the pudding is, in this case, in the drinking, and as yet no successful indirect potable use of recycled water has officially been made in Australia.

Recycled water uses

Another objective of this thesis is to determine the current existing uses that non-potable recycled water is being put to in practice, rather than theory (RQ1 & RQ2). An aim is therefore to investigate how recycled water is being used by the customers of South Caboolture Water Reclamation Plant (SCWRP). Hurliman, Dolnicar & Meyer (2009) identified a gap in research in that exploration of *actual* adoption of water-related behaviours is far less researched than *intentions*. This study provides further research on this area of practical recycled water usage, as RQ2 asks how recycled water is defined, to which level water should it be recycled and what are its uses?

The Murrumba Downs Advanced Water Treatment Plant (MD AWTP) uses reverse osmosis as part of its process (similar to the WCRWP). A second question would be to investigate any preferred processing method, from a customer perspective. Or are the two methods interchangeable? RQ5 asks whether the two methods of producing Class A+ recycled water as identified in the two case studies equivalent, or is there a preferred method? Initial research in Australia has also suggested that acceptance of water use may be influenced by the alternative source of the recycled water (recycled from wastewater, desalinated or other sources), with recycled water being preferred for watering gardens, all sources considered acceptable for car washing, cleaning and toilet flushing, but desalinated water preferred over recycled water from wastewater for drinking purposes. However the use of self-purified rainwater from tanks appeared the most acceptable option (Hurliman & Dolnicar 2010). The customer at Murrumba Downs (MD) was an industrial user. This thesis explored whether they have different expectations/requirements from residential customers. Again, there is a gap in information regarding customer perceptions. RQ1 identifies stakeholders and RQ6 asks what their perceived benefits and risks are of using recycled water.

Water pricing

Quite apart from decisions about acceptability of recycled water use for various purposes, there is the question of willingness to pay and pricing. Efforts need to be made to change public perceptions, judging by the 2007 report by DBM Consultants prepared for Queensland Water Infrastructure Pty Ltd. This found that there were wide differences in the community in their willingness to pay (WTP) for improvements to increase water supply reliability (DBM Consultants 2007). Communities are likely to resist attempts to introduce such a supply unless their concerns are addressed and they are sufficiently prepared, informed and consulted. Accurate cost information would aid policy and could inform public opinion. It is currently an issue causing deep community concern, and conflict with the retail entities. Again this thesis provided an opportunity to gauge consumer attitudes towards willingness to pay for water products. RQ6 asks what the customer perceived costs (risks) of recycled water are (including willingness to pay) and RQ7 looks at factors influencing customer acceptance of PRW for potable use, and this also considers price as a factor.

> NWC (2007, 2009) and COAG (2008) appraisals of the state of urban water reform, inclusive of recycling, stress the research deficits in social, institutional and economic factors and contend that improved understanding in these research areas is central to increasing the levels of recycling production and acceptance. (AWRCE 2010a, p. 3)

The report identified three NWI objectives: (1) to minimise the impact of urban development on regional water supplies (including ecosystems); (2) diversifying water supplies to address urban water scarcity and (3) maximise the urban water cycle by retaining water in the system through re-use and recycling for as long as possible. (AWRCE 2010a p. 4)

> Recycled water augments existing urban supplies, buffers seasonal shortages, partially remedies inter-drought water stresses, potentially replaces potable supplies to maintain environmental flows and defers the development costs of new water resources. (AWRCE 2010a p. 4)

In a review of research requirements AWRCE identified the need for consistent full cost pricing to reflect the scarcity, to account for externalities, and for water for recycling to reflect fit-for-purpose supply (AWRCE 2010a, p. 5). Inclusion of community debate in the process – a ‘partnership approach’ – is also recommended, an acknowledgement of the critical social dimension in order to ensure community and industry acceptance. Identification of stakeholders requires an awareness of supply and demand. Communication with stakeholders would identify perceptions and barriers to acceptance of recycled water, key among these identified as:

> 1. Lack of public confidence in water governance institutions.
> 2. Inadequate policy and institutional capacity to foster the adoption and diffusion of technical innovations in water recycling. (AWRCE 2010a, p.8)

Mooney and Stenekes (2008) identified that acceptance of water recycling decreases the closer it gets to personal contact (e.g. showering/drinking) and also the closer the proposal gets towards implementation. Acceptance is also influenced by demographics, perceptions of risk and trust issues and water quality, and public acceptance is critical. Public confidence is bound up with trust or concerns regarding water regulations, water authorities and the management of the local supply, and is marked by a disconnect between public attitudes and scientific research (AWRCE 2010a; Leviston et al. 2006). Consequently a key aim of water research should be 'systematic social analysis' according to Urban Water Security Research Alliance's first technical report (Nancarrow et al. 2007). Previous research indicates a disconnect between customer perceptions about the extent of their knowledge regarding water supply and their actual knowledge. Telephone interview questionnaires, undertaken in SE Queensland in areas supplied by the Wivenhoe dam, indicated that customers' perceptions of their level of knowledge about recycled water were much higher than their actual knowledge (Nancarrow et al. 2007). Sydney water customers were similarly unaware of recycled water sources and uses (MJA 2014b).

<u>Attitudes to source of supply</u>

In principle support of recycled water may also depend on source of the supply, and knowledge of how the supply system works. A large majority (74%) of SE Queensland water customers surveyed in 2007 agreed in general that they would drink PRW if a scheme were introduced, but the study also found that this general support dropped when faced with a choice regarding drinking PRW. Less than half (43.4%) agreed with the statement 'given the choice, I would not drink water that contained purified recycled water' (indirect potable supply with PRW added to a dam) and this fell to 29% support if the scheme were a direct potable use supply i.e. straight from a treatment plant) (Nancarrow et al. 2007, p.3). The survey instrument in this thesis therefore explained the available sources and examined customer attitudes to them and the effect on willingness to use recycled water, particularly for potable use. This again was to address RQ6 (customer perceived benefits and costs (risks) of recycled water) and RQ7 (factors influencing customer acceptance of PRW for potable use).

2.5 Water standards

In Australia the management accounting tools for measurement and valuation of water resources are still being developed, with the first water standard being issued in 2012. The National Water Initiative (NWI) had a key aim to improve water accounting in Australia. The NWI Paragraph 80 (COAG 2004, p.17) stated that the outcome of water resource accounting is to 'ensure that adequate measurement, monitoring and reporting systems are in place in all jurisdictions, to support public and investor confidence in the amount of water being traded, extracted for consumptive use, and recovered and managed for environmental and other public benefit outcomes.' To further this outcome the three year National Water Accounting Development Project was started in February 2007 under the auspices of the Water Accounting Development Committee (WADC) (which became the Water Accounting Standards Board (WASB) in April 2009), with the following expected outputs (per the NWC website):

- defining the information requirements of users of water accounting information
- development of a conceptual framework for water accounting
- developing a range of water accounting standards and guidelines for water market accounting, water resource accounting, and environmental water accounting
- developing a national common chart of water accounts
- a series of pilot projects to aid development of the model
- recommending reporting requirements, obligations and assurance mechanisms for water accounting. (NWC 2011c)

One project was the development of water standards via the reconstituted Water Accounting Standards Board (WASB), the outcomes being:

- Water Accounting Conceptual Framework (WACF) released for comment in 2009
- Australian Water Accounting Standard 1 - October 2012 (BOM 2012)

- Australian Water Accounting Standard 2 – February 2014 - Assurance Engagements on General Purpose Water Accounting Reports (BOM 2014a)

Under the Water Accounting Conceptual Framework (WACF) water accounting (WASB 2009, p. 13) is defined as 'a systematic process of identifying, recognising, quantifying, reporting, and assuring information about water, the rights or other claims to that water, and the obligations against that water. Water accounting statements comprise Statement of Water Assets and Water Liabilities, the Statement of Changes in Water Assets and Water Liabilities and the Statement of Physical Flows.'

It should be noted that the Water Accounting Standards Board was disbanded after the Australian Federal Budget cuts in 2014.

Cross-disciplinary nature or the research

Whilst this is outside the scope of this thesis, and not a stated aim, it is likely that the analysis of the processes at the two treatment plants, and the identification of inputs and outputs required, may assist in collecting data for future preparation of Statements of Physical Flows, and inform later research in this area. This is the 'how' in RP1 in developing a model that takes a TBL approach. The description of the research process is in effect part of the solution to this. A problem for all research in the area of sustainability is the lack of obvious research discipline area as this type of research crosses over the boundaries of traditional academic disciplines (Jakeman, Letcher & Chen 2007), with consequent variety of approaches to recording and reporting environmental management accounting information and for recording and reporting water. Sustainability research issues, such as global governance, require academics to move beyond an 'intellectual silo approach' (Pattberg & Widerberg 2015, p. 704). This trend had led in turn to a shifting of accounting reporting boundaries (Chalmers, Godfrey & Potter 2012; Franklin & Blyton 2011). Water accounting has been referred to as a variety of inventory management, previously the domain of hydraulic engineers, but the Australian water standards have been developed with strong financial accounting links, with emphasis on transparency and comparability, and a standard setting process akin to financial reporting standards development (Kirby 2011). Potentially water accounting disclosures may be incorporated into an entity's annual report, as part of an integrated accounting approach (Chalmers, Godfrey & Potter 2012). The cross-disciplinary nature of the information was a challenging aspect of undertaking this thesis, and it is not surprising that most recent research in this area has been undertaken by cross-disciplinary teams with substantial research funding (Marsden Jacob Associates 2013-2014; Urban Water Security Research Alliance 2011-2012).

2.6 Full cost accounting and TBL

In Australia the management accounting tools for measurement and valuation of water resources are still being developed. At the time of commencement of work for this thesis, and during data collection, and as far as the author of this thesis is aware, there had been no case studies on the full costing of recycled water (RP1) in academic literature, from a management accounting/economic perspective. One subsequent recent study from an economic perspective (MJA 2013) explores the economic viability of recycled water schemes in general, with the aim 'to develop a holistic framework that will allow for a rigorous assessment of the economics of non-potable recycled water schemes' (p. 10) and does not consider potable water use. They take a cost-benefit analysis approach (CBA) and use total economic value (TEV) methods to assess cost and benefits (including some externalities). These are discussed in this thesis as appropriate. There are some similarities with the findings of this thesis, and discussion of this has been incorporated in the relevant sections, but the framework is very general (all types of recycled water) and not applied to any exemplar facility, unlike this thesis which examines two cases studies to explore the model. This thesis adds support to some aspects of this research and adds depth in terms of the case studies and also the surveyed customer perspectives. The focus of MJA (2013) was to explore the barriers to capital investment in recycled water projects. The single most prominent barrier to non-potable recycled water projects, the most prevalent being cost-effectiveness in comparison to the cost of potable and other alternative water sources (MJA 2013 p.12). The comparative dearth of costing approaches that attempt to value all aspects of water recycling is also the motivation for this thesis.

Various aspects such as community acceptability and greenhouse gas emissions and life cycle assessments have been the subject of recent (2011-12) technical reports by

Urban Water Security Research Alliance (UWSRA), and will be referred to here. In terms of planning models used by governments and authorities in Australia, previous models have tended to be based on engineering and hydrological reports (Uhlmann & Head 2011; AWRCE 2010a).

From an accounting perspective, the study of recycled water costing lends itself to a triple bottom line approach, having social implications (as described above) and also environmental costs and benefits to consider. The processing of recycled water has costs but may also reduce environmental impact by avoiding, or deferring the need for more costly alternative supplies, such as desalination.

Hatton MacDonald and Proctor (2008) refer to the 'comprehensive economics' of recycled water which should include:

1) Full cost pricing to reflect the scarcity value & the uses of the water (independent of source),
2) Costs of delivery which will vary with source & infrastructure,
3) Value externalities (positive and negative) which would include environment, risks of supply failure, energy costs (emissions), risk of idle assets (with variable weather patterns) (AWRCE 2010a p.12).

Some studies have combined an engineering/hydrological approach with an assessment of the cost of alternative investments but tend to focus solely on direct costs and benefits, but lack of consideration of externalities and the system of water supply as a whole may lead to sub-optimal decisions (AWRCE 2010a p.14; UWSRA 2012)

The 2010 AWRCE Discussion Paper 3 on Social, institutional and Economic Challenges emphasised the urgency for research to 'establish rapid and comprehensive methods to estimate the relative cost effectiveness of recycling relative to other water supply investment options when GHG emissions and other externalities are accounted for' (AWRCE 2010a, p.15). Identified challenges included community engagement; communicating to stakeholders about recycling schemes; perceptions of risk (and how these are influenced by the state of water supply); barriers to the uptake of centralised and decentralised water recycling systems; investigation of actual recycling behaviour (longitudinal) and habit formation; community perceptions towards different schemes/frameworks for water supply including decentralised systems.

This thesis explores a number of these aspects by examining direct costs and potential environmental costs (RQ4) and undertaking stakeholders analysis (RQ1) and research into customer perspectives (RQs 6 & 7) at the two case study facilities.

2.7 Environmental perspective

Environmental valuation techniques have been shown to be useful in public policy decisions (where sustainability and equity issues may be of concern along with economic considerations) (relevant to PR1 & RQ4). Evaluation methods put an estimated dollar value on natural resources. The travel cost method (TCM) has been used to estimate recreational value of water resources, but much higher economic values have been obtained from studies of 'passive' or existence values of natural resources using contingent valuation methods (CVM) based on survey evidence, calculating willingness to pay (WTP) to protect ecosystems. In the United States such studies have altered tributary water flow management (Mono Lake in California) and Dam Water management and development decisions (Glen Canyon Dam; Kootenai Falls; Elwha and Glines Dams). CVM in particular allows more of the population a 'say' in water resource management (Loomis 2000). A similar approach is Total Economic Value (TEV) which can be used in the case of water to value not merely the value from using the water supply by wider values appreciated by non-users, and assess environmental or social values (MJA 2014 c), which is therefore a valuation method suitable for a TBL approach.

Traditional approaches to costing urban water supply have concentrated on capital or operating perspectives. To build a full cost model a value chain or a whole Life Cycle Costing (LCC) approach is needed. This would include as a minimum capital, maintenance, operating and replacements costs over the life of the infrastructure (Tucker, Mitchell & Burn (CSIRO) 2000). Tucker et al. suggest that infrastructure lifetime $C0_2$ Emissions could be added and that full LCC should not be limited to impacts within control of water authorities, but should include externalities. The main brake on introduction of such models is the collection of necessary data for a full cost database to enable accurate costing which 'requires water authorities to collect data in an appropriately disaggregated form instead of the traditional accounting methods where breakdowns of costs into infrastructure items are rarely recorded' (Tucker, Mitchell & Burn 2000, p.3). Tucker (2001, p.1) defines LCC which 'involves combining the estimated capital, maintenance, operating, and replacement costs over the whole life of an infrastructure facility into a single value, which takes into account expenditure occurring at different stages in the life of the infrastructure.' He stresses that inclusion of externalities is needed to allow comparison of alternative water supplies and 'if total water cycle is considered, then strategies that reduce water consumption and consider the reuse of wastewater and stormwater are favoured' (Tucker 2001, pp.1-2). Tucker (2001) found little evidence of LCC being applied to a total urban water system, but limited models (usually excluding externalities) being applied to particular aspects, e.g. pipelines, and often only for a limited decision such as repair or replace. Skipworth et al. (2002) developed a 'Whole Life Costing' model for a UK water distribution network, based on a merger of activity based costing (ABC) and life cycle assessment (LCA). The model balanced realistic costs (including maintenance and asset management), future performance and quality of service. Some difficulties encountered in the model included risk assessment, definition of cost boundaries (including geographical, temporal, environmental and social), assigning costs to the appropriate decision level and accounting for the role of regulation. Externalities were not considered.

2.7.1 Including externalities, systems thinking and LCA

That accounting has potentially an important role to play in the emerging use of calculative methods to include externalities in corporate reporting, such as corporate environmental impacts, is being increasingly acknowledged by researchers (Gray, Bebbington & Walters (1993); Hopwood (2009); Hermans et al. (2006)) (RQ4). Most water valuation methods still concentrate on economic benefits from direct and indirect uses, although there has been some research on environmental base-flows or valuing ecosystems (Emerton & Bos 2004), and very little research on social values (Hermans et al. 2006). It has been argued that the significant social and environmental impact of corporate activities should be recognised in, and form part of, the annual statements reporting on the related economic benefits, giving the stakeholders the opportunity to assess and reward all-round performance costs and benefits (Gray & Bebbington 2001). Elkington (1994) in popularising the phrase ‘Triple Bottom Line’ (TBL) noted the integration of an environmental aspect into total quality management (TQM) and life cycle assessments and raised the implications this has on supply chains. Full Cost Accounting (FCA) and Reporting or Full Cost Corporate Social Responsibility Reporting (Henderson, Peirson & Herbohn 2008) in this sense includes potential and actual costs and benefits of environmental and (by possible extension) social externalities. It is possible to argue that this approach has a built-in internal conflict, in that pursuit of an organisation’s economic strategies might of itself be unsustainable. On the other hand, ignoring such conflicts and not reporting them, cannot be healthy for accurate decision-making. Even partially inaccurate or non-subjective information can be helpful in water resource management by providing structure and transparency in the stakeholder negotiations and agreements regarding the use of a scarce resource (Hermans et al. 2006). A TBL approach is increasingly being adopted in practice. Queensland urban utilities, for example, in 2011 described itself as a ‘triple bottom line organisation’ (Lewis & Belz, p.5) (PR1).

This reflects the movement towards thinking in systems, whether that be planetary, natural or eco-systems, or global economic and business systems, as a way to complement more traditional analytical, or reductionist, approaches. In essence a system is ‘an interconnected set of elements that is coherently organized in a way that achieves something’ (Meadows 2009, p.11). A recycled water plant is therefore a system with elements (assets, people, inputs and outputs) and interconnections – physical and economic flows, chemical reactions and procedures for example – and a function/purpose, production of acceptable standard recycled water. It is also embedded in a series of larger systems –state and federal water policies, the state water grid, the natural water cycle, the earth’s ecosystems, and other integrated stakeholder needs (Jakeman, Letcher & Chen 2007). Pattberg & Widerberg (2015, p.684) argue that ‘environmental problem-solving is no longer concerned with isolated problems, but rather with reorganising the overall relation between humans and natural system.’ New actors have emerged as stakeholders and in governance structures that go beyond national government to include governments at all levels (including civic) and non-government organisations, creating new norms (Avant, Finnemore & Sell 2010).

However this fragmentation does not necessarily lead to better environmental outcomes.

How large a systems view it is necessary to take presumably depends on the decision needed. Broader policy decisions would require a wider lens, but information is needed regarding all the subsystems. Attitudes towards stocks and flows in a system may help to explain perceptions regarding water recycling. Meadows (2009, p.22) argues that ‘the human mind seems to focus more easily on stocks than flows’ and ‘we tend to focus on inflows more easily than outflows’. With a stock like water, therefore, people will more readily accept the idea of increasing inflows, but under appreciate the efficacy of reducing outflows. This may mean that people will support increased supply via capital works such as dams and desalination (capturing or creating new inflows) in favour of water-saving measures or recycling. Few people are aware, for example, that electricity production is a major water user. So saving electricity saves water, as does finding alternate water supplies for power generation. In the US, for example, an estimated 49% of water withdrawn is for use in thermal power plants (fuelled by coal, oil, natural gas or uranium), which equates to in excess of 87 litres of water per 1 killowat-hours of electricity (Waterlink International 2011). Australia is a significant energy producer (about 2.4% of world energy production), being primarily coal, uranium and natural gas (Australian Bureau of Agricultural and Resource Economics (ABARE) 2010). This represents significant water consumption. Moreover, Australia’s electricity prices were amongst the lowest of all OECD countries in 2008 (ABARE 2010 p. 26). Hall et al (2009) point out that that there are many other environmental impacts to consider in the urban water sector and a whole system view should be taken. The link between water use and energy use should also be emphasised and strategic planning of these resources should ideally be combined but this has not been the case in many countries (Head & Cammerman 2010). It seems that electricity supply, and its associated water use, are undervalued, and prices do not reflect scarcity of supply (RQ4).

‘When combined with the freshwater used in hydro-electric schemes, around 65 per cent of the generating capacity in the Australian National Electricity Market (NEM) currently depends on access to significant quantities of fresh water’ (Department of Sustainability, Environment, Water, Population and Communities 2010). Water use was forecast to increase as increased carbon capture storage also requires increased water use.

Durham & Turner 2004 (cited by Bennett 2004) argue that the benefits of using alternative water sources such as recycled water to supply power stations or other industry is not well understood, and the benefits derived from the savings in potable water underestimated. He argues that the hydrological cycle needs to be managed in entirety rather than as separate disciplines such as ‘water’ or ‘waste water’, or efficiencies will be overlooked. Bennett (2004) cites a number of case studies where potable water use has been reduced or eliminated for industrial purposes. Since 2003 the Singapore Water Reclamation (NEWater) programme has used secondary treated effluent to provide purified water for industries such as wafer fabrication for electrical and photonic circuits, power companies and industrial complexes, and also for indirect potable supply by supplementing reservoirs. In the US California’s Orange County Water District (OCWD) uses reclaimed water to expand their seawater intrusion barrier and to feed back via percolation ponds into groundwater basin, reducing the need for higher energy importation of potable water. Wastewater from coal mining is recycled to provide suitable water for Tangshan Steel works in Hebei province, China. Anglican Water in the UK recycles Peterborough city wastewater from Flan Fen STP to supply the nearby power station. Bennett (2004) further argues that a ‘big picture’ view of the water supply system may enable power generation and water production to be so linked (hybridisation) that off-peak power could be used to create fresh water supplies, a form of energy storage. The Queensland government attempted to take a wider view with initiatives such as the Western Corridor Recycled Water Project feeding Tarong coal-fired power station and the Murrumba Downs AWTP supplying Amcor’s paper mill (until the mill’s closure in December 2013). Water supply to the Tarong North and Swanbank power stations became an issue in the prolonged Queensland drought (Baynes, Reedman & Turner 2007).

Meadows (2009, p.23) further notes that people ‘underestimate the inherent momentum of a stock’ in a system, so with a natural resource will fail to comprehend the length of time needed to build up (or repair/replenish) a stock. This would explain the difficulties encountered in persuading people to tackle climate change in sufficient time to prevent major consequences, and resistance to such plans as the release of more water into the Murray Darling catchment. It would also make it harder for people to appreciate the benefit of supplying industry with recycled water (an adjustment to outflows), to avoid depletion of potable water supplies, and to defer the need for more costly water supply sources such as desalination.

Attempts to include externalities in organisational reporting have often been unsuccessful. Problems regarding the ability to measure environmental and particularly social impacts have been paramount. This is combined with concerns regarding subjectivity and the variety of possible measurement bases and consequent verification issues. Henderson et al. (2008) outline three of the more common full cost reporting approaches – maintenance cost, asset valuation and damage cost reporting systems (p.1008 & p.1010). A maintenance cost, or net value added approach, concentrates on natural capital and calculates an organisation's 'sustainable cost' or the costs required for an organisation's impacts to leave the environment no worse off. The asset valuation approach maps changes to environmental assets e.g. by including environmental assets in a supplementary economic balance sheet and corresponding income statement. The valuation methods used for the environmental assets are again open to criticism. Henderson et al. (2008, p. 1010) suggest that 'damage cost reporting systems are concerned with communicating estimates of external environmental concerns from a company's operations', citing the Full Cost Environmental Accounting project undertaken over twenty years by Ontario Hydro, a Canadian power utility, until the departure of 'a key motivating manager'.

Baxter, Bebbington & Cutteridge (2004, p.113) describe a full cost system accounting tool used by British Petroleum (BP) – a Sustainability Assessment Model (SAM) – 'to track economic, resource, environmental and social impacts of a project over its full life cycle and then to translate these impacts into a common measurement basis – that of money'. Four steps to a Full Cost Accounting approach are suggested: 1) Define the focus of the costing project; 2) identify the scope and limits; 3) identify and measure external impacts and 4) cost the external impact, which may require revision of the current accounting information system. An overall view was given by graphing the positive and negative monetary impacts (a SAM 'signature'), although this required a number of estimates and was therefore an indication of the general pattern of projected benefits/costs.

Reasons cited for the failure of (TBL) Full Cost Accounting experiments include lack of support from key management and lack of data (from the accounting and information systems (as with Baxter, Bebbington & Cutteridge 2004). There are also the difficulties of valuation and the expression of externalities in economic format (which would allow additivity or integration and comparisons), and a lack of standards (Henderson et al. 2008; Gray & Bebbington 2001; Herbohn 2005). There are even debates about whether expressing externalities in an economic framework in fact lessens their impact and understates the consequences (Gibson 1996).

Some research has drawn a distinction between a 'full economic value' for water that should include both market values and non-market values (such as environmental social externalities) and a 'complete' value that would include 'beyond efficiency' subjective value such as cultural or religious values. A distinction could therefore be drawn between *value* (a subjective, appreciative measure) which cannot be expressed in economic terms but is none the less valid, and *valuation* which places an economic value on the water resource. It should be possible to use established economic techniques to determine a full *economic* value (*valuation*), even though economic valuation has its limits, to provide a useful decision tool and to promote changes in user behaviour (Matthews, Brookshire & Campana 2001). The increased use of environmental valuation techniques internationally has already led to moves to assess the quality of such studies, for example the introduction of a Quality Assessment Instrument (QAI) in Sweden's Environmental Protection Agency (Söderqvist & Soutukorva 2009).

One Australian attempt to introduce 'full cost environmental accounting (FCEA)' by an organisation in the Australian public forest sector is outlined by Herbohn (2005). FCEA was defined as adapting traditional full cost accounting to include environmental externalities. This experiment used techniques from environmental economics to produce a 'damage cost reporting system in which net profit is adjusted for positive and negative estimates of environmental externalities' (Herbohn 2005, p. 19). The damage cost approach was selected as the best fit for environmental economic techniques already being used overseas since the aftermath of the Exxon Valdez oil spill and at Coronation Hill (Kakadu) in Australia. Ultimately the experiment was unable to continue, not due to measurement difficulties per se, but as a result of ‘business as usual pressures’ (as identified by Gray & Bebbington 2001). Support for the project was withdrawn by senior management as a result of funding, internal and external political stakeholder pressures, and resistance of managers to non-market valuation techniques. As with the Ontario Hydro case study, the absence of key personnel driving the project, and lack of consistent and continued support by senior management, inhibited progress.

The Urban Water Security Research Alliance (UWSRA) (2012) addressed a number of of these areas in their technical reports, specifically in relation to south-east Queensland water supply, but primarily from a scientific and systems perspective. This gives useful background in addressing some of the concerns relevant to the case studies being considered in this thesis. One aspect considered was to address common consumer health concerns regarding potable recycled water. In the Singapore example source control was considered important and the input to the system for treated wastewater is primarily from domestic effluent (Lim & Seah 2013). Separation of domestic and industrial waste in Queensland is not as rigorous. A concern over pharmaceutical load in industrial effluent proved unfounded as hospitals contributed a negligible amount compared to wastewater originating from households (UWSRA 2012). In regards to pathogens dams appear effective in their removal, even after flood events, which suggests that indirect potable use may be preferable (UWSRA 2012). NEWater Singapore explained their decision to prefer indirect potable use (IPU) as having three components:

1) Blending with the dam water replenished important trace elements removed in the treatment process (multi barrier & reverse osmosis (RO),
2) Reservoir storage was an additional safety barrier,
3) IPU was considered to be more publically acceptable.
(Lim & Seah 2013, p.56)

2.7.2 Studies relevant to SE Queensland

This section examines relevant research in SE Queensland as regards recycled water, and attempts to model environmental impacts and hence begin to value externalities relevant for building a TBL model (PR1 & RQ4).

As consumer acceptance is an issue in Queensland, it seems that indirect potable use is the most likely to have public support. In terms of quality of recycled water produced the UWSRA research suggests that multi barrier techniques using reverse osmosis or non-membrane techniques such as a combination of ozonation and biologically activated carbon (BAC) produce similar standard water supply, and both would be acceptable for fit-for-purpose water use (UWSRA 2012; Reungoat et al. 2012a), such as replacement of non-potable uses and industry use. For the purposes of this thesis this means that the recycled water produced in both case study plants is currently suitable for non-potable use and potentially suitable for indirect potable use.

Baynes et al. (2009) explored a simplified demonstration framework for modelling energy and greenhouse implications for future South East Queensland water strategies, using water balance and demand models. An assessment of energy use and greenhouse gas contributions for urban water and wastewater, and an estimate of trends was the focus in a study by Hall et al (2009). The highest energy use in SEQ (with desalination plant outputs at minimal levels) was pumping. Desalination plants require a minimum running level for operational maintenance, and thus less than full energy savings are possible when demand is low. This might suggest that more localised solutions rather than large schemes might be more energy efficient. However recycled water and (in particular) rainwater tanks also had a higher energy footprint than current sources. The study also suggested (with some uncertainty) that the potential extent of diffuse greenhouse gas emissions (primarily from reservoirs and wastewater treatment and handling) was greater than energy use emissions (Hall et al 2009 p.1) and likely to grow at a faster rate than population. In accounting terminology when considering recycled water from treated wastewater, however, these could perhaps be considered irrelevant costs for a decision to recycle, as wastewater treatment is necessary anyway to ensure environmentally acceptable release to waterways. Reduction in emissions/reuse of gas from wastewater treatment might however be deserving of further research in terms of the emissions from the water cycle in general.

A number of recent studies have looked at externalities in water strategies. Daniels et al (2012) examined regional water strategies, identifying a ‘compendium’ of externalities such as greenhouse gas emissions (GHG), nutrients (N) and recreation (R) impacts, based largely on prior research. Of particular interest in terms of this thesis is the identification of potential externalities for wastewater recycling (Daniels et al 2012). The research led to the development of a ‘simple externality analysis’ (SEXTAN) seven step methodology for externalities in water supply (Daniels, Porter & Bodsworth 2012) and applied to an example based on the reticulated supply in the Logan-Albert catchment area in south-east Queensland. The methodology builds on previous research, but is more specific and detailed in its application to water supply options, and is based on south-east Queensland, so highly relevant to this thesis. Daniels & Porter (2012) sought to apply this in a ‘preliminary framework’ to the Moreton Bay Regional Council planning process. These studies provide a strategic overview, and emphasise the need for Total Water Cycle Management – rather than concentration on just one aspect such as increasing large-scale supply, but do not constitute a detailed case study as outlined in this thesis. They do highlight a number of relevant externalities which will be considered in the environmental analysis in section 4.1 of this thesis.

Lane, de Haas and Lant (2011) provided a Life Cycle Assessment (LCA) of the Gold Coast urban water system. The study examined GHG and environmental impacts of the water system infrastructure, and compared various water supply alternatives. The first was a ‘traditional mix’, (as available on the Gold Coast 2007/2008). This was based on a supply from dams and conventional water treatment plants (WTPs) with some small scale use of rainwater tanks, and sewage treatment plants (STPs) with 20% re-use of secondary treated effluent for irrigation and all biosolids re-used for agricultural purposes. This was compared to a ‘future mix’ including Tugun desalination plant, potential indirect potable use, actual non-potable class A+ recycled water re-use via the Pimpama dual reticulation scheme, and an increased rainwater tank supply. The situations were modelled and an impact assessment done.

Environmental consequences identified included:

- Use of recycled water substantially reduced STP effluent discharged to the sea and hence reductions in Aquatic Eutrophication Potential (AEP) and Marine Ecotoxicity Potential (MEP), particularly indirect potable use, although some of the toxicity was redirected to freshwater systems if the recycled water was put to land use. Surplus Class A+ water released to sea could also increase MEP due to its chlorine content.

- Fuels for transporting biosolids or chemicals used in water treatment, and power costs even in traditional WTP at the Gold Coast were high due to distances of pumping both for sewage collection and wastewater disposal.

- Power use also rose for more advanced water treatment, particularly desalination. Rainwater tanks may be associated with high energy use, depending on types of pumps used.

- Nutrient loss from agricultural use from biosolids applied to farms also caused run-off problems in waterways, only partially offset by reduced use of traditional fertiliser. However, the potential for phosphorous recovery could be further explored.

- The largest environmental burden (mainly fugitive emissions) was from the initial (necessary) wastewater treatment phase, common to all scenarios, and therefore the largest opportunity for improvement. Fugitive emissions from dams (CH_4) could also be significant, and therefore part of the benefit of recycled water use, as this reduces the need for construction of new dams.

Little research has been done to monitor fugitive emissions from wastewater treatment plants (compared to quality of water emissions from such plants, generally covered by environmental protection legislation due to the immediate potential for human health risk) but the Viikinmäki wastewater treatment plant in Helsinki has been monitoring GHG emissions with a view to their capture, an opportunity made possible by the location of the WTP underground due to freezing conditions (Environmental Xprt 2014). The plant uses biologically activated sludge (similar to biologically activated carbon (BAC) used at South Caboolture WRP) and re-use of the emissions is sufficient to meet all heating needs and 70% of power, with dried sludge sold for agricultural use. Monitoring to date has suggested that ‘the emissions per cubic meter of wastewater equate to 3.5g of methane and 1.34g of nitrous oxide’ (Environmental Xprt 2014, p.2). However nitrous oxide emissions have also been shown to vary greatly between plants, and may be reduced by improved design and operation. Water treatment plants achieving high levels of denitrification may have less emissions of nitrous oxide, which would suggest that treating to greater water quality is desirable, but further research is required (Law et al. 2012).

A set of three complementary studies, from researchers from the Urban Water Security Research Alliance and released in 2012, have taken a life cycle assessment approach to the same catchment area and recycled water plant as this thesis, from a technical perspective. This thesis, begun in 2007 and generated along a similar time frame, takes a management accounting TBL approach to the same subject area, with the added social dimension. The synthesis report (Lane & Lant 2012a) confirmed the opinion that efficient decision making requires consideration of a much broader suite of environmental and other externalities than that captured by electricity or GHG accounting alone. The definition of LCA used for the studies was a ‘focus on three fundamental areas – the protection of natural environments, protection of human health, and maintenance of natural resources. Life Cycle Impact Assessment (LCIA) is the process of converting system inventory flows (emissions; resource extractions) into measures of potential impact in one or more of these areas’ (Lane & Lant 2012a, p.5). The study examined the LCIA for a set of three escalating possible water strategies for the catchment:

1. a minimum business as usual standard with added household rainwater tank use only;
2. adds improved management (e.g. of stormwater & erosion) plus tertiary treated wastewater for agricultural irrigation;
3. the most use of recycled water with non-potable residential and industrial Class A+ reuse, supplemented rainwater tanks and by limited stormwater reuse, and all scenarios postulating a 42,700 increase in population in the Caboolture urban area.

The study highlighted how limitations to available data for LCA hamper analysis, and how a broad perspective is needed – particularly the consideration of study boundaries – for accurate planning. The study also noted a paucity of data regarding water usage for rainwater tanks and class A+ recycled water e.g. the influence of non-mains supply on mains supply water usage, and for electricity usage. The more rigorous GHG analysis of the LCA approach in the study suggested that GHG impacts of scenarios 2 and 3 were underestimated, such as the carbon footprint of higher chemical use in advanced water treatment, and electricity use, 'hence the penalty for moving beyond the business-as-usual water cycle will be greater than expected' (Lane & Lant 2012a, p. 15).

However this conclusion is very susceptible to limitations of boundary in the study. A direct comparison between the three scenarios limited to consideration of the Caboolture catchment area is misleading. The increased potable water savings from scenario 3 may well outweigh any GHG considerations from its operation. The Caboolture weir is already at capacity use and imports potable water from the SEQ water supply grid (Lane & Lant 2012a, p.7). The cost of scenario 3 should therefore include as a minimum the avoided cost of current dam water supplies, which in their model made scenario 3 preferred to 2 (so a choice between 1 and 3). This is further complicated by the lack of data for ongoing fugitive CH4 emissions from water supply dams (in addition to GHG CO_2 released from vegetation when first filling the dam) and other water storage (not considered in GHG calculations by the IPCC or NGERS) (Lane & Lant 2012a p. 26) and early studies suggest this could be significant. It is also possible to argue that the incremental cost of future water supply may not be from current dam sources, as increased population may necessitate alternative mains water supply. Lane & Lant (2012a) also model the scenarios based on a mains water supply sourced from desalinated water (in effect this is therefore including the benefit of avoiding – or at least delaying – the need for increased desalination by reducing demand on current potable water sources). Under this situation scenario 3 becomes a preferred option. Further issues needing future research clarification are the issue of N_2O generation from water supply dams or stormwater. It was again highlighted, however, that the relatively higher emissions from the Sewage Treatment Plants supplying the initial treated wastewater meant that changes to this process could have a much more significant effect on overall GHG contribution.

The more detailed study of the Ozone-BAC Class A+ South Caboolture Water Reclamation Plant (SCWRP) suggested a higher than expected GHG footprint (in comparison to a 2011 LCA study at the Gold Coat Pimpama class A+ plant which uses UF based membrane treatment), although lack of detailed separation of data, particularly with regard to electricity use, may make comparison misleading (Lane, de Haas & Lant 2012 p. 1). This may be mitigated by power savings on water use offsets, but as mentioned data on mains/recycled water offset usage was not available. The GHG footprint was lower than a comparison to a hypothetical reverse osmosis (RO) and advanced oxidation treatment plant and may also be capable of producing water to indirect potable standard without substantial brine by-product and possibly with less chemical use intensity (Reungoat et al. 2012a).

This research considered in this section indicated that recycled water from both case study plants in this thesis would be suitable for non-potable and potentially for indirect potable use (relevant to RQ2 – definition and uses of recycled water). The research also indicates externalities in the system that need to be considered, including fugitive emissions from the plants themselves (although most significant in the unavoidable initial sewage treatment plants) and from dams, and the lack of data concerning these. The possibility of capturing emissions to power the process was also raised. This is relevant as energy costs are a significant consideration, particularly pumping costs, demonstrating that solutions should perhaps be localised, and in operations are likely to be highest for RO. However this may be offset by energy saving from the avoided water use. Data about interactions between water supplies, and the extent of substitution e.g. for rainwater tanks is also lacking. How customers use their water is something addressed as part of the survey in this thesis (relevant to RQ2 which examines uses of recycled water). Previous research also demonstrates that benefits have to be assessed within the wider system – for example energy use could be significantly offset by avoidance of the 'next best alternative' supply – e.g. building new dams or water supplied via desalination, and the value placed on safeguarding supply against population increases and future drought conditions. Other identified externalities included chemical use and nutrient release, and also recreational water uses. The consideration of externalities is necessary for a TBL approach (and particularly RQ4).

2.8 Stakeholder theory and the value chain

Full Life Cycle Costing and value chain costing have their roots in stakeholder theory, and identification of key stakeholders in the case studies is an identified objective of this thesis. Research Question 1 (RQ1) examines the characteristics of the recycled water supply chain in SE Queensland, including identification of key stakeholders, and specifically the stakeholders in the 2 AWTPs studied (see 4.3.6 and figure 4.11 for identification of stakeholders).

Freeman and Liedtka (1997) chart the growth in the concept of "stakeholder" in the management theory literature from the 1960s where business was viewed as an integral part of society. This is linked to ethical debate about the purpose of a business – to serve shareholders or any party affected by corporate actions? They argue that groups necessary for an entity's success, internal or external to the firm, would need to be included in business strategy. Therefore business success has never been purely dependent on satisfying shareholders, but in balancing the needs of various groups, including management and employees who need a sense of purpose and direction to succeed. Porter's Five Forces placed firms in a micro environment of the society in which they operate, considering customers and suppliers and the competitive forces in the industry, and requiring an assessment of core competencies. Porter's description of the concept of a value chain (Porter 1980), where products have value added along a sequence of activities during their life, has also been modified in recent research according to Freeman and Liedtka. Traditionally these were sequential, product-centred and physical, but increasingly value-adding activities are seen as involving inter firm interactions, and may be virtual (informational) rather than purely physical, and capability rather than product based. It has become 'a collection of value-creating processes contributed by different firms working simultaneously both independently and cooperatively' (Freeman & Liedtka 1997, p. 289). Firms work collaboratively and competitively to innovate and add value (value creation), benefitting the customers and the firms concerned, who must then take their share of the value (value capture) and negotiate the tensions created between them in this process. In the interest of long term sustainability of the value creation process (via cooperation) fair profit capture will be achieved. This ‘Stakeholder Capitalism’ system has four principles: Stakeholder Cooperation, Complexity (humans have multiple motives), Continuous Creation (creating new sources of value), and Emergent Competition (Stakeholders have choice). Stakeholders may be managed by assessing their actual/current behaviour, cooperative potential and cooperative threat, but from a perspective of assuming basic goodwill (all want to create value) and that value creation (not just capture) is the dominant motive.

Stakeholder analysis can be applied to various frameworks. Supply chain management (SCM) examines the physical flow of a product from supply to distribution and the two-way information flows along the chain. This calls for closer working relationships between businesses in the chain – from suppliers to customers – to maximise efficiency for mutual benefit in competition with other supply chains. Information technology enhancements have enabled improved integration along chains. Johnson and Pyke (1999) identify a number of key SCM components including location, logistics (global), inventory and forecasting, marketing, sourcing and supplier management, information and electronic media, product design/introduction, and service and after sales support, outsourcing, metrics and incentives (e.g. benchmarking) and global issues. The study identifies modifications to the chain e.g. product returns-reverse logistics as products travel back along the chain – and ‘green issues’ such as management of product recovery for repair, re-works, re-use of parts or recycling.

More recent innovations in supply chain management include the incorporation of corporate responsibility (Strand 2009), and environmental/sustainability considerations (Pagell & Wu 2009; Zhu, Sarkis & Lai 2008). What is meant by sustainability can be ill-defined and has a range of interpretations and crosses research disciplines (Seager 2008). Pagell and Wu (2009) define a truly sustainable supply chains as ones that ‘at worst do no net harm to natural or social systems while still producing a profit over an extended period of time’ (p. 38). This is the ultimate Triple Bottom Line (TBL) approach. They divide supply chain literature into those seeking to base sustainability on existing best practices, those re-thinking the supply chain itself, and those advocating integration of sustainability into corporate strategy.

Improving best practices is useful for making a supply chain more sustainable but may take an incremental approach to improvement that may hinder reaching the level of change required for true sustainability. Useful components of this however are collaboration between suppliers and customers and supplier certification that is useful for promoting social improvements. Reconceptualising the supply chain they argue reconfigures the members of the chain in a broader social context (a broader stakeholder view of supply 'chain' interactions which are no longer linear). Reverse logistics and closed loop (circular) supply chains that involve recycling are examples. Research in this area has tended to remain highly theoretical. Proactive top-down integration of TBL into corporate strategy is necessary for success of any sustainable supply chain. In examining the key common elements across ten sustainable supply chain case studies Pagell and Wu (2009) argue that an equal mix of improving best practice and innovation is necessary. Positive, committed, innovative management integrating sustainable values across the business and able to re-define the stakeholders in the supply chain to include collaboration with non-traditional partners such as NGOs, and who value supplier continuity and are prepared to reduce supplier risk to support this, is the common key.

Early supply chain theory emphasised the physical flow of products, and of information, where value chains examine the activities that add value within the business. As this analysis can and should be extended upstream and downstream, then the reconfigured supply chain and an evolved value chain become remarkably similar concepts, based on stakeholder relationships.

Supply chain management forms part of the overall value chain, as a streamlined cooperative supply chain, with stakeholders as 'customers' adds value for stakeholders. A fusion of the two approaches is suggested in studies of integrated chain management. Seuring (2004) examined integrated chain management in the textile industry, although this was limited to integrating environmental (and not really addressing social) aspects. One of the firms in the case study –ECOLOG- has relevance to research into recycling in that it was a closed loop supply chain. Many 'closed loop' chains merely allow for returns and re-use and limited recycling.

ECOLOG has a strategy of manufacturing clothing using entirely homogenous polyester products. ECOLOG manufacturers must obtain a licence to ensure that their products meet the uniform polyester requirement. The products are labelled before going to retailers and customers may return the clothing items to retailers at the end of their life for complete recycling. The main difficulty has been ensuring that customers ultimately return the products, which means fostering relationships with retailers (in contact with customers) and may require incentives to be offered. Unusually for a supply chain, ECOLOG as the focus (coordinating or driving) company is not the partner in the chain closest to the customer. In a Government owned utility the difficulty of re-take of supply is not such an issue and offers the possibility of a true closed loop supply. A theoretical model for a 'zero waste' sustainable value chain analysis for a wastewater treatment plant was postulated by the project engineering firm CH2M HILL at the 2007 Water Environment Federation's Annual Technical Exhibition and Conference (Whitlock, Daigger & McCoy 2007).

As mentioned in the introduction to this thesis, the original design of the WCRWP in SE Queensland anticipated that water from advanced water treatment plants would either be used as a water supply for Tarong Power Station (still current policy) or would be used to supplement Wivenhoe Dam for indirect potable use, effectively closing the supply chain (see Figure 1.1).

Whilst it should be noted that the price charged for water has a political (and behavioural) dimension, a full cost TBL approach is relevant to providing the necessary data for an informed pricing decision, and to provide evidence for the need for greater cost recovery and a higher value for water as a resource. In 1999 the Queensland Government directed the Queensland Competition Authority to prepare a report on water pricing principles. This report stipulated that water delivered to the end user should reflect its cost (in some circumstances including a value for the resource); be forward-looking; ensure revenue adequacy (a return on the asset investment, requiring a valuation of the regulatory asset base, on a deprival or replacement cost basis including forecast capital expenditure); promote sustainable investment and ensure regulatory efficiency (least compliance costs). (Queensland Competition Authority 2000, 1.4 Pricing Principles and Methods p.3). A valuation of South East Queensland Councils' bulk water assets was undertaken by KPMG in 2007, commissioned by the Queensland Treasury, in response to the Queensland Government decision in September 2007 to transfer ownership of councils' bulk water assets to the State. Attempts to increase water prices to cover costs per QCA were met with consumer backlash, and the Queensland Government sought to put a (temporary) cap on increases from 1 July 2011-30 June 2013 under the Fairer Water Prices for SEQ Amendment Act 2011. Price increases for water are likely in SE Queensland in 2014-15 (Killoran 2014b).

The National Water Commission (NWC) also emphasised the importance of correct pricing of urban water supply in 'ensuring that water is used wisely and that new sources of water supply are brought on line in a timely fashion' (NWC 2008, p. 1) Future priorities identified included more transparent pricing, greater scarcity pricing and improved pricing for new water resources with:

> urgent progress required to improve pricing policies for recycled water and stormwater. Consistent with NWI commitments, pricing policies for recycled water and stormwater should be congruent with pricing policies for drinking water so as to stimulate efficient water use regardless of the source. Recycled water and stormwater re-use schemes need to be considered in a system-wide context and prices should reflect externalities and avoided or deferred costs. Prices for recycled water and stormwater should reflect underlying cost differences associated with providing products of different quality and fit for a range of different users (NWC 2008, p. 2).

The underlying management accounting and information systems would therefore need to provide the data for such costing schemes.

2.9 Review summary and conclusions

Increasingly traditional economic accounting information is being viewed as inadequate for informed decision making as stakeholders begin to favour reporting information on a Triple Bottom Line or similar basis – that is adding environmental and social aspects to financial considerations in planning and decision-making. This requires information and measurement systems capable of collecting and valuing such information. This may include externalities – costs and benefits not captured within the organisation's economic boundaries or by a traditional accounting system (AWRCE 2010a). In terms of strategic water planning, concerns about population growth and climate change, and the effects of the prolonged drought in Queensland and elsewhere in Australia (1997-2010) have prompted national and State initiatives to seek alternative water sources (AWRCE 2010; NWI/NWC 2011a & 2013: Garnaut Review 2011). In South East Queensland this prompted major infrastructure investment, most notably the WCRWP that included the proposed recycling of wastewater for indirect potable use. This highlighted the need to ascertain and manage public perceptions and dissemination of accurate information about water recycling and the costs and benefits of recycling treated wastewater (Hurliman & Dolnicar 2010; Miller & Buys 2008; Browne et al. 2008). Information should be detailed and relevant (Price et al 2012). It is clear that a more holistic approach is required, taking a systems view and incorporating externalities (WBCSD 2012). Only preliminary research has been done in this area (MJA 2013; UWSRA 2012), particularly regarding the social aspects, despite the crucial impact stakeholder views have had in Queensland.

The literature review reveals the difficulty of conducting research in a cross-disciplinary field (Chalmers, Godfrey & Potter 2012). Global environmental research is tending towards approaches combining aspects of social sciences, natural sciences and systems thinking (Pattberg & Widerberg 2015). Psychological theory such as motivation and informational effects, for example, have long been used to examine aspects of management accounting research into budgeting (Birnberg, Luft & Shields 2007). The literature demonstrates problems encountered measuring and valuing externalities, and possible tools for improving this data (Loomis 2000; MJA 2013). It highlights the potential political cost of policies and the need to understand social perceptions of risk, trust and willingness to pay regarding recycled water (Hurlimann & McKay 2006; Marks, Martin & Zadoroznyj 2008; Uhlmann & Head 2011), and how this may be linked to historical water pricing policies (and lower than cost supplies of potable water) (Hunt, Staunton & Dunstan 2013; WBCSD 2012; Withey 2013). It also suggests that attitudes and behaviour patterns can be changed in a relatively short period of time (Beal, Stewart & Huang 2010). Social constructivism may inform how new norms are formed and why this may be short-lived. It shows how long term sustainability planning requires consistent top-down leadership to be successful (Lim & Seah 2013; Herbohn 2005), particularly in a region where weather follows cyclical extremes in patterns (drought and flood influenced by El Niño and La Niña effects) over time (Garnaut 2011a). Strategic planning requires a systems view (Meadows 2009; Bennett 2004) increasingly involving network-based approaches and requiring a broader governance context (Pattberg & Widerberg 2015) and stakeholder analysis (Pagell & Wu 2009; Zhu, Sarkis & Lai 2008) and the ability to incorporate values that are beyond traditional accounting considerations. Stakeholder views on sources of recycled water, preferred processing method for the water, uses of recycled water and willingness to pay (DBM Consultants 2007) are not well known and may be complex, including a value for non-users as well as users (MJA 2014b).

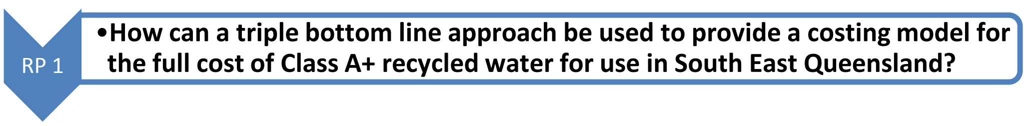
This thesis studies two examples of wastewater recycling in Queensland using a TBL approach to examine economic, environmental and social aspects of the case studies. It also presents data on current (non-potable) recycled water usage and attitudes towards this from water customers using recycled water and others in the same geographical area not currently using recycled water. It gathers data on recycled water use and explores perceptions and attitudes towards indirect potable recycled water use and willingness to pay for recycled water. It also suggests a disconnect between customer perceived use and actual use behaviours (similar to Beal & Stewart 2011and Nancarrow et al. 2007) and a lack of information regarding water recycling (MJA 2014a).

3. Methodology

3.1 Introduction and overview

As this thesis took a Triple Bottom Line approach, this methodology section is structured to explain the approach used for each aspect - economic, environmental and social. This chapter looks at the motivation behind the methodology and the methods used to examine the Research Questions (RQs). A summary of the approach taken/methods used for information gathering is represented in Figure 3.1 at the end of this introductory section.

This thesis is concerned with the costing of recycled water in the specific context of South East Queensland. The literature review pointed to the inadequacy of traditional costing techniques in an area with significant political, environmental and social interactions and consequences. It documented a rise in cross-disciplinary research in the accounting for such stocks and in the sustainability research field in general. This has given rise to concepts such as full cost accounting and triple bottom line (TBL) accounting, in a multi-stakeholder environment. The literature also suggested that water accounting, and recycled water in particular, was less researched and that research to date indicated significant gaps, particularly into the social aspects of recycled water, despite the costly consequences of policy-making without consideration of social costs and customer perspectives and values. It also pointed to the need to include consideration of non-economic externalities i.e. values not captured in traditional accounting systems, in policy decision-making in this area. This informed the research problem – 'How can a triple bottom line approach be used to provide a costing model for the full cost of Class A+ recycled water for use in South East Queensland?' The methods themselves used to acquire non-traditional information for the TBL approach form part of the solution to Research Problem 1 (RP1).



(extract from **Figure 1.2**)

As with any TBL approach, data for each aspect is required – economic, social and environmental. In the literature review, this required consideration of a number of cross-disciplinary approaches. From the perspective of methodology, the lack of a fully-formed theory to test in the circumstances of water recycling suggested an inductive approach. It was expected that the research would add new information (particularly as regards social costs and perceptions) arising from a more in-depth practical examination of stakeholders. This involved a greater synthesis of results across the three TBL aspects in one report (rather than previous research looking at aspects in isolation). In other words the model, whilst including aspects of previous research, would be developed from the results of a particular examination to a more general view. As the information gathering (and synthesis of other research) was being undertaken by one researcher, the interaction with the subject matter would inevitably be coloured by the researcher's perspectives as part of the research process.

> '*Inductive analysis* involves *discovering* patterns, themes, and categories in one's data. Findings emerge out of the data, through the analyst's interactions with the data, in contrast to *deductive analysis* where the data are analyzed according to an existing framework' (Patton 2002, p.453).

To increase validity and robustness of researcher observations, a mixed methods approach was used (as discussed below). This also required a flexible approach to the research structure (Saunders et al. 2007).

In depth examination of water recycling suggested a case study approach. Stake (1995) outlines three types of case study – intrinsic, instrumental and collective instrumental. An intrinsic case study does not intend to be representative but examines the specific case to understand details relevant only to that particular case. An instrumental case study also seeks to understand the details of the case but the case is chosen to increase understanding of and develop/test theory in an area of interest. Collective instrumental extends the instrumental design by looking at more than one related case study, each case study being individual but these can then be used in combination to inform the area/theory in question e.g. by comparison. The background, physical location, political/regulatory setting for each case is necessary for a holistic approach. A social constructivist approach is appropriate (Merriam 2009) where the researcher interacts with the subjects e.g. via interview. As the object was to combine all three aspects of

TBL then these needed to be examined in the same geographical area and as part of the same wider system, and be accessible to the researcher. Recycled water from treated wastewater was being used for indirect potable use at the time of the commencement of the project by Moreton Bay Regional Council (later transferred to Unitywater control) at two sites. This offered the opportunity for a collective instrumental case study approach. After initial contact was made with senior staff, it was decided to examine the research problem of the study of costing recycled water via two case studies of advanced water treatment plants. Both plants treated secondary effluent to sufficient standard for release into surface waters by producing Class A+ recycled water, and were operated by UnityWater in South East Queensland (SEQ). The plants both had multi barrier processing, but the South Caboolture Water Reclamation Plant (SCWRP) primarily used biologically activated carbon (BAC) and ozonation and the Murrumba Downs Advanced Water Treatment Plant (MDAWTP) primarily used reverse osmosis (RO).

The aim was to develop a model for full costing of these recycled water facilities in South East Queensland (SEQ), which recycled water to A+ quality, taking a triple bottom line (TBL) approach. Full cost includes traditional economic costs (direct costs & capital costs) and environmental and social costs and this may include externalities, cost and benefits not captured by traditional economic accounting information systems. A stated aim of the restructuring of water management in Southeast Queensland was ‘to ensure that in the face of climate change and massive population growth, water supplies and wastewater services are sustainable and efficient’ (DEWS 2010, p. 42). Recycled water use is intended to address supply sustainability. The structure for South East Queensland water supply has been outlined in section 2.2 (supra) and SEQ is defined as the geographical boundaries covered by SEQwater (Figure 1.4).

At the time of conducting the research no such similar study combining these TBL aspects had been undertaken in Australia (and to the researcher’s knowledge not internationally either) for a recycled water facility. The research design was therefore partially exploratory (in its combination of aspects to form a model) and in its enquiry regarding customer perceptions and social aspects, and partly confirming previous research.

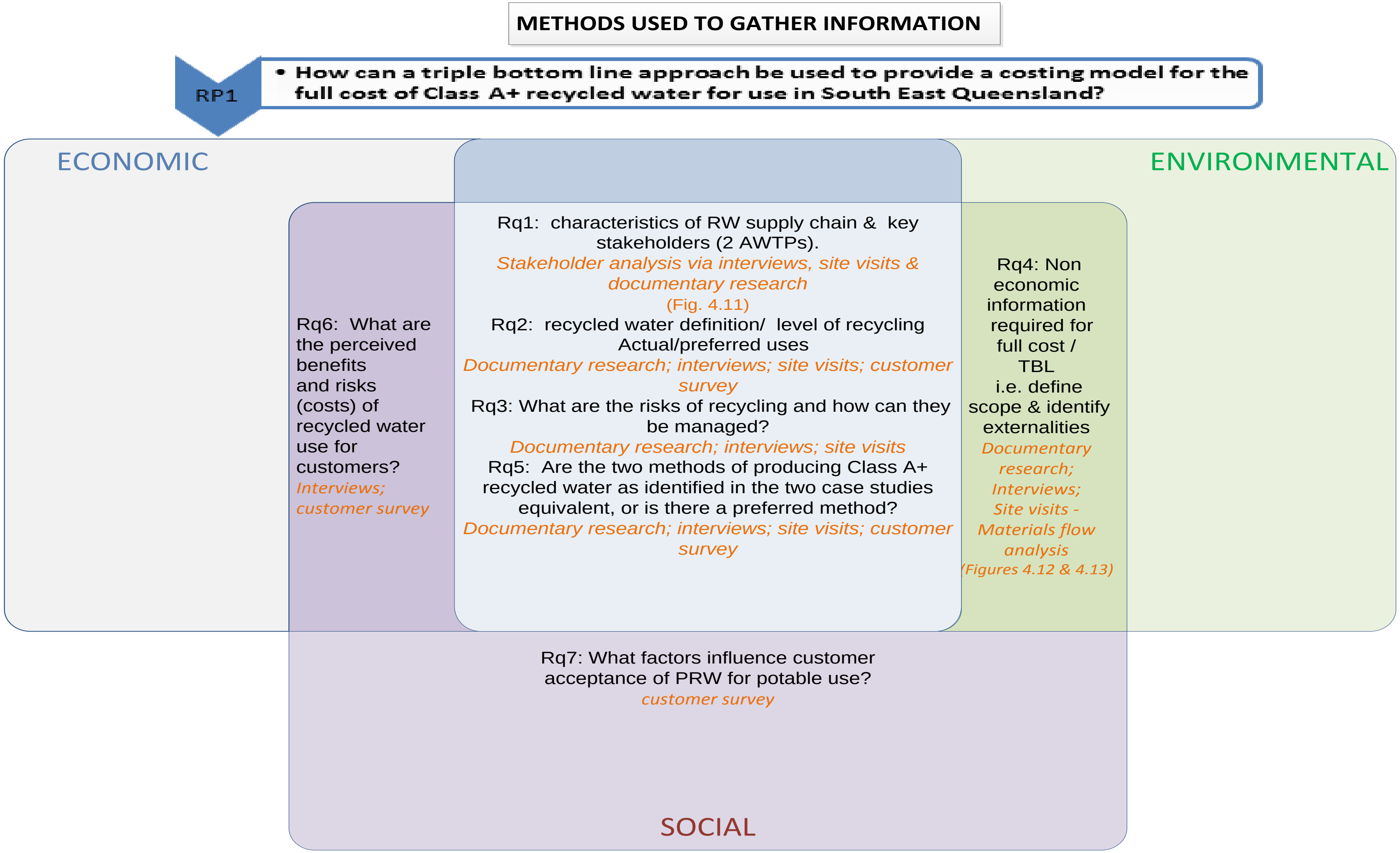


Figure 3.1: Mapping methods to research questions

3.2 Study methodology - general

The general paradigm of this study is that knowledge is socially and historically constructed, an active process of interaction between stakeholders. However this does not exclude liberalist theory of rational actions based on preferences. 'Competing' theories can in fact each shed light on aspects of decision-making, as argued by Finnemore and Sikkink (1998, p. 887) who noted the 'rational and strategic nature of many social construction processes' and argued that 'theoretical progress will only be made by placing attention on the connections between norms and rationality rather than by opposing the two'. Investigating these interactions informs the model, hence an inductive approach.

Validity and Mixed methods

To improve validity, and also to reflect a TBL approach connecting information from various disciplines, a mixed methods approach was taken. This method may be described as mixed due to the data (a combination of qualitative and quantitative data) and also analysis of that data (e.g. qualitative data 'quantified' and analysed) and permits a flexible and interactive model (Teddlie & Tashakkori 2009).

Information was gathered from a variety of key stakeholders using qualitative and quantitative field research techniques such as examination of public documents, site visits, sampling and direct observation, informant and respondent semi-structured interviews, and water customer survey i.e. multiple methods and multiple observations (Eisenhardt 1989; Miles & Huberman 1994; Creswell 2009). As with any inductive research, a threat to validity is its subjectivity (observer/researcher bias). Efforts were made to ensure the validity and reliability of the field study data, following strategies and tactics suggested by the following prior research. Using a variety of measurement methods enhances validity and reliability (Miles & Huberman 1994). All site visit interviews were recorded and transcribed, although these remain anonymous and largely confidential (and are not reproduced here in entirety). Non-interview data was used as part of a triangulation process for background information (Herbohn 2005; McKinnon 1988). Examples include using documentary evidence such as process flow diagrams obtained on site visits from Unitywater and the contracted plant operator and information from prior research at the same sites (e.g. Halliday 2006; Pipe-Martin, Reungoat & Keller 2010; Reungoat et al. 2012a) to check against staff interview data and observational data to reduce observer bias and confirm recorded information.

Each water treatment plant was visited twice, and Unitywater head office visited three times, in order to increase observational opportunities and to reduce potential observer bias, observer-caused effects, and data access limitation (McKinnon 1998). Contact with key Unitywater staff via email and telephone was more frequent to clarify information. This was to enable the researcher to clearly explain the nature of the research, and to build up trust and confidence of participants, and to promote uninhibited interactions. One problem encountered with this approach was that senior central management and accounting staff personnel changed several times during the period of research (although senior operational staff at the sites tended to be consistent). This did however provide a variety of points of view/perspective for comparison. Note-taking used a schema separating Observational notes (ON), – recording facts; Theoretical notes (TN) – researcher's interpretations; and Methodological notes (MN) –strategies for data collection and analysis, in order to highlight any biases (Schatzman & Strauss 1973, pp.99-104; McKinnon 1998).

Interviews – selection and validity

For initial information gathering interviews were held with Unitywater and the external contracted plant operator management and operational staff. These informants were selected based on criteria such as length of service and function. These interviews followed a cascading pattern (Herbohn, 2005), starting with a meeting with the initial Unitywater CEO and senior accountant, with interviewees then providing contacts for other stakeholder interviews. Manager interviewees were selected according to their involvement in cost accounting functions and from areas identified as being necessary for implementation of a full cost TBL approach. This included those involved in data gathering and estimations, operational staff and also those with a role to communicate with stakeholders. Initial interviews were open and exploratory – qualitative survey and observations. Later interviews were semi-structured and sought views on/information about specific aspects but also included opportunities for open non-structured discussion. Interviews were recorded and transcribed verbatim for the observational notes (ON) described above. The views of customer stakeholder respondents were gathered via a survey instrument, selected via sampling techniques. The survey methodology is discussed in more detail in section 3.5.2.

Research design followed techniques suggested by Malhotra (2007) and Patton (2002) regarding preparation of data, survey design, coding and the use of SPSS. These will be explained in the following sections, which are sequenced to flow with the investigation of TBL aspects. The mapping of research methods to research questions is shown in Figure 3.1 (supra).

3.3 Study methodology – stakeholders and systems context

Investigating interactions between stakeholders sheds light on the context in which norms are constructed and the literature review suggested that a stakeholder or network approach was necessary to inform understanding of the social aspect of a TBL approach (Eklington 1998). Identification of stakeholders is necessary for decision-making in order to understand key stakeholders needs and meet these proportionately (Freeman 1984; Dimitriadis 2005).

Stakeholder risk can be ameliorated and trust perceptions improved by transparency and improved information and communication with stakeholders (DEWR 2007; AWRCE 2010a; Lim & Seah 2013) and this may avoid significant political/social costs of opposition (Hurliman & Dolnicar 2010). Stakeholder views may be positively or proactively managed by providing information (Freeman & Liedtka 1997) and organisations can act to promote a new norm (Oels & Zelli 2015). Stripple (2015) used Foucauldian discourse analysis to explain power relationships and the creation of new constructions of self (new behavioural norms) with regards to the issue of carbon emissions. Government can seek to ‘problematize’ carbon emissions as an issue requiring solution and thus shape our conduct/ how we think about the issues and perceptions about appropriate conduct. He highlights three discourses with relation to carbon that form part of climate politics and are changing norms, and which could have parallels in the issue of sustainable use of water:

1) carbon footprinting, on macro and micro level by encouraging self-analysis of habits and comparison to others/other households, and promotes changes in individual actions e.g. length of time in the shower, reduce laundry;
2) carbon dieting, thinking about emissions via the metaphor of a diet, counting emissions like counting calories, again promotes consideration of ethics in a micro day-to-day personalised way;
3) climate fitness, benefits of low carbon lifestyle e.g. biking to work (fitness and money saving);

Changing discourses since the prolonged Queensland drought may well be altering water customer perceptions and is an area of research that has had little attention. Stakeholder identification is also necessary for a system or network approach to analysis (Pattberg & Widerberg 2015). It was important therefore that the stakeholders were part of the same system, again making a case study approach with two case studies from the same local authority organisation ideal.

This theory helped to form the first research question (Figure 3.2), and stakeholder identification was also necessary from a practical standpoint to help identify participants for interviews and survey. It was also helpful in identifying those stakeholders who may be affected by any environmental impacts, so the approach was linked to other aspects of TBL.

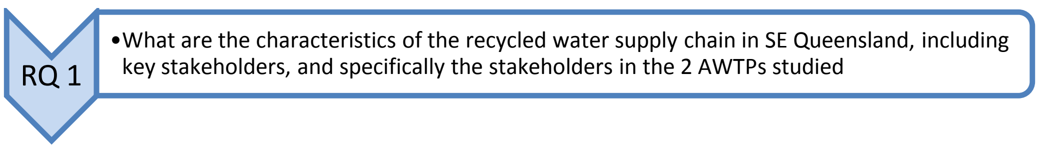


Figure 3.2: Research Question 1

With regard to the first Research Question (Figure 3.2) the supply/value chain of each of the case study water treatment plants (WTPS) was analysed using a stakeholder analysis approach, in order to map the chain and identify components. Information was gathered from a variety of sources including examination of public documents, particularly from Queensland State Government bodies, SEQWater and Unitywater, local press and literature reviews, site visits and interviews with key stakeholders. The resulting interconnections are shown in Figure 4.11.

3.4 Study methodology – economic & environmental aspects

The economic and environmental strands of the TBL approach were examined via the collective instrumental case studies, and by reference to research literature. Site visits were undertaken to establish and map the procedures followed at the treatment plants. This mapping helped to identify how the plants fit into the larger water supply chain in the region. This was accomplished by observation by the researcher and by direct questioning of key staff. This, combined with background academic research and examination of public documents, assisted in identifying key stakeholders. This led to further lines of enquiry and data collection, and helped to inform the customer survey design. This also demonstrates the interactive and flexible nature of a mixed methods research design (Teddlie & Tashakkori 2009). It also allowed a preliminary risk assessment with regards to environmental aspects of the processes, as observation of site efficiency and management quality forms part of an assessment of environmental impact.

This part of the study was most relevant for Research questions 2-5 (Figure 3.3).

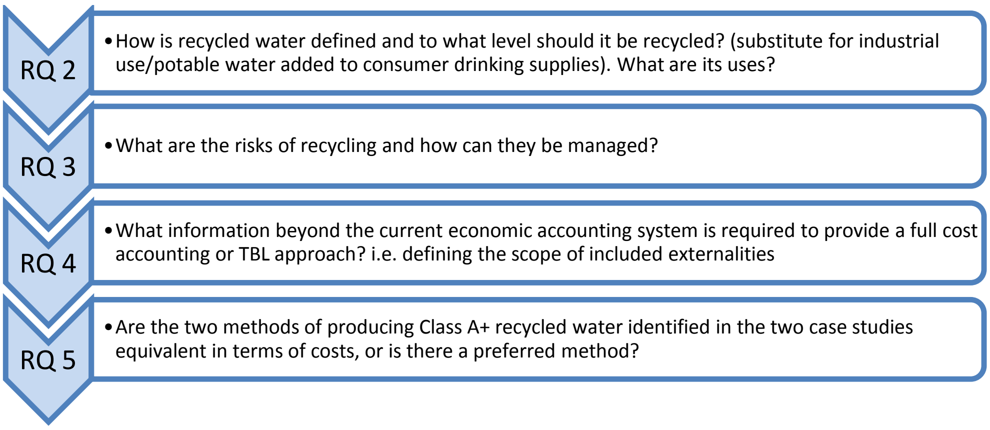


Figure 3.3: Research Questions 2-5

<u>RQ2:</u>

Research of public documents and information from Unitywater obtained via site visits and interviews was used to define what is meant by recycled water in the context of this thesis, and the uses for which class A+ recycled water was permitted (Figure 4.3). An assessment was also made of the research evidence regarding its fitness for these purposes and as a result of interviews (and data obtained via the survey in the social section 3.4 below), some examination of the possible preferred treatment methods/sources for recycled water made. Actual use made of available recycled water was also investigated via the survey instrument.

Examples of Mixed methods triangulation of data to improve validity

RQ3:

Patton (2002, p.248) described how a 'rich variety of methodological combinations can be employed to illuminate an inquiry question' where a study might 'intermix interviewing, observation, and document analysis'. In this mixed methods approach 'different types of data provide cross-data validity checks.' Again this methodology was employed to examine the potential risks of recycled water including environmental risks (and benefits) and potential health risks. Environmental and health risks were assessed by site visits, staff interviews, interviews with the external plant operator and verified by triangulation with other evidence from prior research in this area and other public documents. Examples of external information include information from Healthy Waterways (Figure 4.5) and simplified process diagrams informed by observation, company schematics and prior research (e.g. Figures 4.7 and 4.10). The interactive nature of the research approach was evident in the preparation of material flow diagrams which also provided evidence of stakeholders to inform the stakeholder analysis for RQ1. There is also a social (and political) risk/cost in the sense of willingness to use recycled water and willingness to pay for it. Social risks and risk perceptions are considered via the customer survey and also via interviews (section 3.4 below).

RQ4:

The required data needed to extend accounting to a TBL approach was considered in interviews (and anticipated problems discussed). The environmental aspect was considered via review of previous research and by attempting to apply an Environmental Management Accounting (EMA) approach to the case studies. The EMA technique used was to trace both physical inflows and outflows through the respective recycling plants, to attempt to balance inputs and outputs – or create a material flow balance (Jasch 2009; Deegan 2003; Jones 2009) and to assess the carbon footprints of the plants. This mapped inputs into the processes (effluent from treatment plant; chemical; energy use) and traces physical flows through the system to all outputs, including waste. Non-product output is by definition considered a waste or emission (material; energy; water; gases etc.). Emphasis is on flows considered to have environmental implications (Deegan 2003). Particular note is taken of any so-called ‘greenhouse gases’ covered by the 1997 Kyoto Protocol (e.g. Carbon Dioxide, Methane, Nitrous Oxides, Sulphur Hexafluoride, Perfluorcarbons and Hydrofluorcarbons), resulting from fuel combustion, process reactions and treatment processes. Anticipated problems included the difficulty of ‘splitting’ inputs between processes or functions, and the tendency of most accounting systems to include waste costs as part of a general overhead or indirect cost category (Jasch 2009).

Data gathered from the organisations included:

1. A chemical usage table i.e. details of chemicals used for 2 different but representative months, and for the same time period,
2. Energy/power usage for the same two monthly periods,
3. Flow of influent and effluent volumes through systems for the same two time periods,
4. Selected operational costs of the plants for the same period.

The physical size of the two plants was also considered, although the scope of this research was limited to a carbon footprint of the operational processes at the plant rather than the built structure of the plants themselves. A full assessment of the carbon footprint of the built plants would need to consider the entire life cycle including construction of the built environment (e.g. concrete/steel in construction), and eventual decommissioning, but full information was not available.

Other social and environmental considerations were identified in interviews with plant staff and other local stakeholders, and via the customer survey (see section 3.4). For a comprehension of the AWTP processes site visit information was further researched and verified by comparison to industry publications e.g. the process and results of de-nitrification.

RQ5:

Research question 5 is an application of the collective instrumental case study design (Stake 1995) in that it concerns comparing and contrasting the two processes in terms of full costs and customer attitudes, and asked if the analysis resulted in a preferred method of producing Class A+ recycled water. The TBL economic and environmental aspects were explored by the mixed methods already described. Consideration of the material flow information provided information to consider in assessment of the full costs of the two processes (including externalities) and an assessment of the preferred treatment process for recycled water. Customer preferences were explored via the survey instrument, which directly asked water customers (both users and non-users of recycled water) for their perceptions of and preferences for methods of water recycling, discussed in the methodology for the social aspect in 3.5.

3.5 Study methodology – social aspect

3.5.1 General

<u>Seeking a customer perspective on the RQs</u>

Whilst the previous environmental and economic aspects of the case studies examined the research questions from a practical perspective (e.g. examining actual costs, identifying material flows and environmental risk), perceptions of risk and attitudes were also of interest for the social aspect of the study. This was partly examined via semi-structured interviews, from the perspective of the recycled water provider, but this section considers customer attitudes gathered directly via the use of a customer survey. The aim was to look at a number of the research questions again, but from a different perspective, that of the end user, both actual and prospective, to add the social dimension to the TBL research problem. Research Question 1 requires identification of key stakeholders and their characteristics (Figure 3.2). Clearly customers (both existing and potential) for recycled water are key stakeholders. Research question 2 seeks to identify uses for recycled water (RW) and ask what type of recycled water should be used for these. The previous methods looked at regulations and the science, here RQ2 would have a customer focus. What is RW water actually being used for (and not used for) and why (why not)? What is the customer perspective on appropriate use? Do they value externalities (e.g. environmental concerns) or not? (RQ4). How informed are customers about RW methods and do they express a preference (RQ5)? What risks do they perceive (RQ6)? What factors influence customer acceptance of purified recycled water (PRW) for potable (drinking) use (RQ7). So although research question 6 and 7 are those specifically considering customers perspectives, there is a social dimension to the other research questions and hence they are re-examined via the survey.

Reluctance of water customers to use recycled water, particularly for indirect potable use, has been identified as a key reason for the failure to introduce recycled water by water authorities or governments, with a consequent high level of political risk for policy makers. Unsuccessful attempts to introduce recycled water on a more widespread basis, particularly its use by domestic rather than business customers, have been costly in both political and economic terns in Queensland. Social attitudes have repeatedly stymied attempts to introduce potable recycled water use in Australia. In Queensland the public reaction to one of the earliest attempts to introduce indirect potable water use in 1996 at Caboolture led to the political demise of the then Caboolture Shire Mayor, who supported the proposed project (Uhlmann & Head 2011; Khan 2007). Similarly, the failure in 2006 in Toowoomba to introduce potable recycled water, was in large a result of a lack of public acceptance. Witness also the more recent expense of the Western Corridor Recycled Water Project, online in 2007, originally designed to supplement the potable water supply, but after a State Government back down as a result of public opposition, now supplying three regional power stations. A number of prior studies have identified community attitudes as crucial in the acceptance (or otherwise) of recycled water use (Hurlimann 2007; Marks, Martin & Zadoroznyj 2006 & 2008; Hurlimann & Mckay 2006; Higgins et al. 2002; Po, Kaercher & Nancarrow 2003). The Australian Water Recycling Centre of Excellence (AWRCE 2010a) report noted the lack of research into social factors regarding recycled water supply and the need to inform communication strategies with further research to identify ‘perceptions, acceptance and barriers to the uptake of decentralised recycling systems’ and ‘an assessment of community perceptions towards recycling water schemes’ (p. 7). Social science research in general, and the need to include and to survey stakeholders in particular, has been identified as a water research gap (Jakeman, Letcher & Chen 2007). A lack of confidence in water authorities and governance institutions was cited as one of the barriers to acceptance.

Marsden Jacob Associates (2013) 'identified that the two most prominent barriers to the successful implementation of non-potable recycled water projects have been the relative cost of recycled water compared to other water sources and commercial risk, in particular demand risk' (MJA 2013, p. 4) The identification of risks and attitudes to risk is also relevant for Research Question 3 (Figure 3.4):

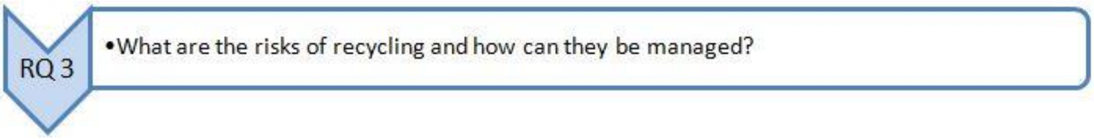


Figure 3.4: Research Question 3

However research question 6 looks specifically at customer attitudes to risks and benefits. Customers attitudes towards recycled water, their views on acceptable uses of recycled water, and their perception of the risk associated with recycled water use are all important factors to understand in planning for water use. The AWRCE (2010a) report also recommended an investigation into how 'different states of water supply security can influence consumer perceptions' (p. 7). This last aspect makes the results of a Queensland based study particularly interesting, as Queensland has suffered in recent years both prolonged, severe drought, and subsequent widespread flooding. Has the drought made customers more prepared to consider the use of recycled water, or has the flood swept any changes in attitude away? Studies have suggested a change in consumer attitudes towards water use, and in actual water use, during the drought years (AAP 2009) that have continued beyond the drought even when water restrictions were relaxed with households continuing to use less water (Beal, Stewart & Huang 2010). Customer perceptions of risks and possible factors relating to acceptance and non-acceptance of recycled water for both non-potable and indirect potable use were explored in the survey instrument and were therefore relevant to research questions 6 and 7 (Figure 3.5).

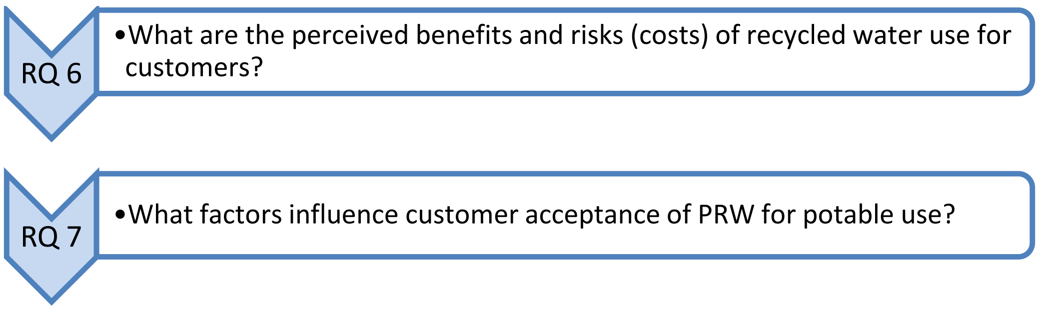


Figure 3.5: Research Questions 6 & 7

Matching customer perceptions regarding the uses of recycled water to provision of recycled water of an appropriate quality (fit for purpose) is also relevant to Research Question 2 (Figure 3.6) in determining definitions of what is meant by 'recycled water' and the methods of recycling currently preferred by customers.

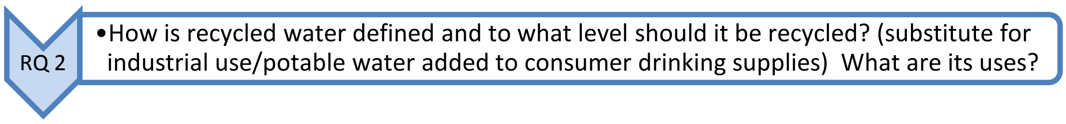


Figure 3.6: Research Question 2

Identifying stakeholder attitudes outside the water authority, and particularly customer attitudes, goes part way to identifying additional information required for informed decision making, beyond a traditional model, as it begins to identify social aspects or externalities that need to be included in the model, relevant to Research question 4 (Figure 3.7):

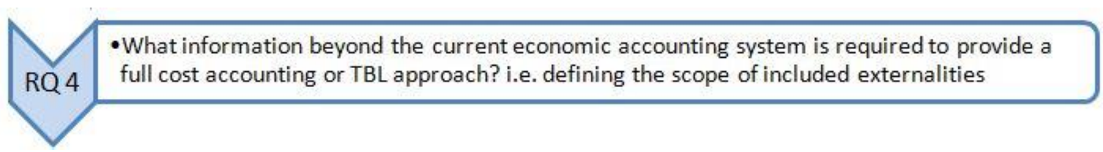


Figure 3.7: Research Question 4

<u>Some scope limitations</u>

For a social aspect therefore it is necessary to investigate customer (and by extension taxpayer/ratepayer) attitudes to water recycling. This thesis has limited the social aspect to this dimension, in order to keep a manageable scope for the study, but it is worth noting that there are other social aspects that could be included. One of these might be the effect on recreational use of waterways in recycled water infrastructure.

At one of the recycling plants in this case study, for example, ‘excess’ class A+ recycled water was regularly re-introduced into the river system which some stakeholders interviewed identified as improving the river quality, which was almost in a stagnant state due to repeated droughts prior to the operation of the plant. It may be possible to identify river users, such as recreational fishermen, who would see an added value to the existence of that recycling plant which has not been included here. As with many other studies on the value of natural resources, it is generally easier to identify costs than to capture the value of all the benefits of a project (Frontier Economics 2011).

Finally, customer attitudes may also be relevant in the comparison of the two methods of recycling used in the case studies, as they may shed light on customer preferences and prejudices regarding the methods used, which would inform policy maker decisions about the political or communication costs of the alternatives. This is relevant to the examination of Research Question 5 (Figure 3.8):

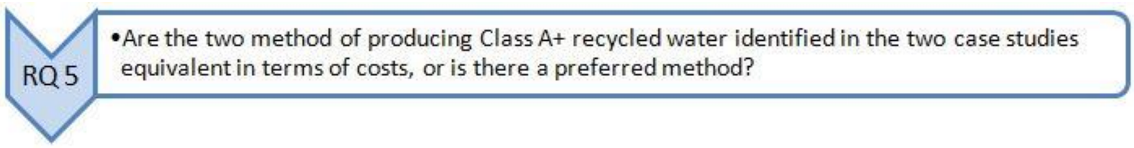


Figure 3.8: Research Question 5

3.5.2 The survey instrument

The survey instrument is provided in full in Appendix A.

Van der Stede, Young, & Chen (2007) identified a 5 point framework for evaluation of good survey design in the following areas:

1. Purpose and design of the survey
2. Population definition and sampling
3. Survey questions and method issues
4. Accuracy of data entry
5. Disclosure and reporting

<u>Purpose and design of the survey</u>

The introduction to the survey included a statement describing the purpose of the survey and the research project objectives and survey was designed with research objectives in mind (Van der Stede, Young, & Chen 2007). Some research questions are descriptive e.g. RQ2 includes identification of the current uses of recycled water, or were intended to gather customer opinions e.g. RQ6 asking what are the perceived benefits and risks (costs) of recycled water use for customers. Other RQs such as RQ7 seek information (What factors influence customer acceptance of PRW for potable use?) but also seek to look for patterns and to examine theories about what may influence attitudes (such as gender, age and level of education). Consequently the survey was intended to be both qualitative and quantitative/statistical in the sense outlined by Jansen (2010) or both descriptive and explanatory in the terminology of Van der Stede, Young, & Chen (2007). This was reflected in question design. For the qualitative/descriptive aspects respondents were given a number of open-ended questions and asked for opinions (open inductive and qualitative survey questions). Many of these questions were seeking new information and were 'open' to allow a range or diversity of opinions. Other questions were more structured with some selected to confirm (or otherwise) evidence from previous research. Quantitative/statistical analysis was used for these types of questions, using scaling, and investigating frequencies and looking for patterns via correlation and factor analysis. However, results of the survey inform the TBL viewpoint by adding a social dimension that is then considered, in conjunction with the other aspects, for a holistic view of the research problem. A design based on research objectives also served to ensure that an appropriate population was selected as the target of the survey.

The survey was in four sections (A-D) with Section A consisting of respondent demographic information, Section B relating to recycled water in general (non-potable), Section C relating to potable (drinking) standard recycled water and Section D related to the pricing of recycled water (both potable and non-potable). As one of the research questions was an examination of appropriate levels of water recycling (RQ2) and others were interested in perceptions of risk and benefits (RQ6) and acceptance of PRW (RQ7), questions about recycled water for non-potable and for potable uses were kept separate, as perceptions and attitudes were expected to be different for the different uses; and also because non-potable use was already in place (and customers could speak from experience) whereas potable use is still hypothetical and has not yet been successfully introduced in Queensland.Section D was included because the price customers are prepared to pay for water in general, and particularly investment in recycled water, has traditionally been much lower than actual cost. Politically it has been difficult to pass on full cost (Hunt & Dunstan 2007; Hunt, Staunton & Dunstan 2013). Recently in Queensland the State government has also met resistance to passing on capital costs relating to replacement of water infrastructure, and relating to new recycled water infrastructure such as the Western Corridor Recycled Water Project and the Tugun desalination plant. Local Queensland councils, water providers/authorities and the State Government have debated the reason for increased water charges in the face of severe community opposition, with the former blaming the increase on bulk water charges (i.e. State government attempts to pass on capital costs) (Tuttiet & Killoran 2011; Wuth 2010; Hurlimann & Dolnicar 2010 (regarding Toowoomba)). The State Government gave the reason for 'mothballing' the new Tugun desalination in 2011 as a move to reduce bulk water charges which was described by the plant operators as putting the plant in 'stand by' thereby 'saving tax payers about $10 million a year' (ABC Gold Coast 2011).

The survey was cross-sectional, an appropriate design for qualitative/descriptive research but a longitudinal study may be more appropriate for the explanatory research aspects (Van der Stede, Young, & Chen 2007). Research into changes in attitudes over time would be helpful is assessing the social aspect of the introduction of recycled potable water, for example, and this study does add a post-drought perspective on earlier research in this area, but further research may be required to assess how long-lasting attitudinal changes may prove.

Table 3.1 provides some examples of the links between areas of interest arising as a result of prior literature (from Chapter 2) and question design in the survey aimed at providing information for the research questions. Table 3.1 is not exhaustive and a number of other issues were also explored, such as satisfaction with the water sources used and desired levels of water quality for various uses. Other aspects explored included respondent attitudes towards water restrictions and the use of PRW in a drought, fixed charges versus usage charges for water, knowledge of water use in electricity generation, and there were a number of open-ended questions inviting respondent comments.

Table 3.1: Examples of links between the literature, survey design, and RQs

Example Issues	Literature	Survey Section/Qu	RQ
Lack of research on water use and sources from a customer perspective	Lane, de Haas & Lant 2012	A8 , B13-14; B22; B30; D35	RQ2 RQ5
Desirability of using a variety of RW sources	Dimitriadis 2005	B16;	RQ2
Lack of research regarding actual levels of recycled water used (as oppose to intentions)	Hurliman, Dolnicar & Meyer 2009	B12; B20-21; B31	RQ2
Factors affecting willingness to use recycled water:			All - RQ6 & 7 and
- public confidence in health issues/perceived health risks	Dimitriadis 2005; Browne et al. 2008; Uhlmann & Head 2011	B27; C29; B31;	RQ3
- trust in the authorities	Dimitriadis 2005; Browne et al. 2008; Mooney & Stenekes 2008; Uhlmann & Head 2011	B27; B31	RQ3
- trust in the science of PRW	Browne et al. 2008; Leviston et al. 2006; Hurliman & Dolnicar 2010; AWRCE 2010a;	B27; B31;	RQ3
- trust in climate science/attitudes to climate change	Oreskes & Conway 2010; University of Queensland 2014a	A9-11; B27; B31; D32	RQ4
- previous use of PRW	Dimitriadis 2005; Hurliman & McKay 2006; MJA 2014b	B17; B19; B23	
- adequate information about PRW	Nancarrow et al. 2007; Miller & Buys 2008; Hasham 2012; MJA 2014b	B16; B31; D32	RQ3
- media influence	Hurliman & Dolnicar 2010; Lim & Seah 2013	B31;	RQ3
- pricing, particularly if traditional sources under-priced	Dimitriadis 2005	B27; D32-34	RQ3
- closeness of the personal contact to the PRW	Mooney & Stenekes 2008	B25; C29	
Evidence of perceived additional value of PRW:			RQ6 & 7 and
- willingness to pay a premium for properties with PRW	MJA 2014a	B27	RQ3 RQ4
Perceptions (e.g. willingness to pay and acceptance of PRW) influenced by demographics e.g. gender, age	Hurliman & McKay 2006; Mooney & Stenekes 2008; MJA 2014b	A1-7: used for analysis of influence	RQ7

Population definition and sampling and external validity

The sample selection was in one sense purposeful in as much as the opinions of customers already using recycled water were sought (Patton 2002), and to this end Unitywater was asked to provide their full customer list of *all* customers billed for recycled water use (the majority being customers of their dual reticulation or 'purple pipe' schemes). This was therefore an homogeneous group (as all respondents should be using recycled water or at least have such water available for use), and a survey of the entire population rather than a random sample. In practice not all customers included on the recycled water customer list supplied by the water authority (759/917) were sent the survey instrument. The aim was to include all relevant respondents in the population, but exclude inappropriate respondents. Respondents needed to be actual customers for recycled water, and therefore customer accounts relating to landlords not residing in a property in the target area, or agents such as real estate agents/trustees (and therefore not using dual pipe recycled water system themselves) were excluded.

A control sample (434 residents) was selected from customers in the same geographical region who were not on the list of recycled water customers, as the researcher was also interested to investigate earlier research findings that indicated that customers already using recycled water for one purpose were more open to its use generally and may be more accepting of the use of recycled water for indirect potable purposes. This second sample was selected by picking names and addresses from the region's white pages directory. As the total population was unknown, and the selection was done manually, this was not a truly random selection. However an attempt was made to randomise the selection as far as possible by starting with a random page in the 'A' section and then moving a set number of pages on each time to get a section from throughout the book. Once a page was selected, the researcher then chose the first listing (reading alternatively from the top and the bottom of the page) which was in the correct geographical region (i.e. the same water authority as the recycled water customers).

Survey questions and method issues & internal validity

The survey instrument was developed with reference to prior research surveys in this area, particularly work done with Mawson Lakes dual reticulation customers (Hurlimann & McKay 2006). Other questions were selected in response to discussion with Unitywater management. A preliminary draft was tested on a small sample of the researcher's colleagues at USQ and some changes were made to refine the instrument, particularly in regard to format, in response to feedback from this. A variety of question formats were used, from 'yes/no' questions, to more open-ended questions designed to elicit respondents' views on particular aspects (qualitative for more in-depth inquiry (Patton 2002)), to 5 point Likert scales (Agree to disagree) (quantitative use of standardised question (Patton 2002) to aid comparison and analysis of responses). This mixed methods approach aids triangulation of results to check for consistency. As a further internal validity check several of the questions were repeated with slightly different phrasing to enable analysis to ascertain whether the same respondents were answering questions consistently.

Response rates

The survey was longer and more complex than most postal surveys. This made it likely to have a low response rate. Following Edwards et al. (2002) to improve the responses care was taken over the survey appearance, such as using colour and graphics. It was also made clear that it was a university research instrument (and not from Unitywater), as this was seen likely to elicit a higher response than a commercial survey. As the survey was being sent from a customer list (for dual reticulation customers) or from names from the telephone book, it was possible to personalise the envelopes for the surveys by including the householder's name. Reply paid and addressed return envelopes were also used for ease of response. Unfortunately research budget constraints were such that it was not possible for such a large survey to undertake a second mail-out, neither was it possible to offer every respondent a non-conditional monetary incentive, even though Edwards et al. (2002) demonstrated this to be most effective method. However a reward was offered in terms of a prize draw consisting of two $100 shopping vouchers offered to respondents who wished to give their details to enter into the draw. Winners were selected using random numbers generated online by Random.Org (http://www.random.org). The surveys themselves were otherwise anonymous, to reduce social desirability bias (Zikmund et al. 2013). The survey was designed so that it could be answered either in paper format or respondents could choose to follow a link to an identical electronic version hosted by Surveymonkey.

The survey resulted in 129 responses. This was a low response rate at 11% (see 5.2.2 for greater detail), as expected with a lengthy mail survey. Although non-response bias is less of an issue with a sample of individuals rather than organisations, as being less likely to reflect self-selection bias (Van der Stede, Young, & Chen 2007), it is still a concern, as it questions the representativeness of sample. In an effort to ascertain the respondent sample's representativeness of the population the demographic statistics of the respondents were compared to the 2011 census data for Caboolture. The sample did appear to be generally representative of the population (see 5.2.3.1 for details), with the exception of education levels which were higher for the survey respondents than average for the area (MBRC 2015). The effect of education was therefore investigated in the survey analysis, but there was no consistent evidence that it played a part in key responses.

Accuracy of data entry & Disclosure and reporting

All (anonymous) surveys were numbered on receipt and the results entered question by question in SPSS, including written responses to open questions, so that all responses were in one data set. Answers were coded and a number of steps taken to ensure accuracy of data entry. Methods included selection of 2 random samples of 10 responses (randomly selected using the numbers 1-129) being selected and checked by a colleague of the researcher. The researcher also scanned all answers visually checking for anomalies (e.g. only values 0 and 1 in columns for coded yes or no questions). Inconsistencies in answers were also checked with reference back to the original survey document e.g. if the number of members stated in the household did not match the break-down given in age ranges. All 129 responses were usable, although for some questions the sample size was slightly less, if data was missing for that question, for example if a respondent declined to answer. Sample sizes are clearly disclosed for each result. The full survey instrument is included in this thesis as Appendix A.

3.6 Ethical considerations

As this research included human participants ethical approval was sought and received following the University of Southern Queensland ethics procedures.

Regarding site visits all observations on site were overt and followed usual site visitor protocols. Consent for visits and participation of staff was obtained from Unitywater. All participants in interviews were advised that their participation was confidential and voluntary and were given a pre-approved USQ Participant Information Sheet outlining the nature of the research and procedures, information regarding confidentiality/voluntary participation and giving the name and contact details of the researcher and the Ethical and the USQ Research Integrity Officer, should they have any queries or concerns.

The survey instrument was anonymous and participants were not personally identified. A USQ Participant Information Sheet was included in each mail out (and was included in the online version). Consent was inferred from a respondent's participation/completion of the survey. The only personal identification information obtained was from those participants wishing to be included in the prize draw, and the information was detached from the questionnaire and used only for the purposes of the draw.

3.7 Conclusion

This methodology chapter described the inductive approach of this research and the motivations behind this and the mixed methodology used to explore the three aspects of the Triple Bottom Line model. This included consideration of appropriate research design, sampling, validity and ethics. The following Chapters 4 and 5 report in turn the results of various methods used, first the site visits and related research and then the survey instrument, linking the results to the research questions at the end of each section and in the concluding section of Chapter 5 to the overall model.

4. Results – economic, environmental & stakeholders

4.1 Introduction

This thesis concentrates on a Triple Bottom Line (TBL) approach (economic, environmental and social aspects) to the costing of recycled water, via two case studies of advanced water treatment plants, both treating secondary effluent to sufficient standard for release into surface waters by producing Class A+ recycled water in South East Queensland (SEQ). The research problem asks 'how' to build a TBL model, so the approach to obtaining information with which to build a TBL model for costing an A+ recycled water facility, is as important as the end model in answering the research problem (RP1):

RP 1

- **How can a triple bottom line approach be used to provide a costing model for the full cost of Class A+ recycled water for use in South East Queensland?**

(extract from **Figure 1.2**)

In order to investigate different aspects of the model site visits and interviews were undertaken, stakeholder analysis completed and a literature review carried out to confirm/supplement observations. These results are reported in this Chapter 4. In order to investigate customer perceptions a survey of all recycled water customers for the non-potable recycled water supplied from South Caboolture Water Reclamation Plant, and of a sample of water customers with properties in the same area not supplied with recycled water, was conducted. Chapter 5 reports the results for the customer perspective survey.

The results section reports in turn the results of various methods used, first the site visits and related research and then the survey instrument. This approach is taken to help answer the 'how' part of RP1, as methods for gathering 'non-traditional' accounting information and problems encountered in that journey, shed light on the approach to creating a TBL model. The results are linked to the research questions at the end of each section and in the concluding section of Chapter 5 this is linked to the overall model.

4.2 Overview

Contact was made initially with Moreton Bay Regional Council in 2009 with a view to using recycled water use in the Council area as a basis for a study on recycled water costing. Initial research had identified two water assets then controlled by Moreton Bay Regional Council – South Caboolture Water Reclamation Plant (SCWRP) and the Advanced Water Treatment Plant at Murrumba Downs (MDAWTP) – as potential case studies. The first meeting was held in March 2010, and as they were 'currently charging Class A+ at the short run marginal cost not including any externalities' (2010, pers. comm., 19 March) a full cost model was of interest, as was a comparison between the two plants. There followed two site visits each to the two treatment plants, and four visits to Unitywater's head office. These visits included guided tours of the plants (during one of which the researcher was accompanied by an environmental engineer for advice about risk assessment) and interviews with management and staff between March 2010 and 2012. A survey of customers was conducted in late 2012. The interviews and visits will be referred to in the relevant sections of the results and helped to identify stakeholders and relevant issues. All participants will remain anonymous, however, and only the date of the interview is given.

The first and persistent difficulty with the conduct of the research was the constant state of flux in the industry over this period. This was true both at the State level with restructuring and significant changes of policy, but also as it directly affected management of the two plants. Initially the water assets were controlled by Moreton Bay Regional Council, but following the establishment of the new South East Queensland (SEQ) Water Grid (see supra pp.35-38 and Figure 2.2) under the state government South-East Queensland Water (Distribution and Retail Restructuring) Act 2009, responsibility was transferred to Unitywater. This is the statutory authority for northern SE Queensland, owned by Moreton Bay and Sunshine Coast regional councils, but directed by an independent board (appointed by the councils) and officially began trading on 1 July 2010. A map of the region serviced by Unitywater is presented in figure 4.1.

Source Unitywater 2014, *Map of region*, viewed 25 May 21014, http://www.unitywater.com.au/Map-of-Region.aspx

Figure 4.1 Map of region serviced by Unitywater - May 2014

The two advanced water treatment plants are located in the Caboolture River catchment (SCWRP) and the Pine Rivers catchment area (MDAWTP). For an overview of the regional catchment areas see Figure 4.2.

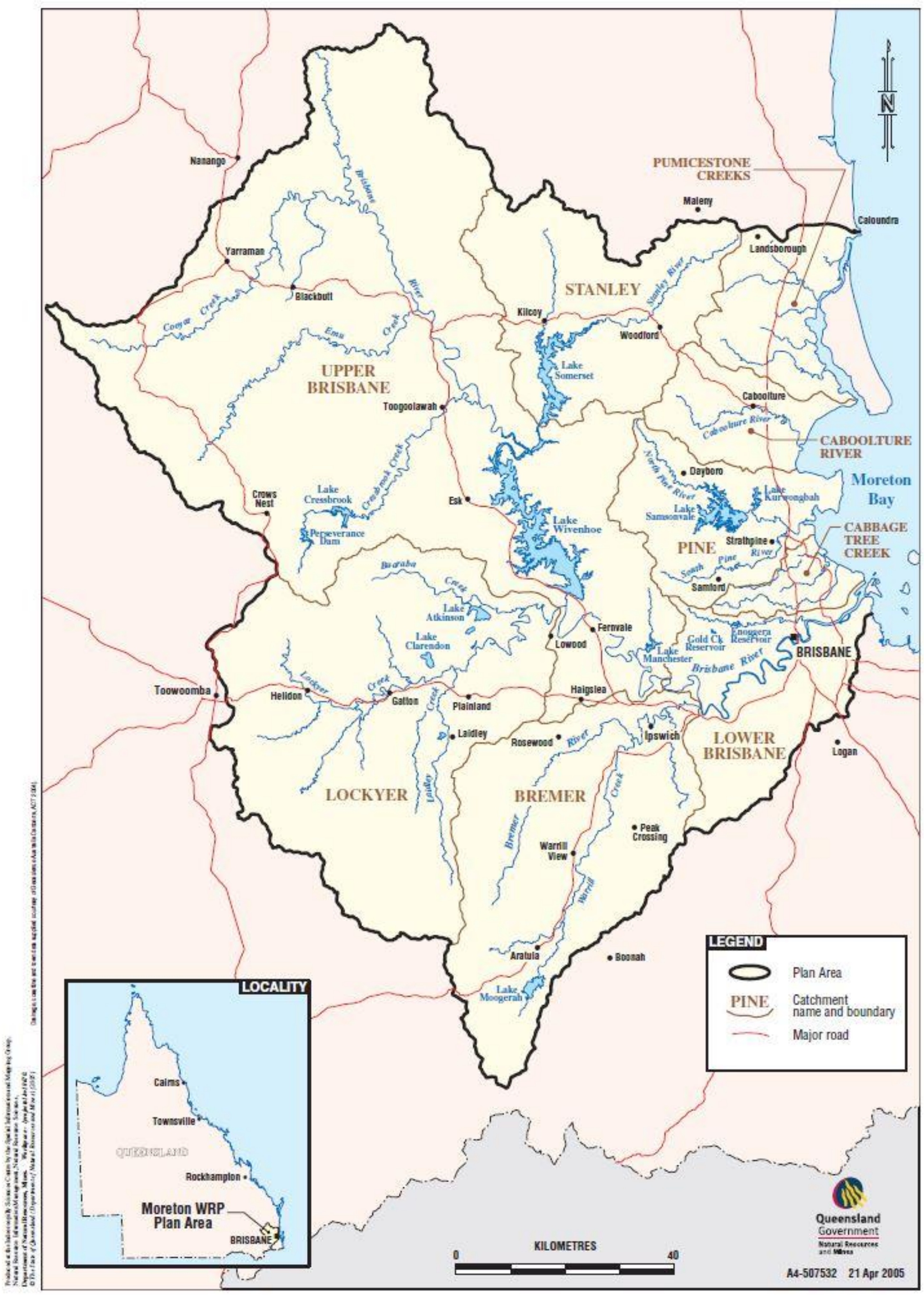


Figure 4.2 Overview of catchments in SEQWater/Moreton area- (Department of Natural Resources and Mines 2005)

As a starting point the 'product' recycled water needed to be defined for the context of this thesis. Both plants produced water classified as Class A+ purified recycled water. Class A+ Recycled water is defined as water that has been treated and disinfected to a level sufficient to look and smell like drinking water. The quality of Class A+ is such that it meets or exceeds Australian Drinking Water Guidelines Limits in a number of key respects, although quality may degrade during distribution or storage. The water is treated and disinfected and meets State Government’s Environmental Protection quality guidelines, but is not approved as potable (drinking) water, or for use in swimming pools or spas, and is separately identified by labelled lilac pipe work (Moreton Bay Regional Council 2010a) .

The permitted uses of the grades of water in Queensland are summarised in Figure 4.3 below (Unitywater 2014b p.1):

Suitable uses for recycled water

Suitable uses	Class A+	Class A	Class B	Class C
Irrigation of residential gardens and lawns – spray irrigation	√	X	X	X
Irrigation of residential gardens and lawns – sub surface	√	√	X	X
Dust suppression, compaction	√	√	√	X
Watering parks, playing fields, footpaths and roadside plants with minimal controls	√	X	X	X
Watering parks, playing fields, footpaths and roadside plants with controlled spray drift and restricted irrigation hours (spray irrigation) or sub surface irrigation	√	√	√	X
Watering parks, playing fields, turf farms, golf courses with controlled access and restricted irrigation hours	√	√	√	√
Filling fenced ponds, lagoons and dams (not used for recreational purposes)	√	√	X	X
Filling non-fenced ponds, lagoons and dams (not used for recreational purposes)	√	X	X	X
Road works	√	√	√	X
Washing cars	√	X	X	X
Washing animals (except pigs)	√	X	X	X
Hydraulic testing of sewer infrastructure	√	√	√	√
Irrigation of landscaping on construction sites	√	√	√	X
Filling or topping up of swimming pools – not allowed	X	X	X	X
Filling or topping up of residential “non-drinking water” rainwater tanks - not allowed	X	X	X	X

*The suitable use of Class D recycled water is determined on a case by case basis

Legend: ✓ the listed class of recycled water is suitable for this use.
X the listed class of recycled water is NOT suitable for this use.

Figure 4.3 Permitted uses for grades of recycled water – Unitywater 2014

Note: At the time of the distribution of the survey instrument, Class A+ recycled water was approved for ‘Filling or topping up of residential “non-drinking water” rainwater tanks’ (Unitywater 2010a, p.1)

Currently A+ is the highest grade of recycled water and is used for all non-potable, low-contact purposes. As can be seen from Figure 4.3, other classes of water are also permitted for some of these functions. This is relevant to Research Question 2 (Figure 3.6) in defining recycled water and assessing the level of recycling fit for various uses, and it establishes that current non- potable Class A+ water is acceptable as a potable water substitute for most low contact uses.

RQ 2

- How is recycled water defined and to what level should it be recycled? (substitute for industrial use/potable water added to consumer drinking supplies) What are its uses?

There are a variety of grades of recycled water and, although both plants in the case study produced class A+, most treatment plants in the region also provide other classes of water via delivery points where they may be collected by customers (generally commercial users). Residential customers in estates built with this facility have class A+ recycled water delivered via a dual reticulation system. Customer perspectives on ‘fit for purpose’ use of recycled water were explored via interviews, research and direct customer survey.

In 2010 UnityWater provided a comparison on key qualities between recycled water types, presented in Figure 4.4 (Unitywater 2010a p.3):

Parameters Average Values	South Caboolture Class A+	Bribie Island Class A	Woodford Class A	Brendale Class B	Murrumba Downs Class B	Maroochydore STP Class A	Landsborough STP Class A	Nambour STP Class B	Suncoast STP Class B	Coolum STP Class B	Kawana STP Class B
pH	7.16	7.42	7.35	6-8.5	6-8.5	7.3	7.4	7.6	7.3	7.9	7.1
Conductivity (us/cm)	967	1563	724			1207	511	678	898	680	742
Total Dissolved Solids (mg/L)	655	1050	485	< 1000	< 1000	845	358	475	629	476	520
Turbidity (NTU)[1]	0.08	0.5	0.9	< 3	< 3	1.6	1	2.2	2	1	2.2
Suspended Solids (mg/L)	1.5	2.7	2.5	<15	<15	4.5	4	5.4	10	4	3.5
Total Nitrogen (mg/L)	<1.0	2.2	4.6			2.6	3	7	5	4	3.5
Total Phosphorus (mg/L)	<0.02	0.38	1.09	< 2.0	< 2.0	0.2	3	1.4	2	1	4.8
E.coli (orgs /100mL [2]	<1	0 (median value)	0 (median value)	< 100	< 100	<10	<10	<100	<100	<100	<100
Bacteriophage	Not detected					N/a	N/a	N/a	N/a	N/a	N/a

1. Final effluent

2. Median value of 5 samples taken in a single day

pH – Indicates the extent to which it is acidic or alkaline
Conductivity (us/cm) – Helps estimate dissolved salt content
Total Dissolved Solids (mg/L) – Measures dissolved solids content
Turbidity (NTU) - Measures cloudiness of water
Suspended Solids (mg/L) - Measure of suspended material in water
Total Nitrogen (mg/L) - Nitrogen is a nutrient and can be stored in the soil or taken up by the plant
Total Phosphorus (mg/L) - Phosphorus is a nutrient and can be stored in the soil or taken up by the plant
E.coli (orgs /100mL) - Indicator bacteria for assessing the microbiological quality and safety of water
Bacteriophage - Indicators for the presence of enteric viruses in water (PFU/100mL)

Figure 4.4 Comparison of qualities of recycled water products –Unitywater 2010

4.3 Preliminary background research, site visits & stakeholders

4.3.1 Background & Processes at the AWTPs

The first Advanced Water Treatment Plant (AWTP) in the study was located at Morayfield, South Caboolture. The South Caboolture Water Reclamation Plant (SCWRP) treated secondary effluent to sufficient standard for release into surface waters (class A+). There was a six-stage process with a key process being the use of Biologically Activated Carbon (BAC).

The second AWTP in the study was located at Murrumba Downs (MD). Murrumba AWTP also treated secondary effluent to class A+ standard and would require only relatively minor upgrades to the treatment for the water to be considered potable standard. As with SCWRP, there is a multi-stage treatment process, with the building completed at the AWTP in 2008, and the key process being Reverse Osmosis (RO), in contrast to the BAC process at South Caboolture. This process is broadly similar to that used by the Western Corridor Recycled Water Project, which was designed for indirect potable water use via Wivenhoe dam.

Both plants were relatively self-contained in as much as they were located on dedicated sites adjacent to their feeder Sewage Treatment Plant from which they received their secondary treated effluent as the starting input to their processes. As such their initial input was similar (residential waste with a minority mix of trade or industrial waste). For the purposes of this study it was assumed that the output was also similar, with both producing recycled water rated Class A+, just falling short of direct potable water drinking standards.

4.3.2 South Caboolture Water Reclamation Plant (SCWRP)

This study assumes that the water quality from both treatment plants was broadly comparable, being classified as Class A+. Whilst this is not a scientific paper, some justification of this view is perhaps required.

The South Caboolture Water Reclamation Plant treated secondary effluent to sufficient standard for release into surface waters (class A+). There was a six-stage process: denitrification, pre-ozonation, coagulation/flocculation/dissolved air flotation and filtration (DAF), main ozonation, activated carbon filtration and final disinfecting ozonation, as analysed in a 2010 case study of the South Caboolture Water Reclamation Plant (Reungoat et al. 2010a). Reungoat el al. (2010a) found that the coagulation/flocculation/DAF, main ozonation and activated carbon filtration processes were the keys to the plant's performance. The study monitored for the occurrence of 85 compounds of potential micropollutants (pharmaceuticals and pesticides) in order to assess the effectiveness of their reduction and of the reduction in biological activity and found a 90% concentration reduction and reduced biological activity ranging from 62% (AhR response) -99% (estrogenicity) depending on the response being assessed. The study noted that: 'Whilst the plant provides water for non-potable applications, it has been designed to meet drinking water standards' (Reungoat et al. 2010a, p. 626). The results indicated that under the parameters of the Australian Guidelines for Water Recycling: Augmentation of Drinking Water Supplies the plant produced water several orders of magnitude below the guideline values. It should be noted, however, that the then Australian Drinking Water Guidelines (ADWG) (2004) were revised in 2011. The ADWG addresses both the health-based and aesthetic drinking water quality aspects.

A further study (Pipe-Martin, Reungoat & Keller 2010) found that Biologically Activated Carbon (BAC) was a considerably more efficient filtration method for the removal of dissolved organic compounds (DOC) than sand filters. Sand filters were useful for biological degradation of specific compounds such as cyanobacterial toxins, and therefore a two-stage sand-BAC filter was most effective. Improvements in the process also included pre-treatment with alum coagulation and Dissolved Air Flotation/Filtration and Ozonation. Aeration was important as the oxygen consumption in the filters was high.

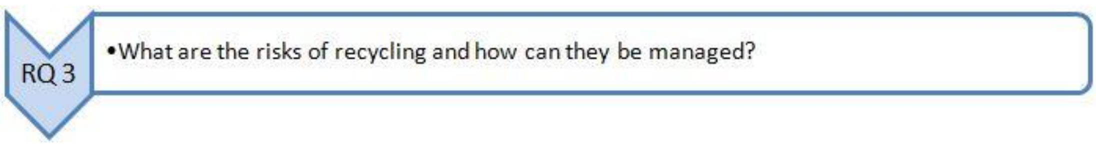
> Slow flow BAC treatment appears to be an extremely effective means of removing micropollutants from water, even without the ozone pre-treatment. (Pipe-Martin, Reungoat & Keller 2010, p. 4)

Reungoat et al. (2010a) concluded that further analysis of risk management, the effects of mixed compounds (as they were analysed singly) and the removal of pathogens such as viruses and bacteria would be required in considering its use for indirect potable water reuse. However the results suggest 'that such a treatment train could be considered as an alternative to the combination of microfiltration and reverse osmosis for indirect potable reuse schemes. It has the advantage of not producing a waste stream and would certainly be less energy intensive' (p. 635).

Further studies to date have continued to indicate that BAC/ozone systems are capable of similar water quality to alternative systems (Gerrity et al. 2014; Reungoat et al. 2012b). There is arguably a social value in the innovative nature of an ozone/BAC treatment stream as used at Caboolture in the pursuit of a sustainable option for potable water re-use and scientific studies of the efficacy and applications of this technology are ongoing (Gerrity et al. 2015; 2014).

The effectiveness or otherwise of the particular treatment process is relevant to the actual risk of recycled water – health risk - which may differ from the perceived risk. Ozone-based potable reuse treatment trains have been used without reported adverse health effects in the United States (particularly California) (Gerrity et al. 2015).

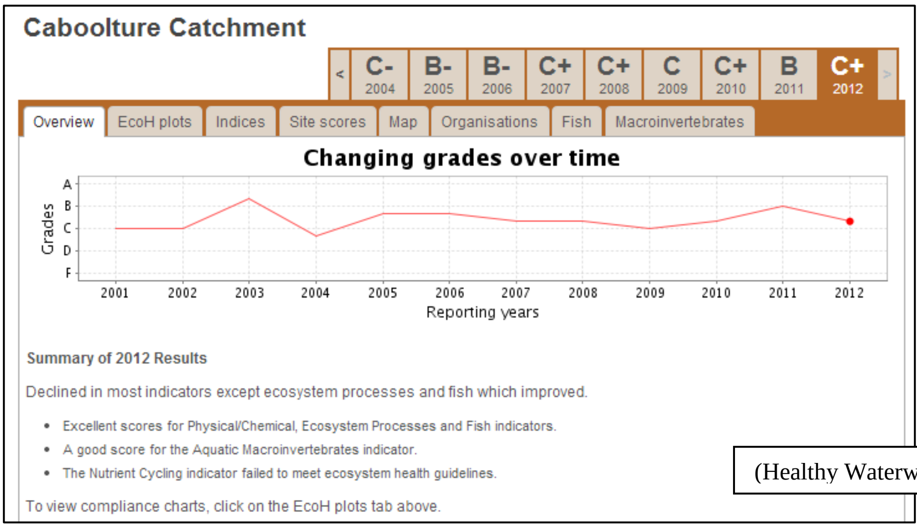
These are aspects of Research Question 3 (Figure 3.4) regarding the identification of risks of recycling water.



The combination of BAC/Ozone Environmental risk is also relevant here if this process has less of an environmental impact in terms of waste and carbon footprint (due to lower energy consumption than alternatives (Gerrity 2015). This also has relevance to research questions 4 (environmental benefits) and 5 (preferred method).

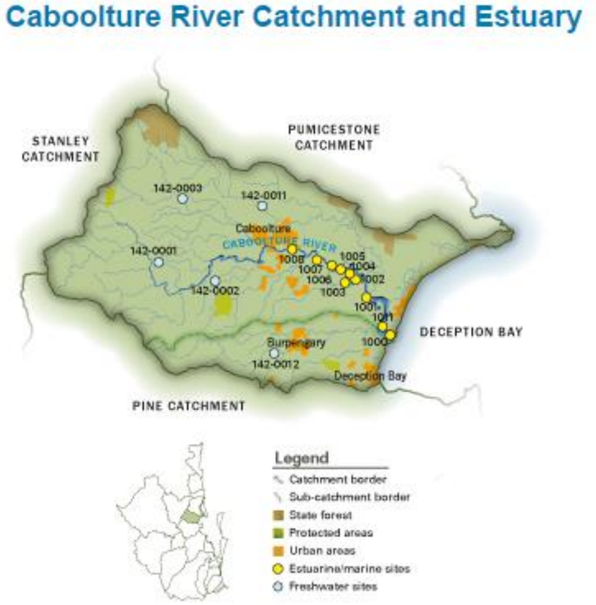
Commissioning, Capacity & Catchment

SCWRP was commissioned in 2010 to produce water of sufficient quality to be discharged to river, at a time when the primary water treatment plant (WTP) effluent was negatively influencing Caboolture river water quality. The water was intended for indirect potable use due to concerns regarding the adequacy of potable water supply from the weir and the pressures of a growing population (Moreton Bay Regional Council (MBRC) 2010). The health of the Caboolture River has been of ongoing concern since a SEQ rating of ‘F’ (the lowest possible) in 2008 for the Caboolture estuary, ‘largely due to the elevated nutrients, high levels of phytoplankton and low dissolved oxygen in the estuary system’ (Moreton Bay Regional Council (MBRC) 2013). The Moreton Bay Regional Council has a current ‘river recovery plan’ in which treatment plant upgrades play a part (MBRC 2013). The Caboolture catchment area was rated C+ but the estuary D- in 2012, and it was noted that two WWTPs discharge into the river (Healthy Waterways 2013a). In 2013 ratings improved to C+ for the Caboolture catchment and D for Caboolture Estuary. Healthy Waterways’ explanations for the poor grading of Caboolture Catchment and Estuary are shown below in figures 4.5 and 4.6 respectively.



(Healthy Waterways 2013b)

Figure 4.5 Explanation for grading of C+ for Caboolture Catchment in 2012



(Healthy Waterways 2013a)

Catchment Facts

- Total area: 468km^2
- Stream network length: 795km
- Local Councils: Moreton Bay Regional Council
- Dominant land uses: native bush, grazing, rural residential, urban, poultry farms, strawberry and pineapple farms
- Upper catchment includes the undisturbed streams in the D'Aguilar National Park
- The mid and upper catchment is characterised mostly by agricultural and rural residential areas
- Two WWTPs discharge into the Caboolture River

Freshwater results

C+ C Caboolture Catchment

- Streams generally in fair condition with an increase in nutrient cycling offset by a decrease in ecosystem processes.

Estuarine results

D D- Caboolture Estuary

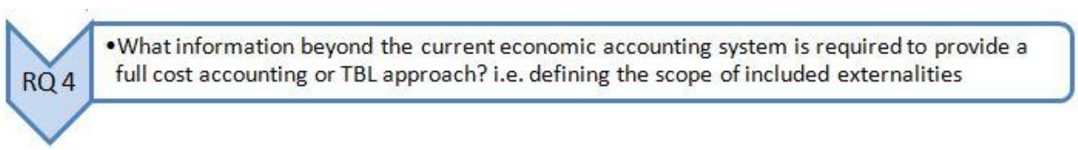
- Continued high nutrient and phytoplankton concentrations.
- Increased dissolved oxygen concentration, small decrease in turbidity and increased sewage nitrogen signal.

Figure 4.6 Caboolture River catchment and estuary in 2013(Healthy Waterways 2013a)

Historically the emphasis of environmental concerns regarding wastewater treatment has been on river and estuarine environmental protection, in part as a reaction to legislative requirements. This does suggest that planning considerations have always included externalities that relate to public wellbeing. Both the AWTPs examined in this thesis discharge to a river catchment (rather than offshore) and therefore have a direct bearing on a variety of stakeholders using the river for recreational and business purposes, as well as residential property owners, and on health risk. The cost of failure and non-compliance for the community is therefore high.

SCWRP capacity was as much as 10-14 megalitres per day (ML/d) but averaging 7-10 ML/d and discharge 1-1.5ML/d. (Unitywater staff 2010, pers. comm., 24 June), This is consistent with Lane, de Haas & Lant 2012 p. 2 (7.5 ML/d). The actual uptake by customers via dual reticulation system to residential and by collection for industrial use was approximately 2 ML/d (Lane, de Haas & Lant 2012). The plant was therefore underutilised in terms of commercial customers, but this is using conventional commercial assessment, not considering externalities. There is an environmental benefit to the river system in terms of both increased flows and reduction in low quality effluent which protects the river from nutrient build up and consequences such as algal growth (which was the original motivation for the upgrade). This is of value to the local environment (and possible recreational use) as the river below Caboolture Weir has suffered in the past from limited fresh water flow. Similar to the problem outlined in MJA 2013, identifying the extent of any improvement in the catchment that is related to a particular cause (or indeed the degradation of the same), when there are multiple users of the catchment and a complex natural ecosystem, is problematic. However as part of the suite of improvements introduced in the river recovery plan the improvement in water treatment has value.

This would suggest that an important externality not captured by a traditional economic model is the health of the natural waterways and the benefit of this to residents and both recreational and business users of the waterway, which is a relevant consideration for research question 4 (Figure 3.7) in ascertaining necessary information for full costing not captured by the traditional economic aspect of accounting systems. Traditional economic measures include those prepared for external financial reporting according to mandatory accounting standards, as represented in published income statements and balance sheets. The potential benefit of a healthy waterway includes use and non-use components: downstream users and residents local to the Caboolture River catchment have improved recreational and social uses and other customers & stakeholders not using the Caboolture River may still value lack of environmental degradation. Attempts to measure this include examination of a willingness to pay for non-use (MJA 2014b survey of Sydney non-potable customers). The practice of putting an economic cost on a subjective value has been criticised for likely underestimation, but it does suggest a minimum, and the lack of a precise economic value should not preclude qualitative information from consideration in decision-making and policy.



Demand in the area for potable water (as opposed to non-potable recycled water) currently exceeds local supply. According to Lane & Lant 2012a, the 3.6 GL/y from Caboolture Weir was fully utilised, and approximately 11GL/y of potable water was imported from SEQ Water Supply Grid (Lane & Lant 2012a Table 3 p.7) and this is an area of expected high population growth. It seems that the original motivation for augmenting the local potable water supply, or reducing demand on existing potable supplies, remains. The avoided cost of importing water (which is expensive to transport) or of developing other potentially costly water supply alternatives (such as desalination) in the long term, is therefore a relevant consideration in any policy decision regarding recycled water use. The costing of these alternatives is beyond the scope of this study, except as a reference point for the likely cost of the next best alternative e.g. replacing current recycled water with additional water sources from a desalination plant or from water transported long distance is likely to be more expensive than recycling the water in situ.

Overview of process & initial risk assessment

The plant was run using a programmable logic controller (PLC), with a supervisory control and data acquisition (SCADA) system (Unitywater staff 2010, pers. comm., 24 June; observation). There were multiple test points for water quality throughout the system, and regular flow meters, and the site was clean and well maintained. Efficient management and operation of a facility should not be understated, as one element of (human and environmental) risk is management error. The potential for error is increased at times of change and restructuring, and research has indicated that integration of technologies during such change can be problematic and cause errors. Potential problems in the Queensland bulk water distribution, following amalgamations, were identified with non-integrated SCADA systems in previous research (Cloete, Horberry & Head 2011 & 2012). This was found to be much less likely to occur at a recently commissioned AWTP with a highly automated stand-alone SCADA system (Cloete, Horberry & Head 2012). However human risk assessment and management remains essential, as demonstrated by the *E. coli* contamination in Walkerton, Ontario in 2000 from farm runoff which was largely the result of human error and subsequent cover-up (Wu et al.2009). Human error was also a contributing factor in excess fluoride entering the North Pine Dam in Queensland in 2009 when a water treatment plant was shut for maintenance (Fraser 2009; Cloete, Horberry & Head 2012), and also in the spillage of treated sewage and industrial effluent as a result of faulty valves at Bundamba AWTP in 2008 (Roberts 2009). The Bundamba incident was not disclosed until 2009, fuelling public fears about lack of trust. Public perceptions regarding trust in water authorities, and fear of human health risk are examined in the social aspect of this thesis. This is a consideration relevant to Research Question 3.

RQ 3 •What are the risks of recycling and how can they be managed?

The input of the SCWRP was the secondary treated effluent pumped (2 pumps) from the adjoining STP, and was high in nitrates, as a result of treatment of ammonia in the STP. Some customers may prefer lower quality water – with nitrates – for agricultural use (2010 pers. comm, 24 June) although Lane, de Haas & Lant (2012) note that agricultural use may transfer environmental issues associated with nitrate release to other locations in the water cycle.

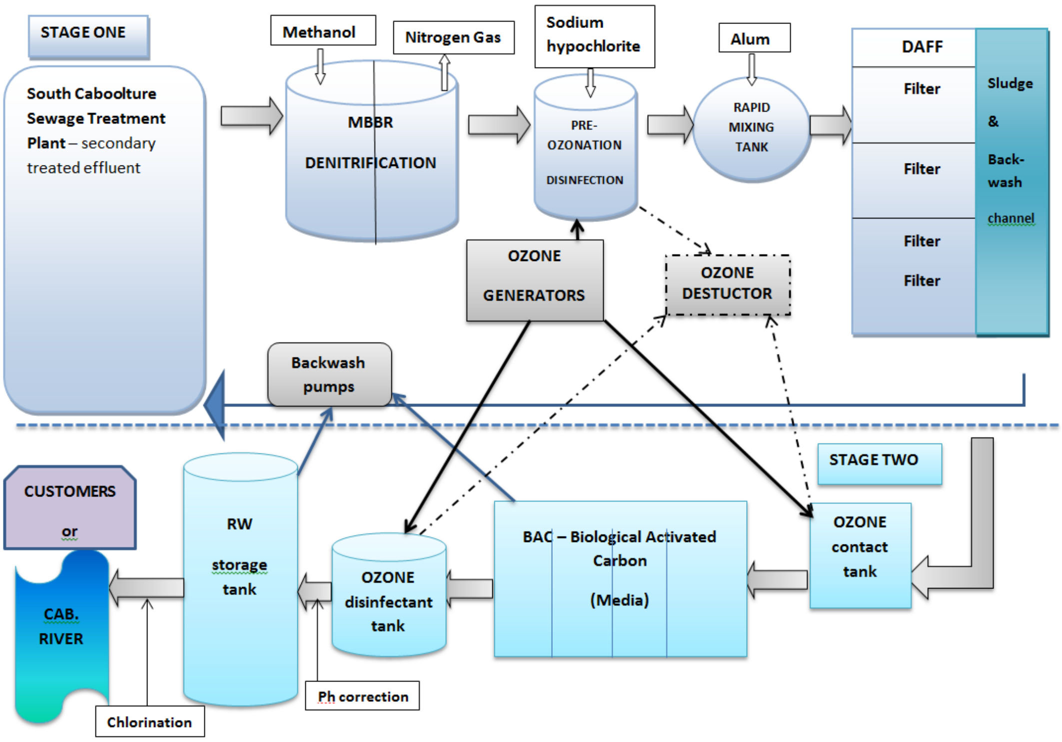
The effluent was primarily residential in origin with approximately 4% trade waste (2010 pers. comm., 24 June). The SCWRP plant had two stages to the processing. The first could be run independently and was designed to improve the water quality for any release to the river (Lane, de Haas & Lant 2012). This stage consisted of de-nitrification and dissolved air flotation & filtration (DAFF). Methanol was added in the dual (split) Moving Bed Biofilm Reactor (MBBR) to increase the carbon source for the microorganisms (living on the surface of added media) which then converted the nitrates to nitrogen gas (released to atmosphere). Pre-ozonation was used for initial disinfection followed by a standard coagulation/flocculation (DAFF) process used to remove sedimentation or particulate matter, with alum added as the coagulant (similar to many water treatment plants), and also to remove iron and manganese. The process reduces alkalinity (decreases pH of the treated water) so pH correction was occasionally needed (sodium hydroxide/sodium hypochlorite). The flocculation sludge was decanted and removed via a channel and returned to the STP, as was any backwash water, 'and that's a cost saving [for the STP] because the alum coming off the top of that sludge helps remove the phosphorus down at South Caboolture as well' (Unitywater staff 2010, pers. comm, 24 June).

The effects of ozonation are short-lived, so for any storage and transfer in pipe work the water needs to be dosed with chlorine. The amount of chlorine in water released to the river was highly regulated and the level was checked daily, however there was residual chlorine in the water released to the river (less than 0.7) which may have some environmental effects. At this stage treated water could be released to the river but further processing is required for class A+ water suitable for dual reticulation residential use. It should be noted that currently the South Caboolture STP is being upgraded which would mean that the first stage of the AWTP is not essential for nutrient removal prior to river release of the secondary treated effluent (Lane, de Haas & Lant 2012 p.3). The recycled water facility has been closed during the work due to quality concerns during the upgrade, and potable grade water is being piped to existing customers via the dual reticulation system (and hence suitable only for non-potable uses). As mentioned, the demand in the area for potable water exceeds local supply, so this potable water is purchased from the State government at a reputed $2.44/kl (Caboolture News 201

3). It is also worth noting that at least one customer is complaining because he bought his property partly because it was to have a dual reticulation recycled water supply, suggesting a likely premium on properties with such a supply, as found by MJA 2014a.

The second processing stage consisted of ozonation and biologically activated carbon (BAC). The water was dropped through biological filters. Final ozonation took place prior to recycled water storage and dosing with chorine for continued disinfection allowed for distribution to customers (chlorine is also present in small quantities in mains drinking water). A simplified diagram of the process is provided in - Figure 4.7 below. Figure 4.7 also shows an ozone destructor, not part of the original design of the AWTP, but added by Unitywater to eliminate any ozone emissions.

Customers consist of 'purple pipe' dual reticulation to residential homes and business use, such as watering the swimming pool grounds and the local soccer field.



Sources: Halliday 2006 (p.5), Unitywater schematics & C James-Overheu site visits

Figure 4.7 Simplified process diagram of South Caboolture Water Reclamation Pant

An overview of the system is necessary for assessment of environmental impacts of the process and identification of stakeholders, and an understanding of where this sits in the overall water system.

4.3.3 Summary of RQ information relating to SCWRP

As with all of chapter four, the methods used to obtain information to inform a TBL approach form part of the answer to the research problem itself, as RQ1 asks 'how' a TBL approach can be used. In other words the source of the information and the methods such as mapping stakeholders are suggested approaches to solving how to gain information including and beyond a traditional economic model.

RP 1

- **How can a triple bottom line approach be used to provide a costing model for the full cost of Class A+ recycled water for use in South East Queensland?**

Sections 4.3.1 and 4.3.2 describe the information gathering process, including research and site visits, and the mapping of background for SCWRP necessary to set the study in context for a TBL approach (RP1) and identifies information obtained by this approach in relation to RQs. This culminates in a process diagram of SCWRP (Figure 4.7). Some issues identified were:

- Difficulty in separating costs between STP and SCWRP e.g. Alum returned in flocculation sludge. Return of waste to STP. Input from STP – free or transfer cost (providing service for STP?).
- SCWRP in initial years partly being used to improve treatment before release to river to meet environmental requirement at a time when the STP needed upgrade (upgrade now complete), so may be cross-functional issues in recycled water studies.

The following is a summary of key information gleaned in relation to the RQs:

RQ 1

- What are the characteristics of the recycled water supply chain in SE Queensland, including key stakeholders, and specifically the stakeholders in the 2 AWTPs studied

- The process diagram (Figure 4.7) and materials flow chart (Figure 4.12) aid identification of characteristics of the recycled water supply chain and *economic costs*: Inputs – effluent (free or transfer price?); chemical costs; electricity costs – operating costs and distribution to customers; plant wages (Developed further in section 4.4)
- The materials flow diagram aids identification of stakeholders: suppliers, staff, customers (residential dual reticulation and business/agricultural users), stakeholders regarding catchment area (could be use and non-use) (Developed further in section 4.3.6)

RQ 2

- How is recycled water defined and to what level should it be recycled? (substitute for industrial use/potable water added to consumer drinking supplies)

- Class A+ water has multiple non-potable uses (although these do exclude more personal use e.g. pools and rainwater tank filling which might be valued by customers). Research suggests that the BAC multi barrier process could be modified to produce water suitable for indirect potable use.

RQ 3

- What are the risks of recycling and how can they be managed?

- Health risk: Treatment process when working efficiently appears adequate for non-potable use and *may* be possible to modify to meet drinking water standard; Operation of plant as observed efficient, with monitoring and checks in place, separate clearly labelled pipework for residential customers – greatest risk human error?
- Trust: If human/water provider error is a concern then acceptance of recycled water is linked to Trust in providers. For this, transparency of information may be key to building trust.
- Environmental risk: Low risk regarding chemical spills; Low emissions compared to STP; Residual chlorine in outflow (monitored).

RQ 4

- What information beyond the current economic accounting system is required to provide a full cost accounting or TBL approach? i.e. defining the scope of included externalities

- Environmental benefit: Some evidence of reduction in nutrient levels. As output is under-utilised, more purified water is released to the river – improves quality and increases healthy flow so may give downstream benefits (increases water flow below the weir). Already a consideration in MBRC planning. This may have use value to river users and non-use value to society.
- Social benefit: non-residential customers include sporting/recreational facilities with possible health benefits for community.
- Drought resistant water supply – increase in water security.
- Deferred costs – Water demand in local area already exceeds supply. Any additional water needs to be sourced from SEQWater. Ultimately this puts pressure on the system and increasing supply at a ‘bottleneck’ is beneficial in times of drought and may help to delay the need for other sources and more

costly infrastructure (dams/desalination?). Imported water also incurs increased transportation costs (pumping: electricity & emissions costs; storage & chlorination).

- Emissions from electricity use – highest use are pumps, although variable speed pumps fitted. Highest pumping use is distribution to residential customers (commercial tankers collect at site). There is also therefore a benefit from having decentralised water sources and wastewater recycling is possible even in inland areas more prone to drought.
- Benefit of innovation: BAC processes for treatment of wastewater innovative and still being developed.

RQ 5

- Are the two method of producing Class A+ recycled water identified in the two case studies equivalent in terms of costs, or is there a preferred method?

- Largest cost is electricity used to pump for distribution to residential customers – need comparisons. Energy costs of processing possibly less than alternative treatments.

RQ 6

- What are the perceived benefits and risks (costs) of recycled water use for customers?

- Anecdotally some users may prefer higher nutrient (nitrate) levels and not wish to improve processing e.g. for irrigation – but some risk of increased agricultural nutrient high run-off.

RQ 7

- What factors influence customer acceptance of PRW for potable use?

- Customers may have different preferences regarding the degree of purification required.

4.3.4 Murrumba Downs Advanced Water Treatment Plant (MDAWTP)

The site originally only had a Sewage Treatment Plant (STP), but an environmental impact statement completed in 2006 highlighted the need for an upgrade to cope with a rising volume of wastewater generation in the catchment, and to respond to increased stringency in the standards for treatment and environmental discharge. The project was started in 2008 with stage 1 (Budget $45m) adding an Advanced Water Treatment Plant (AWTP) immediately adjacent to the STP, capable of treating the secondary treated effluent from the STP to produce Class A+ recycled water, and stage 2 (budget $152m) to upgrade and extend the capacity of the existing STP and to reduce odour impact and improve effluent quality.

> The Murrumba Downs Sewage Treatment Plant upgrade and Advanced Water Treatment Plant accommodates projected growth between 2006–2016, and can now service around 159,000 people living in the Moreton Bay Regional Council area's fastest growing areas.
>
> The plant also provides highly-treated recycled water suitable for industrial and commercial re-use, in local manufacturing industries, reducing the community's reliance on town water from the SEQ Water Grid. (Unitywater 2011. p.1)

Stage 1 was completed in September 2008. The recycled water formed part of the Queensland Government's commitment to the Regional Drought Strategy by saving drinking water supplies. The recycled water was for industrial use and during the period of the research for this thesis (2009-2013) all capacity (4ML per day) was used by one major client- Amcor - at their CartonBoard Mill in Petrie, Queensland. Amcor stated that this reduced the Mill's consumption of potable town water by 90% (i.e. the 4 million litres per day). This is relevant to Research Question 4 (externality value – saving potable water use and drought proofing) and RQ6 (lower commercial risk; CSR value - benefit to customer and encouragement to local business and hence employment in the region).

Council and customer motivation

The plant update was completed in September 2010, resulting in a reduction of nitrogen and phosphorus content in the treated sewage, and reduced odour, with discharge compliant with EPA regulations (John Holland 2013). The intention for the upgrade was also to plan for regional population increase 2006-2016 (Unitywater 2011; Borskjaer 2012) (relevant to Research Question 4: social benefit - future planning).

The motivation for the major customer Amcor was also to manage business risk – in this case the risk of water scarcity and the need for continuity of water supply for a water-intensive manufacturing process, brought to the fore by the severe water shortages and restrictions in south-east Queensland in 2006. (Collins 2010) (relevant to RQ3- supply risk & RQ6 - customer benefit).

The council was also motivated to supply Amcor, again looking beyond the economics of the particular product, as the Mayor noted Amcor 'was an important driver of the local economy' while the upgrade 'means we can preserve water capacity for future population growth' (Collins 2010). Amcor was located next to Murrumba Downs so transport costs were not a factor. A capital infusion was necessary however for Amcor in terms of the need for additional pipework to accept the water and to be able to revert to mains water as needed. Amcor consulted with customers but did not find customer objections to be a factor, and monitored quality of the product, with the ability to revert to mains town water if necessary, but had not needed to do so on quality grounds. In fact the ability of the MDAWTP to 'tailor' the water quality/attributes to suit the client, particularly in regards to low salt content, may have been an attraction (Unitywater staff 2010, pers. comm., 27 September). The price to Amcor was the 'same as mains water' (Collins 2010). This was effectively the price cap for recycled water that business was prepared to pay (Unitywater staff 2010, pers. comm., 27 September). (This is relevant to RQ4 - employment benefit to local economy and society; planning for population & RQs 6 & 7 - customer benefits and motivations).

Catchment

The Murrumba Downs AWTP is situated on The North Pine River and therefore, like South Caboolture, discharges to a river and estuary rather than the sea, which is one reason why concerns have centred on the quality of discharge from the waste water treatment plant (WWTP).

The Pine catchment was rated C in 2006 (Health-e-Waterways 2009) but the Pine Rivers Estuary catchment area was rated D, at the time when the environmental impact statement was done that prompted the upgrade at Murrumba Downs. In 2013 the Pine catchment was rated B- and the estuary C and it was noted that 'residential development is the major pressure on the catchment' (Healthy Waterways 2013c). Compared to 2012 the catchment had improved slightly and the estuary declined. An outline of the 2013 results is given in Figure 4.8. Again, it is not possible to isolate the particular influence of the advanced water treatment plant, although the major pressure on the catchment is residential development which suggests increased pressure on available potable water supply, particularly in times of drought.

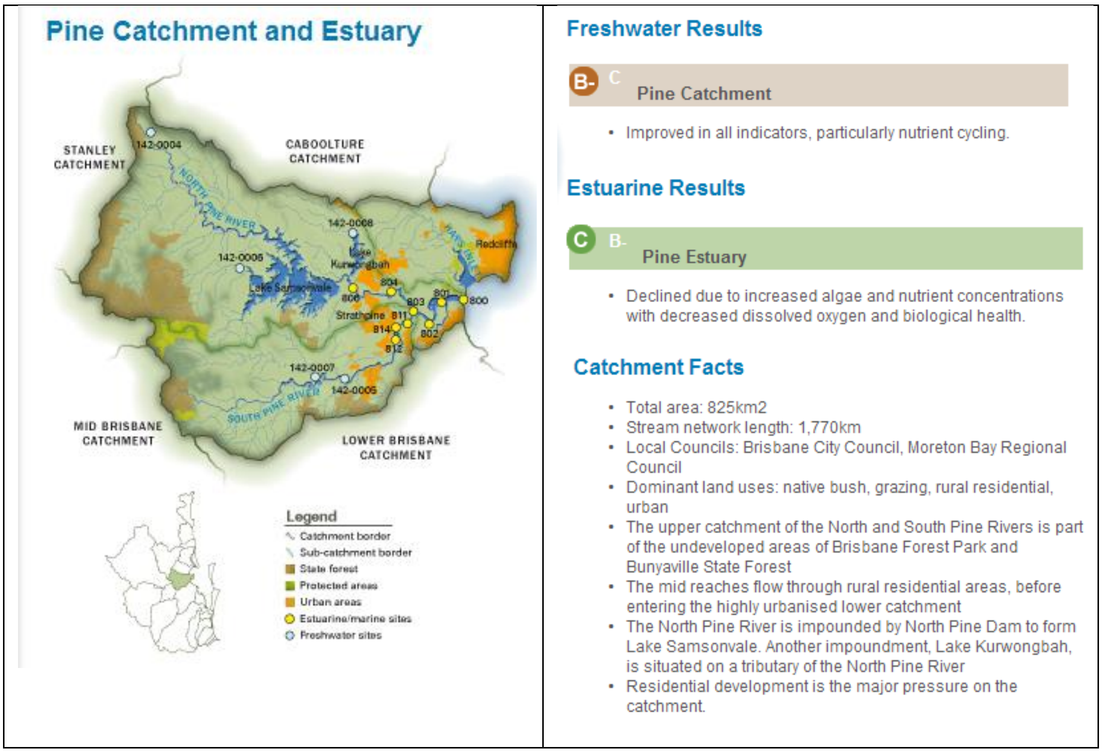


Figure 4.8 Pine Rivers catchment and estuary 2013 (Healthy Waterways 2013c)

Overview of process & initial risk assessment

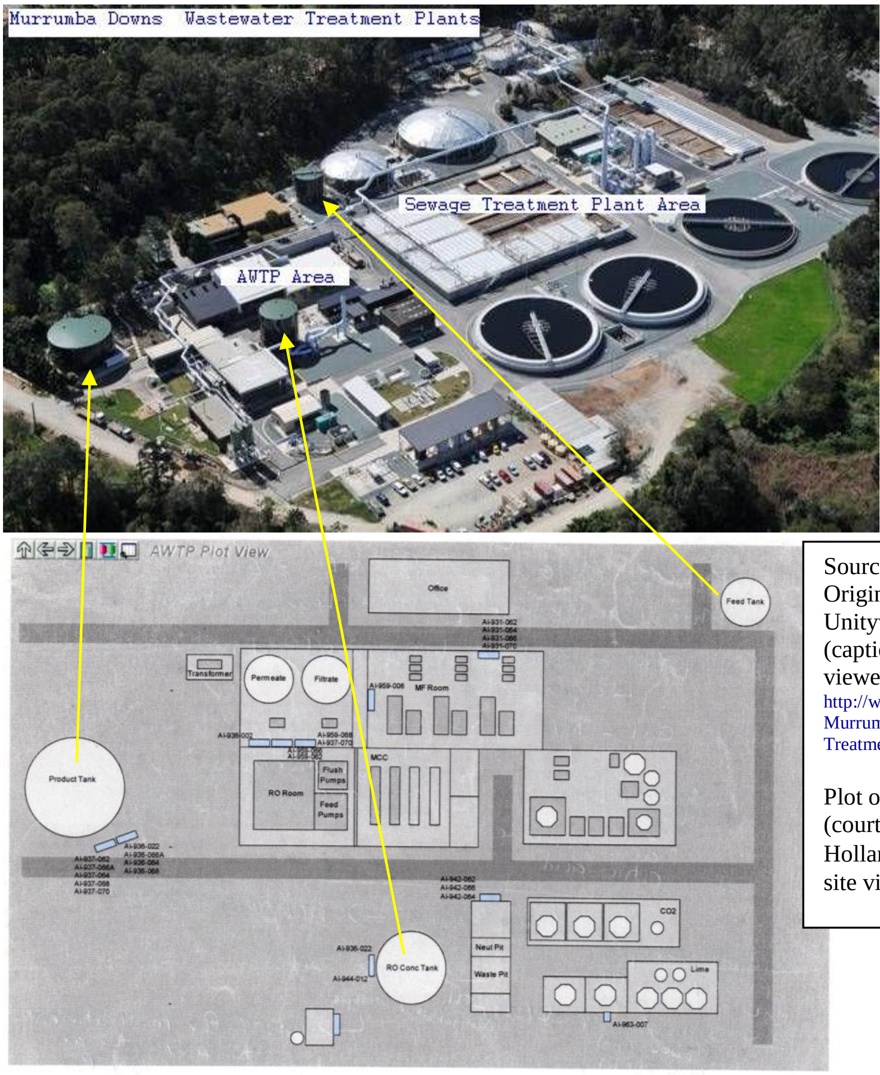
The MDAWTP was initially run by an external contracted plant operator. This firm had a two year contract for the maintenance and operation of the plant – fixed costs and variable costs. All site visits for this thesis took place while the external contracted plant operator was operating the plant. The AWTP had only been recently commissioned and the plant presented as technologically efficient with a modern control room and SCADA system. However no in-depth human risk assessment was done as part of this thesis, and it is acknowledged that further research in this area would be beneficial (Cloete et al. 2012). A factor in human risk is often system or management change, and it should be noted that the contract with the external plant operator was not renewed on expiration and the AWTP returned to Unitywater control. This thesis only addresses the situation that existed prior to the handover, although there is no reason to suppose that plant is any less efficient. It should be noted that the situation has changed significantly in other respects as Amcor's cardboard packaging plant at Petrie was closed at the end of 2013. Amcor cited failing earnings, operational costs, international competition and the high value of the Australian dollar as contributing factors in the decision to close, unrelated to water issues (Spencer 2013). Partially as a result of this, output from MDAWTP has since been reduced.

The MDAWTP received treated effluent from the adjacent WWTP and treated it to class A+ recycled water standard, using primarily a reverse osmosis (RO) process. Although in the same category as the production from SCWRP, the quality of the water produced using reverse osmosis treatment may be slightly higher, and generally has a lower salt content (which was a desirable quality for the customer AMCOR). The A+ output would require relatively minor improvement to meet indirect potable water use standards, should that be required (Unitywater staff & management 2010 & 2011, pers. comm., 27 September & 24 June). For non-potable uses it has the same range of application as the A+ water from South Caboolture.

This is not intended as a chemical engineering thesis, but a basic understanding of the process is necessary to identify risks and materials flow. A hindrance to management accounting full costing, and sustainability accounting in general, is the need for cross disciple and cross organisational boundary co-operation. The process as described here was that in place during site visits in 2010-2011, as informed by operational staff and management, with corroboration by site visits and review of relevant academic research and industry information. A simplified diagram of the process is given in Figure 4.10 below.

Secondary treated effluent was pumped by submersible pumps in a small underground pit to a large buffer tank. The tank had mixers and it was dosed with ammonium sulphate and sodium hypochlorite in order to form monochloramines as a disinfectant to prevent microbial growth. Monochloramine was preferred as the reaction does not leave residual free chlorine which can oxidise and damage the reverse osmosis membrane. The tank acted as a buffer for the microfiltration units and was used to maintain regular flow levels (in contrast to the varied supply levels of treated effluent from the WWTP). From the tank the treatment water flowed through three (parallel) microfiltration units and on to the Micro Filtration (MF) filtrate tank, which acted as a buffer tank for the reverse osmosis (RO) process. Some of the MF filtrate tank water was used as service water for general site cleaning. There were two RO trains in parallel and with their own feed. Prior to the RO process the treated water was dosed with Sodium Bisulphate (SBS) to remove free chlorine, an antiscalant to prevent build-up on the RO membranes, and sulphuric acid (H_2SO_4) for Ph correction to aid antiscalant. The process was producing in the region of fifty-six litres/second with the remainder being rejected as brine, collected in the RO concentrate (ROC) tank. Purified water from the RO process was initially collected in an RO permeate tank. A small amount of the RO product from the RO permeate tank was used as process water, to prepare lime solution for dosing and for cleaning MF and RO units. Once the RO permeate tank was full the water moved to the RO product tank. The site was subject to continuous monitoring and the product was tested over a range of factors to meet Unitywater recycled water guidelines (and also to meet customer specifications). Dosing was therefore automated and adjustments made by the computer system in live response to testing. Prior to the RO product tank further dosing was done with sodium hypochlorite (for free chlorines); CO_2 for water remineralisation; and lime solution to balance Ph and increase hardness of the water to prevent corrosiveness from ‘pure’ water. The brine was dosed with Sodium Bisulphate (SBS) to neutralise chlorine to licence levels (0.1mg/l or below) and the brine was then combined with WWTP outfall in a 1:4 brine to outfall ratio and was released to the North Pine river.

A ‘bird’s eye’ view of the Murrumba Downs site is given in Figure 4.9 below.



Sources:
Original photo from Unitywater website (captions added) viewed 31 Jan 2011
http://www.unitywater.com/Murrumba-Downs-Sewage-Treatment-Plant.aspx

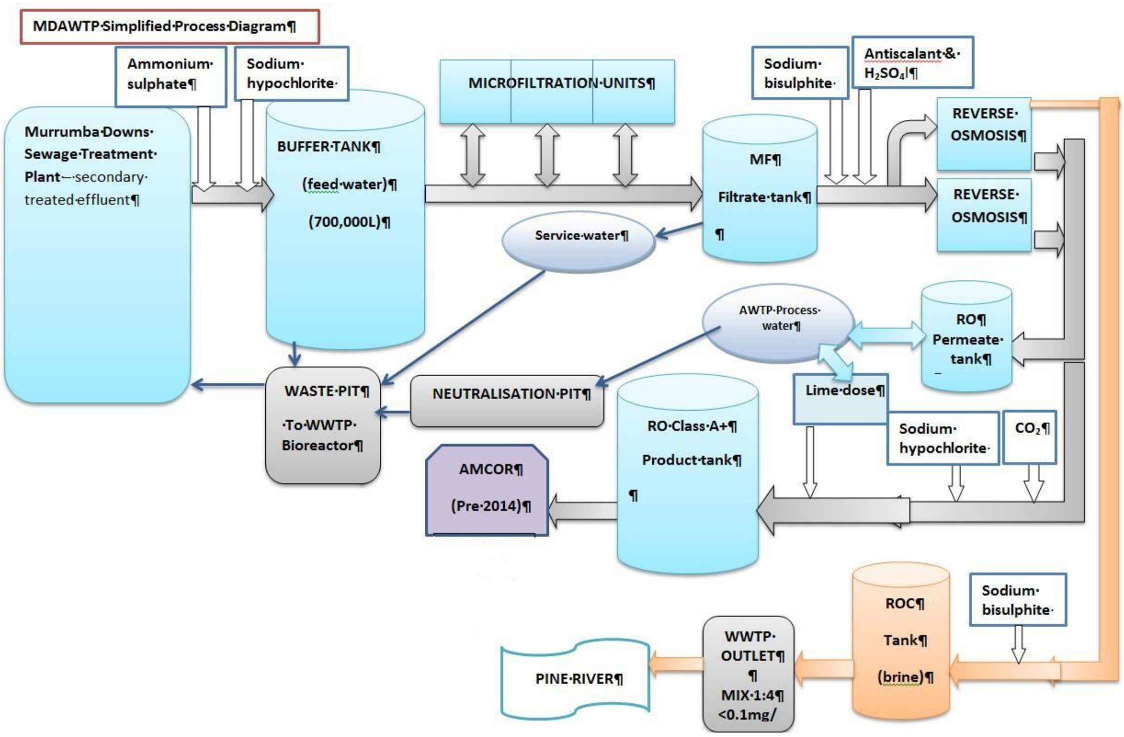
Plot of MDAWTP (courtesy John Holland/Unitywater) site visit 27 Sep 2010

Figure 4.9 Aerial and plot views of the Murrumba Downs AWTP

Details of process

A number of other chemicals were also used for process cleaning of Microfiltration (MF) (sodium hypochlorite) for the RO membranes (sodium hydroxide, citric acid & EDTA). Waste from cleaning was transferred to a neutralisation pit to be tested and dosed as necessary (SBS and sulphuric acid (H_2SO_4) and sodium hydroxide (NaOH) (both for Ph adjustment). From the neutralisation pit the waste was moved to the waste pit and returned to the bioreactor at the WWTP for re-treatment, including ultra-violet disinfection.

The processes in the adjacent WWTP are sufficient to produce tertiary treated effluent and this can be discharged to the river directly. The AWTP treats the water to close to potable standard, and could be adjusted to produce indirect potable water without much difficulty (Process engineer, pers. comm., 27 September 2010). The original plans for the site were for a large AWTP and some of the infrastructure (such as pipework) was installed with a view to moving to six MF units (from 3). However the plant is on a very small scale compared to similar RO processes in the Western Corridor Recycled Water Scheme, and may lack economies of scale. On the other hand proximity to customers is desirable to reduce pumping costs.



Sources: John Holland schematic & C James-Overheu site visits

Figure 4.10 Simplified process diagram of Murrumba Downs AWTP

4.3.5 Summary of RQ information relating to MDAWTP

RP 1

- **How can a triple bottom line approach be used to provide a costing model for the full cost of Class A+ recycled water for use in South East Queensland?**

- cross-functional issues with STP/WWTP - MDAWTP initially used to improve treatment of effluent from STP/WWTP before release to river (until STP/WWTP upgrade completed). Return of waste from AWTP to STP.

RQ 1 • What are the characteristics of the recycled water supply chain in SE Queensland, including key stakeholders, and specifically the stakeholders in the 2 AWTPs studied

- The process diagram (Figure 4.10) and materials flow chart (Figure 4.13) aid identification of characteristics of recycled water supply chain and *economic costs*: Inputs identified– effluent (this presented a costing issue – whether it should be free from the associated STP or have a transfer price); chemical costs; electricity costs – operating costs and distribution to customer; plant wages (Developed further in section 4.4).
- The materials flow diagram aids identification of stakeholders: suppliers, staff, customers (business), stakeholders regarding catchment area (could be use and non-use) (Developed further in section 4.3.6).

RQ 2 • How is recycled water defined and to what level should it be recycled? (substitute for industrial use/potable water added to consumer drinking supplies)

- Class A+ water has multiple non-potable uses (although these do exclude more personal use e.g. pools and rainwater tank filling which might be valued by customers). Research suggests that the RO multi barrier process is easily modified to produce water suitable for indirect potable use. May be tailored to suit customer specifications (e.g. lower salt) for industrial use. Was used in this case study to successfully replace potable water for an industry customer.

RQ 3 • What are the risks of recycling and how can they be managed?

- Health risk: RO treatment process adequate for non-potable use and could be readily modified to meet drinking water standard; Operation of plant as observed modern and efficient, with monitoring and checks in place.
- Trust: No concerns were expressed by commercial customer or their clients.

- Environmental risk: Low risk re. chemical spills; Potentially higher carbon footprint of RO processing operation but less energy required for distribution to a sole commercial customer compared to residential reticulation. Residual chlorine in outflow and saline (both monitored with no observed adverse effects (but riparian system complicated by multi-use and further research required).
- Business risk mitigation for high water use commercial customers.

RQ 4

- What information beyond the current economic accounting system is required to provide a full cost accounting or TBL approach? i.e. defining the scope of included externalities

- Environmental benefit: Initial motivation to reduce outflow nutrient levels, as supporting STP.
- Community benefit: council motivated to retain local industry to promote local employment
- Drought resistant water supply – increase in water security & planning for population increase
- Deferred costs – 4ML per day of potable water supply saved when supplying commercial customer – reduced pressure on alternative sources
- Emissions from electricity use – RO process has higher electricity use for processing (although also perceived as higher quality product and more possible to tailor to customer needs e.g. commercial). At the time of this study when supplying one local commercial customer the energy needs for distribution were lower (direct to one local customer) than would be required for residential indirect potable use. (Explored further in section 4.4)

RQ 5

- Are the two method of producing Class A+ recycled water identified in the two case studies equivalent in terms of costs, or is there a preferred method?

- Largest cost is electricity used and RO operating process higher cost but also depends on use – may be more suitable for some commercial clients (e.g. tailored for lower salt specifications) and may be perceived by customers as higher quality. Also if used to supply commerce and located close to client then distribution costs will be less than a residential reticulation scheme. However removal of brine from RO may be difficult in more remote locations.

RQ 6
- What are the perceived benefits and risks (costs) of recycled water use for customers?

- Benefits: Commercial customer able to specify quality e.g. reduced salt; CSR obligation – commercial customer promoting the water saving on their website; reduced business risk of supply loss to customer in water-intensive industry, particularly in times of drought.

RQ 7
- What factors influence customer acceptance of PRW for potable use?

- Originally one commercial customer taking all output and recycled water meeting customer specifications (attractive to customer – lower salt from RO output; lower commercial risk regarding loss of water supply).

4.3.6 Identification of stakeholders

This section primarily addresses research question 1 and 2, the identification of stakeholders and the need to manage stakeholder risk and issues of trust:

RQ 1
- What are the characteristics of the recycled water supply chain in SE Queensland, including key stakeholders, and specifically the stakeholders in the 2 AWTPs studied

RQ 3
- What are the risks of recycling and how can they be managed?

A broad definition of stakeholders was taken in this thesis in order to better capture the implications of water recycling policy as it applies to the case studies, and also to identify the stakeholder's place in the wider system – natural and social. Freeman (1984) defines a stakeholder as: 'any group or individual who can affect or is affected by the achievement of the organization's objectives' (p. 46). Stakeholder analysis is carried out by a wide range of organisations, as entities became aware of how stakeholders could support or threaten the enterprise, and analysis covers a wide variety of approaches and definitions. ‘However within policy, development, and natural resource management, stakeholder analysis was increasingly seen as an approach that could empower marginal stakeholders to influence decision making processes’ and with increasing awareness of a sense of political will (Reed et al. 2009).

Community engagement and communication with stakeholders has proved to be essential in acceptance of change and perceptions of risk and trust in authority, and hence acceptance of water recycling for both non-potable and indirect potable use. (Lim & Seah 2013; AWRCE 2010a). The experience of local and state government in Toowoomba, South Caboolture, and in the case of the Western Corridor Recycled Water Scheme (WCRWS), speaks to the need to manage wider stakeholders and the media.

Reed et al. (2009) suggest stakeholder analysis starts with a descriptive analysis and then tends to take one of two main approaches – normative or instrumental. In policy development and natural resource management a normative approach is often favoured where the emphasis is often on inclusiveness and empowerment of various stakeholders (often with key representative figures) in order to come to a consensus on approach and hence legitimise the decision made – a ‘soft system’. Stakeholder analysis permits investigation of the perspectives of the (often conflicting) stakeholders with regards to a scarce resource. An instrumental approach to stakeholder analysis seeks to identify and understand the views of various stakeholders in order to better manage them generally towards a specific purpose i.e. it is part of strategic management (Reed et al. 2009 pp. 1935-1936).

Both approaches appear evident in water policy creation. Often the policy is led by government, which in a democracy seeks consensus. An example might be how best to settle a dispute over riparian irrigation. It may be the intention to encourage all those immediately affected to determine a solution. Very often with a government policy, however, the need for something is clear (e.g. reduce water use) and the method is the area which needs agreement. Or it could be that the decision about the best policy has been made e.g. use of indirect potable water and it is a case of strategic management of stakeholders in order to seek agreement with this approach. This requires a planned, concerted and consistent effort, as was the approach taken in Singapore (Lim & Seah 2013).

The situation in Australia, and in Queensland, may call for both approaches. It would seem that attitudes regarding water scarcity are changing, as prolonged drought conditions did much to open the debate, and therefore consensus on the best method of securing a water supply was (and is) needed i.e. there is a problem that most stakeholders would acknowledge but not a consensus on the best approach. It was this aspect of normative stakeholder engagement that was perhaps lacking in planning for water scarcity and that worsened a (potentially expensive) lack of synergy between policy and public opinion, evident in the WCRWS. Many of the decisions for capital projects were made in 'crisis' mode and therefore large scale infrastructure is in place, currently underutilised due to the nature of Queensland weather patterns (drought replaced by flooding) but also because the utilities are not being used as intended i.e. no indirect potable use of recycled water has been introduced and dual reticulation is not widespread. In that situation strategic management of the stakeholder base may be more important in order to achieve the goal of using water assets more efficiently, an instrumental approach.

An instrumental approach first needs identification of stakeholders and an understanding of their perceptions. This thesis sheds light on customer perceptions, and key stakeholders, via the social aspect and survey data sections. Stakeholders in general were identified via site visits and 'snowballing' interviews, as well as wider research. This was used to draw up a list of stakeholders (identification of stakeholders), then these were grouped into categories (influencers; governance; providers; users/beneficiaries (OGC 2007) and the relationships between them explored (Reed et al. 2009). This is relevant to research question one (Figure 3.2) identifying the characteristics of the recycled water supply chain and identifying key stakeholders.

A stakeholder identification chart is provided in Figure 4.11. The four categories included (adapted from Office of Government Commerce (OGC) 2007) are 'Governance, Providers, Users & Influencers', as follows:

Governance:

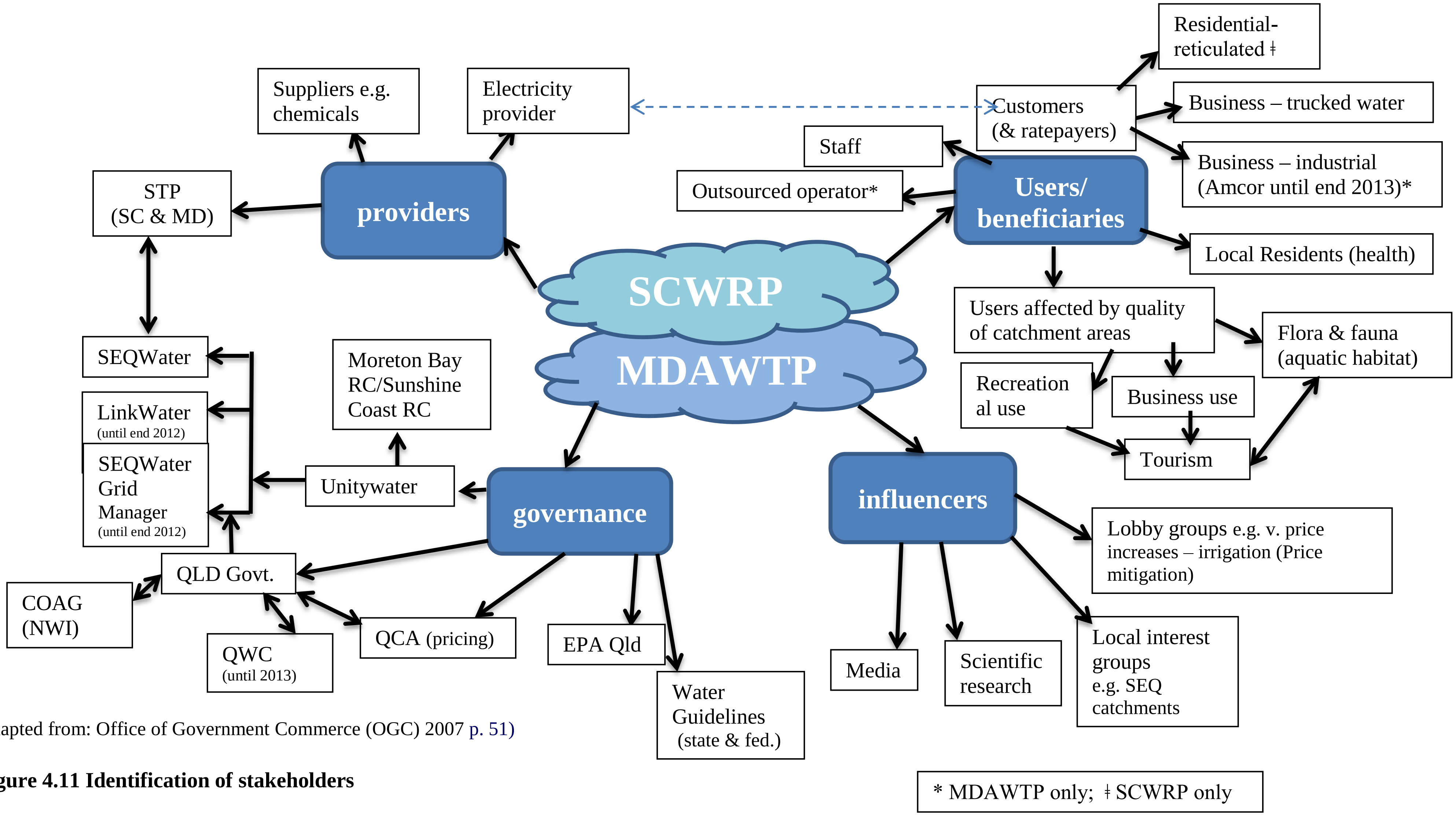
As the two advanced water treatment plants considered in this thesis are both located in the Moreton Bay region and are both operated by Unitywater, many of the stakeholders are in common and Figure 4.11 depicts them together with only differences between being identified. Unitywater is itself owned by Moreton Bay and the Sunshine Coast Regional Councils and the regulatory authority in which Unitwater operated during the study (as described in section 2.3 pp. 28-40 supra) was the SEQWater grid with Linkwater the potable bulk water supplier and SEQWater the manufactured water supplier with ownership of dams and infrastructure including treatment plants. Until 2012 the SEQ water grid had an overall manager (WGM) also in charge of managing the 'price path.' Unitywater is therefore the retail distributor for the region. However this function was taken over by SEQWater from 1 January 2013. The Queensland (QLD) Government is a signatory to the National Water Initiative (NWI) (negotiated by COAG between the States), which includes the aim of seeking to secure water supply by investigating alternative water sources. Until January 2013 the Queensland Water Commission (QWC) was the independent body offering advice with regards to water management to the Queensland (QLD) government, including advice on prices. Prices are also regulated through the Queensland Competition Authority (QCA), using a formula to determine maximum price (QCA 2000). The water industry (and particularly recycled water standards) is regulated via State and federal water guidelines (via legislation) regarding quality standards and permitted uses and is monitored by the QLD Environmental Protection Agency (EPA).

Providers:

Providers include suppliers. The main 'source' product for both plants is the treated sewage from the adjacent sewage treatment plant (STP) which would otherwise be released to the river (in the case of South Caboolture in the timeframe of this thesis the sewage needed further treatment before release but since the recent STP upgrade this additional nutrient removal role is not essential (Lane, de Haas & Lant 2012 p.3)). The other main suppliers are suppliers of chemicals for both plants and the electricity provider (although it should be noted that as the electricity providers in Queensland are also large water consumers they are also potential customers for recycled water, as is the case with Tarong power station supplied by the WCRWS). Residential non-potable water supplied by SCWRP (and the water supplied to other users collected by tanker) would replace some of the potable water supply delivered by SEQWater. Similarly the non-potable water delivered during the timeframe of this thesis to Amcor paper mill at Petrie by MDAWTP replaced potable water use there, and was an important supply for that business during drought (Collins 2010).

Users/beneficiaries:

As with other businesses, beneficiaries include the staff (both at the treatment plants themselves and at Unitywater head office in Caboolture) and in the case of MDAWTP for part of the period also the operators of the plant which was initially operated by an external contracted plant operator. The customers were businesses and residents of the local area, who were also therefore ratepayers and could affect Unitywater, as they had potential influence with their respective local councils. The customers for SCWRP were residential customers (and some businesses) supplied with dual-reticulated water, and other business users generally collecting water by tanker (or buying water from such collectors). It is possible that the needs of these users differ. Residential users may have a preference for class A+ water (for multiplicity of uses and also quality issues such as colour and odour) but some business users, such as horticultural users, may accept a lower grade of water (as they may prefer nutrient rich water). For MDAWTP during the period of this thesis all water was supplied to a single industrial user, Amcor. Industrial users like Amcor may prefer Class A+ water and RO processing as it enables a greater reduction in salt and precise specifications regarding minerals to be met to fit in with their processes (John Holland staff 2010, pers. comm., 27 September). An alternative water supply may also be critical in terms of minimising the risk of shortages, particularly in a water-intensive industry such as a carton board mill (Collins 2010).



(Adapted from: Office of Government Commerce (OGC) 2007 p. 51)

Figure 4.11 Identification of stakeholders

In a sense, particularly during any drought period, *all* customers of potable water are beneficiaries in as much as any re-used water or alternative supply takes pressure off the potable water supply. With predicted population increase in the area this could be an important future benefit. In the broader area all users affected by the quality of water in the catchment area may be affected by the operations of either advanced treatment plant in terms of health. The effect could be negative if the plants were to degrade the waterway e.g. via an accidental spillage, or positive if their presence reduces the nutrient content of the water and decreases unwanted side effects such as algal blooms. This has the potential to affect both recreational and business users and the health of flora and fauna in the region (particularly aquatic habitat) and is also therefore of relevance to the QLD tourism industry which has a vested interest in maintaining natural habitat and the clean condition of waterways.

<u>Influencers:</u>

As noted, the customers are also ratepayers and voters, and therefore have potential influence over both local councils (and therefore indirectly Unitywater) and the QLD government. The interaction between these stakeholders and the media is also important, both in terms of colouring perceptions but also in terms of providing a platform for lobby groups. In South Caboolture local opposition prevented the introduction of indirect potable use of water from SCWRP and was thought to be instrumental in removal of the long-standing mayor from office (Halliday 2006; Uhlmann & Head 2011).

In relation to price increases, local retail water providers are at pains to point out that the majority of the increases relate to bulk water charges (paying for major infrastructure) and are outside local provider control (Tuttiet & Killoran 2011; Wuth 2010). As stated, the price charged was regulated by QCA and during the period under consideration of this thesis Unitywater did not charge the maximum permitted by the QCA formula (Unitywater staff 2010, pers. comm., 27 September). Public opposition in the region to price increases has been vociferous and ongoing and widely reported by local media (Tuttiet & Killoran 2011). In response to public opinion the QLD government introduced legislation to require a 'price mitigation plan' from all participating local governments for a water distribution retailer (Fairer Water Prices for SEQ Amendment Bill 2011).

Apart from lobby groups over prices, other local interest groups would include environmental concern groups such as 'SEQ Catchments'. Customer attitudes towards pricing and involvement in environmental groups are two aspects included in the customer survey in this thesis and reported in the social aspect. Other influencers (though apparently less powerful) include scientific and other researchers in the area of recycled water, and also more generally research regarding weather patterns and the influence of climate change and the attendant media coverage of this. The media may also have played a role in channelling and shaping public opinion regarding water use and scarcity during the prolonged drought, and in promoting acceptance of water restrictions. The role of the media is also investigated in the customer survey in this thesis (see particularly section 5.2.5.5).

Understanding stakeholder perceptions and managing these has been critical in overseas acceptance of the introduction of recycled water, particularly for potable use, as in Singapore (Lim & Seah 2013).

4.4 Economic aspect

The aim of this thesis was to develop a Triple Bottom Line (TBL) costing model for recycled water, using the case studies to highlight likely costs and difficulties and thereby inform the model. The economic aspect of TBL reporting is the 'conventional' role of accounting information systems, and is therefore the part of a TBL costing model that is generally least problematic. Tools for accumulating direct costs and operational overheads are well established, so the focus of this economic aspect was to look at specific issues for the water recycling industry, as identified during the case studies. This section looks at the approach needed to undertake a more accurate economic assessment, and highlights problems that may be encountered.

The costs for both plants included direct operational production costs (such as chemicals and wages and electricity), and costs of delivery to customers. They should also include an element of capital cost (ideally using full life cycle assessment including construction and decommissioning, but the full information to do this was not available for the case studies). There were differences between the facilities regarding these, and between whether the recycled water is for indirect potable use or non-potable recycled water uses. In some cases costs may be offset by benefits, some of these also being economic and others having value but currently treated as externalities. A full cost approach should consider all these aspects.

As already stated, water has been traditionally under-priced and in large part this has also meant that accurate costing has not been undertaken. The National Water Initiative's aim to include full costing requires management accounting systems capable of undertaking that costing approach. For many water authorities recycled water, particularly at the Class A or A+ quality level, is a relatively new product. In Queensland the re-structuring of responsibilities for water has also meant that a number of the entities responsible for reporting were also new, including Unitywater. The QCA regulatory environment requires calculation of maximum allowable revenue for regulated products (including recycled water), calculated by applying a Weighted Average Cost of Capital (WACC) to the regulated asset base. Similar to a calculation for tax depreciation, this valuation is regulated via a formula and does not often equate to the asset base valuation as determined by usual accounting rules. The two separate valuation regimes require sufficient information in the management accounting system to easily produce reports. This may be problematic in many existing accounting systems, at least initially, for the entity involved. This was found to be initially time consuming by Unitywater, but as a new enterprise they were able to design a sufficiently flexible chart of accounts from the outset. As stated, during the period under consideration of this thesis, Unitywater did not charge the maximum permitted by QCA formula (Unitywater staff 2010, pers. comm., 27 September), due to sensitivity towards customer concerns over price issues. At Unitywater class A+ recycled water was being charged 'at the short run marginal cost not including any externalities' (Unitywater staff 2010, pers. comm., 19 March & 24 June).

Customer willingness to pay often limits passing on the full cost to customers, and this willingness is naturally limited to the cost being charged for alternative supplies, namely the cost of mains potable water (a consideration for the industrial customer Amcor). It has been noted that under-pricing of mains potable water supply promotes undesirable user habits in terms of water use (UEA 2007; European Union 2007) and limits the likelihood of the introduction of alternative water supplies due to apparent lack of economic competitiveness. However, as a public policy, a range of water supply options may none the less be desirable in order to plan for future population expansion and to mitigate supply risk. This may be particularly true when the natural water system is periodically under stress as in an environment like Queensland where weather patterns can alternate between drought and flood.

Regardless of the politics surrounding the price of recycled water to the ultimate consumers, policy makers and water suppliers need an accurate picture of the costs in order to make informed decisions. One possible accounting methodology for this would be to take an Activity Based Costing (ABC) approach to the product costing, looking at the processes concerned. This methodology can be used to look at all processes (i.e. can be adapted to measure environmental aspects and to allocate overheads and identify waste (defined as any output that does not form part of the end product)). To this end a detailed overview of any process is needed, and for this thesis for the two AWTPs these are identified in Figures 4.7 and 4.10 respectively. It is not the purpose of this thesis to undertake an ABC costing exercise, as models for doing this are well documented, but rather to highlight difficulties pertaining to recycled water and to the case studies being considered. There are two levels of cost object to consider – the advanced treatment plants themselves and the class A+ product produced. As both AWTPs under consideration in this thesis produced class A+ recycled water as their product (essentially a single product) then effectively this was only an issue of splitting out costs for the AWTP itself and the plant was the cost object. For other facilities where different grades of recycled water are produced, allocating joint costs between products may be difficult, although if material flows are monitored then a volumetric basis could be used at the split off point.

<u>The recycled water plant as the cost object</u>

Analysis of costs depends on being able to adequately separate the recycled component of the operations from the other processes/business units. In the case of recycled water this can be problematic as the recycled water facility is often a later addition ‘tacked on’ to an existing waste water/sewage treatment plant (STP). Most waste water treatment plants in Queensland provide some lower grade recycled water. Figure 4.4 shows some of those available from Unitywater plants in 2010. This structure makes separation of costs, particularly overheads such as utilities (especially electricity), more difficult and may require retrofitting of metering if a materials flow exercise is to be undertaken (as was undertaken at SCWRP for electricity). It may also be difficult to separate staff costs if the same staff have duties in both areas and no time sheet allocation between the various functions are kept.

In the case of the two AWTPs being examined in this thesis this was not as problematic as they were both purpose built relatively recently and to a great extent were ‘stand alone’ each with separate metering for electricity and with sophisticated SCADA real time monitoring of flows through the production process. Operational staff were also specific to that facility (and in the case of MDAWTP in the period of this thesis was sub-contacted initially to the commissioning firm). However, even with this distinction, some issues arise with the close relationship between the AWTP and its neighbouring waste water treatment plant. At SCWRP, for example, both the waste water treatment plant and the recycled water facility use Alum in the process (p.104 *supra* and Figure 4.7). Quantities of the alum were still present in the sludge decanted in the DAFF process that was then returned to the STP, which in turn helped in the removal of phosphorous in the STP. In this case it was not thought to have a significant effect in terms of costs (of alum), but it was not separately monitored or calculated. Due to the closed loop aspect of much of the recycling, events at one treatment plant were likely to affect their neighbour, such as heavy rainfall.

Similarly there may be a cross-over in function between the facilities. Often a partial motivation for adding a recycling facility may be to meet more stringent environmental regulations. In other words the existing STP may fail to adequately meet the environmental specifications for discharge, particularly if that discharge is to a river rather than to an off-shore outflow into the sea. A choice may be made, as was initially the case at South Caboolture, that a necessary upgrade to the STP could be avoided (or deferred) by processing in the recycled water plant prior to discharge. Hence the facility at SCWRP to release treated water to the river after stage one of the process, if desired. If an entity then wishes to report separately for its segments (such as the recycled water plant) then problems arise with transfer pricing. Should the AWTP ‘charge’ the STP for the additional service? Generally you might assume that the treated effluent input is ‘free’ in as much as the STP would exist anyway to meet the regulatory environment and its product would otherwise be discharged to the outlet (river or sea). Again, this may depend on the social aspect – an issue of policy – as environmental regulation is a ‘minimum’ and it may be desirable for a particular location (with a history of poor quality riparian flows or of particular environmental sensitivity or importance) to release water of a higher standard.

A significant cost of both treatment plants was the cost of electricity. Based purely on the data for the two months in 2011 and 2012 the MDAWTP output used just over 7 times the electricity per Megalitre (MGL) of class A+ output (2,174 kwh/MGL) compared to SCWRP (306 kwh/MGL). By 2011/2012, however, production for MDAWTP had significantly reduced from the time of site visits in 2010 (from about 4MGL/day output to c.1MGL/day). Using simply a high/low method across the two months to estimate the proportion of fixed and variable cost it appears that the fixed level of use is relatively high. Estimating total use in kwh for an output of 4MG/d reduces the usage per MGL to approximately 3.4 times the level of electricity usage per Megalitre (MGL) of class A+ output compared to SCWRP (306 kwh/MGL & 1,040 kwh/MGL). The differential in terms of cost would be slightly higher for MDAWTP, however, as the percentage of peak electricity used (c73%) was higher for this plant than SCWRP (c59%). Analysis of electricity consumption did suffer from a problem of lack of disaggregated data with a lack of analysis of the various activities’ use of electricity, and in particular no appreciation of electricity used for distribution to customers. The circumstances at the time of the site visits in 2010 were such that delivery to a sole industrial customer for MDAWTP would be more cost effective than delivery of a full reticulated scheme over multiple customers. This would suggest that use of recycled water for indirect potable purposes could be relatively cost effective in that it would involve a single delivery to a dam and from there existing infrastructure could be used.

This raised the issue of economies of scale. A small-scale plant, possibly built for water security reasons in a particular area (and water supply is a local issue unless you wish to invest in large infrastructure to pipe water from one area to another, with attendant high pumping costs), may not be of sufficient size to benefit from economies of scale.

Several of the recycled water infrastructure projects in south-east Queensland have not operated on the scale originally intended, particularly with regard to indirect potable water use, most notably the WCRWP. In South Caboolture the SCWRP for example was designed to be returned to indirect potable water use via Caboolture Weir and the class A+ water produced at MDAWTP could similarly be used for indirect potable use (perhaps via Lake Kurwongbah).

As with any business that is an early adopter of technological innovation, the innovation must be widely accepted or diffused to self-sustain (Rogers 1962; 2003) and has to establish a customer base (in this case with infrastructure) and has the task of marketing a novel situation to customers, and being an opinion leader. However the role of 'opinion leader' is generally associated with exposure to (and influence over) the mass media, so this could also apply to lobby or pressure groups and is a significant concern if trying to manage stakeholders, as already noted. Rogers (1962) in his seminal book argued that there are five stages of innovation diffusion – knowledge, persuasion, decision, implementation, and confirmation. The customer survey analysis in this thesis suggests that customers are still seeking information, with imperfect knowledge, particularly as regards principles knowledge. This relates to uncertainty regarding the workings of an innovation, so uncertainty about the health risks of recycled water would be an example (Rogers 2003 p. 171). Although 51.6% of the respondents to the survey in this thesis agreed that they had sufficient information to make a decision about using PRW (below p. 178), there was a significant amount of uncertainty with 31.1% neutral and 17.2% disagreeing with that statement. An individual's decision to accept (or otherwise) an innovation may also be influenced by its 'trialability' – a user may more readily accept an innovation that can be trialled (Rogers 1962). In the social research regarding Mawson lakes existing users of recycled non-potable water seemed more receptive to the use of recycled water in general (Hurlimann & McKay 2006). Again this is a matter of public policy and will. If recycled water is needed as a long-term supply option, then the diffusion and dissemination of knowledge and persuasion stages may require support. It is also interesting to note that Rogers used the case study for the failure of diffusion regarding a Peruvian village where the social stigma attached to drinking boiled water (an activity culturally reserved for the old and infirm) was sufficient to prevent its use among the village as a whole, despite the evident health and other benefits to the community. Again, the social aspect was crucial to the acceptance of the innovation.

4.4.1 Key economic points in relation to research problem

RP 1

- **How can a triple bottom line approach be used to provide a costing model for the full cost of Class A+ recycled water for use in South East Queensland?**

- Established management accounting techniques can be adapted for use in this environment e.g. ABC costing
- Issues arising:

1. Inclusion of capital costs – An LCA approach is preferable, but data for this is not usually available.
2. Recycled water a new product – may require adaptation of existing accounting system and categories.
3. Challenges of compliance with regulation e.g. QCA regulatory environment
4. Identification of costs objects.

   - The plant as the cost object: May be difficult depending on extent of co-dependency in systems between recycled water plant and (original) waste water treatment plant (e.g. separate metering for electricity; staff). Complicated by closed loop nature (output of one is the input for the other in each case) particularly if both needed to comply with environmental protection standards.

   - The product as a cost object: may be difficult to differentiate costs if multiple grades of recycled water supplied – suggest an allocation on a volumetric basis as split-off point.

- Electricity costs for operation: Significantly higher electricity operating costs for the RO process compared to BAC/Ozone process in this example, however this included a large fixed cost component, so results affected by the low output as RO plant operating below capacity and the actual capacity much less than the original design, so no economies of scale. Higher use of peak electricity for RO process (continuous).

- Electricity costs of distribution: Lack of disaggregated data for electricity use. Costs for distribution to residential customers via a non-potable reticulation system may be higher than to limited industrial use customers depending on plant location. Costs of distribution also likely to be less for indirect potable use as added distribution only as far as dam and exiting infrastructure used after this point.
- Possibilities to reduce electricity costs at both plants: biogas retrieval and conversion into energy from the STPs and SCWRP could be explored (see section 4.5).
- Demand affected by the innovation and lack of acceptance of the product? (Need to improve information and to manage stakeholder concerns & to support business innovation through and 'trial' period before acceptance achieved).

Aspects of this section are also relevant to stakeholders (RQ1) and social/political risk (RQs 3 & 4) and the choice of preferred processing option (RQ5) and demonstrate the interconnectedness of the issues.

4.5 Environmental aspect

4.5.1 Boundaries & assumptions

As the site inspections and interviews occurred in a limited time frame (2010-2012) this is not a longitudinal study and the results are to a large extent specific to these case studies at this time, although the methodology is applicable to other scenarios. The process was as described throughout the period, and the influent and effluent volumes and other data (such as financial and electricity use data) were based on two actual months in 2011 and 2012 respectively, provided by Unitywater. However, this was further checked for representativeness by comparison to Lane et al. (2012) where process data from 2009-2011 was used.

Similar to Lane et al. (2012) it has been assumed that all input secondary treated effluent to the recycled water treatment plants avoided the discharge of the input effluent directly to - a river catchment at this stage (as both case study advanced treatment plants are located in a river catchment), although it is acknowledged that in this period (prior to current upgrade work) further treatment may sometimes have been necessary at SCWTP to meet discharge standards.

4.5.1.1 Boundary limitations

The thesis examined the flows from the processes within the advanced treatment plants, using materials flow analysis, but did not set this within the context of the water system beyond considering the replacement of other water sources with the recycled water and the effect on the immediate catchment area. Potential externalities are identified and discussed, but not quantified.

4.5.2 Materials Flow

Initial mapping of the systems was carried out after site visits and is reported in sections 4.3.2 and 4.3.4 and Figures 4.7 and 4.10. Inputs and outputs of the processes were then mapped in a materials flow chart for each treatment plant.

The materials flow chart for South Caboolture Water Reclamation Plant (SCWRP) (Figure 4.12) shows inputs and outputs of the processes at the plant. The National Greenhouse and Energy Reporting Act 2007 (NGER) in Australia requires reporting of Scope 1 (Greenhouse gas (GHG) emissions from sources owned and controlled by the entity) and Scope 2 emissions (indirect GHG emissions e.g. from electricity, heating or cooling) purchased by the entity over a threshold. Analysis of the environmental footprint of wastewater disposal facilities suggests that Scope 1 and 2 emissions are likely to be high (fugitive emissions from Methane (CH_4) and Carbon Dioxide (CO_2) and Nitrous Oxide (N_2O) and Scope 2 emissions in terms of electricity use in particular). Such emissions at both South Caboolture and Murrumba Downs STPs however far outweigh those of the adjoining advanced water treatment plants and offer the best opportunity to reduce the entity's footprint (Lane, de Haas & Lant 2011; Lane & Lant 2012b). Use of lagoon covers -at Melbourne Water's Western Treatment Plant, for example, has halved their greenhouse gas emissions and enabled methane gas capture to provide biogas energy (via AGL onsite biogas power station) for other uses such as powering aerators (Melbourne Water 2015).

However fugitive emissions from the recycled water treatment at South Caboolture should not be ignored as research is beginning to suggest that emissions of Nitrous Oxide (N_2O) may be higher than previously thought from any denitrification process which could be significant given the severe Global Warming Potential (GWP) in terms of ozone depletion of N_2O.

Scope 2 emissions are the highest contributing factor to environmental footprint, even when a life cycle analysis approach is taken rather than a more limited GHG accounting approach. A recent life cycle assessment study by Lane, de Haas & Lant (2012), looking specifically at SCWRP, indicated that between the scenarios for recycled water production at the plant being explored, scope 2 emissions in terms of power generation dominated (p. 18) but pointed out that the marginal power supply source going forward would make a significant difference. The current power source in south east Queensland is coal-fired power generation, which as already noted, is itself water-intensive (and at Tarong uses water from the WCRWS). So increased population and demand for power generation generally increases demand for water recycling. It also suggests that a desire to reduce overall emissions should concentrate on alternative methods of power generation, which would reduce the cost of water production and its subsequent use, as heating of water may be the biggest household contributor to environmental footprint (Kenway, Lant & Priestley 2011).

Combining water infrastructure with investment in alternative energy may be one solution. Saudi Arabia, for example, announced a plan in 2012 to build three solar powered desalination plants (Lack 2012). Sydney’s desalination plant sources energy from a purpose-built wind farm at Bungendore (Sydney Water 2014). Western Australia also sources energy for a Perth desalination plant from Emu Downs Wind Farm (Water Technology 2014). Melbourne Water (in conjunction with AGL) had developed biogas capture at its Western treatment Plant to cover much of its energy needs (Melbourne Water 2015).

Water recycling is a lower cost alternative for water supply in terms of energy use than many alternatives. Reverse osmosis (RO) used for wastewater recycling uses less energy than RO for saltwater, and the process at South Caboolture uses less energy for operation than RO at MDAWTP. Lane, de Haas & Lant (2012) did however suggest that the power consumption at SCWRP per volume of output was surprisingly high for a plant of its type. The study used a backwash rate of 18% which is higher than the data from either of the two months observed in this thesis in 2011 and 2012 (11-16.5% backwash and 83.5-89% product), and although the longitudinal study is more accurate, it does cover a slightly earlier period, and power efficiency may have improved. It also covers a period of the severe rainfall/flooding in late 2010 and early 2011. The mutual processes of a combined STP and attendant recycled water plant are highly susceptible to major rainfall events. Heavy rainfall was not a feature of either of the months in this case study. By contrast, in the two months examined here for the same period at the MDAWTP, the average product to input effluent ratio was 57% purified water (and 43% waste), with Lane et al. 2012 reporting 82% product in a similar system. However for the months in question the MDAWTP was running well below normal operating capacity and this may have affected results. Again the longitudinal approach of Lane et al. 2012 is likely to be more accurate.

As the results of studies based on power usage per level of output are highly dependent on accurate measurement of power use (compared to normal output levels for an operational plant), more accurate tracking of power use and a power audit at SCWRP would be beneficial, separating out the power use for various functions including delivery to end consumer.

NGER legislation is insufficient to capture the environmental implications of wastewater recycling compared to a life-cycle approach in respect to Scope 3 emissions. For both plants the GHG footprint of the chemicals used – primarily aluminium sulphate and sodium hydroxide for South Caboolture (Figure 4.12) – is another consideration, and this relates to the footprint of the manufacture rather than transportation (Lane, de Haas & Lant 2012 p. 23).

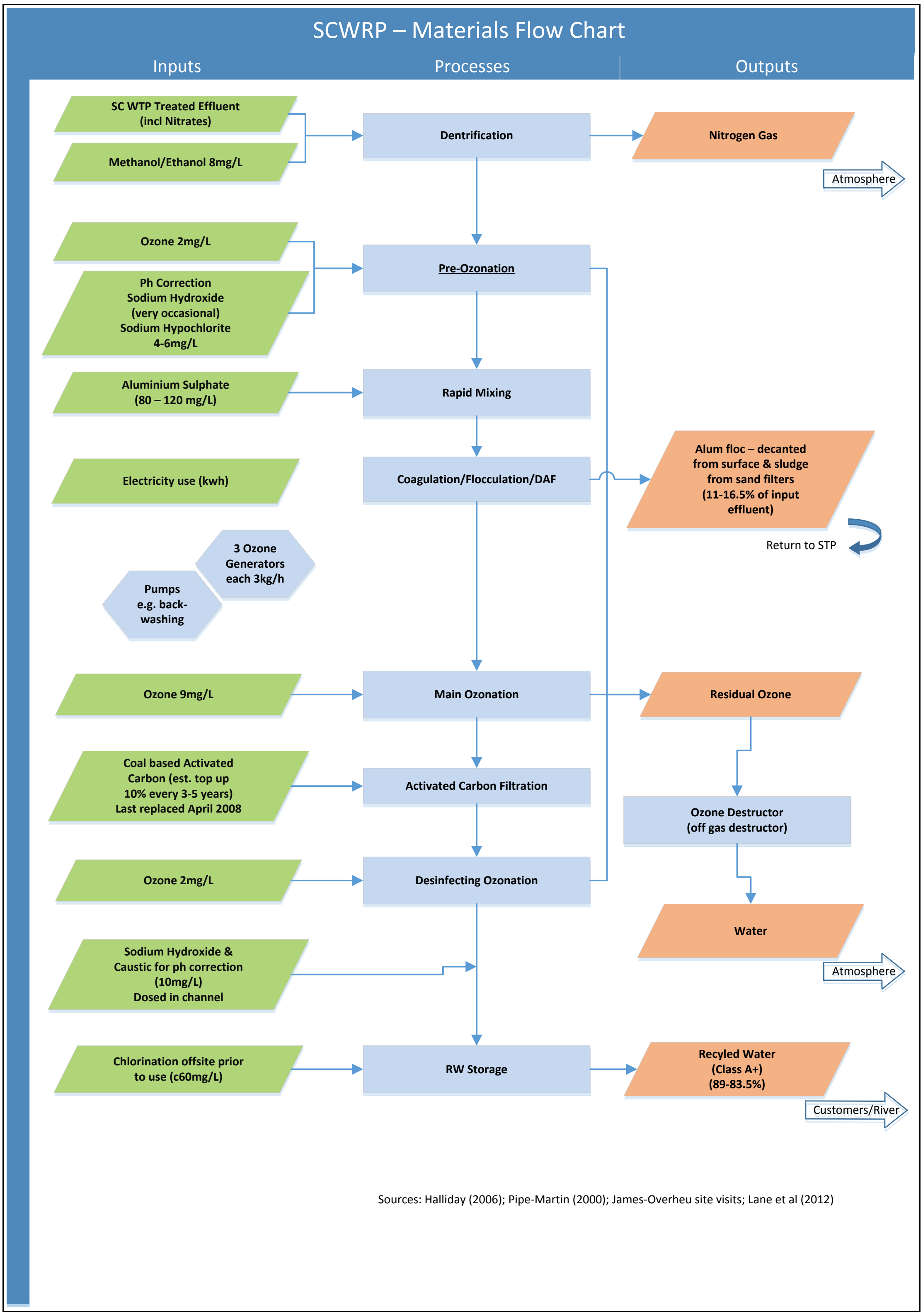


Figure 4.12 Materials flow chart for South Caboolture Water Reclamation Plant

Specific to MDAWTP, apart from higher energy use and the carbon footprint of chemicals used, there is also disposal of the brine waste to consider. The materials flow chart for MDAWTP is given in Figure 4.13. As the facility is located on a river, brine could be more problematic than at an ocean site. However release of brine was closely monitored and mixed in a 1:4 ratio with treated wastewater effluent from the adjacent waste water treatment plant (see Figure 4.13). This effluent also contained small quantities of chlorine (kept within monitored guidelines). More detailed monitoring of the river water quality in both rivers (Caboolture and Pine) would be beneficial (Lane, de Haas & Lant 2012). RO may be a less attractive option for a plant located further inland, as it may incur excessive transport costs in satisfactory disposal of brine effluent. Benefits of RO are that this water may be more attractive to industrial users who may have a lower salt or mineral tolerance in their production process. RO product water should also require less additional processing to be available for indirect potable use. It is possible that this may be a more socially acceptable methodology for treatment, given its use in desalination plants, although water *source* may still be a psychological barrier. Preference for treatment process was a question specifically asked of respondents in the survey section of this thesis, addressed in section 6.2.3 (see Table 6.1).

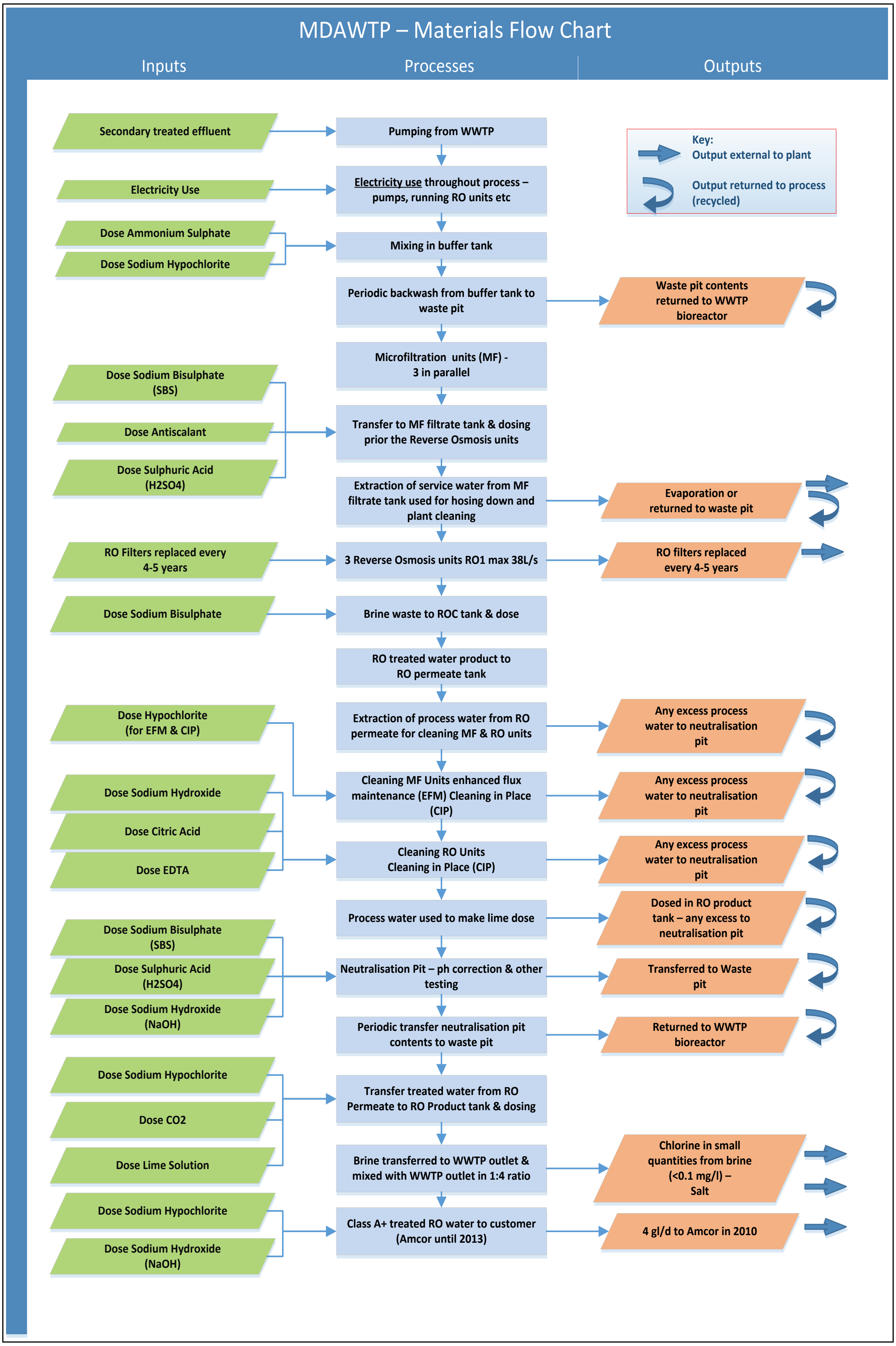


Figure 4.13 Materials flow chart for Murrumba Downs AWTP

4.5.3 Other externalities

The emphasis on wastewater treatment upgrades in the both the Caboolture and Pine river catchments has been on improvement in water quality in the waterway and estuary and this seems borne out by a reduction in waterway nutrient build up (eutrophication) (Daniels et al 2012b; Lane, de Haas & Lant 2012). However the eutrophication potential of power generation may also be significant, and recycled water use for agricultural use, whilst benefitting in reduction in fertilizer use, may also transfer contaminants from the riparian to the terrestrial environment (Lane et al 2012 p.18). Historically the river below Caboolture weir had had limited flow and poor tidal flushing which may be improved by excess recycled water flows added to the river and may result in improved recreational use opportunities. However the preferred option would presumably be to have greater uptake of recycled water to replace higher grade water sources (Lane, de Haas & Lant p. 23). Life cycle assessment suggests that the higher the replacement use, the greater the environmental benefit. So indirect potable use is preferable to non-potable use, and higher volumes of uptake of recycled water are important. This again suggests that the social aspect of recycled water use – willingness to use it and to use it for higher-end purposes- is key.

Lane, de Haas & Lant 2012 found that their study was sensitive to assumptions made about water displacement – and the assumptions made about the marginal source of mains water (desalination was assumed) - and data was lacking regarding the interaction between the available water sources. Unanswered questions included:

- How far will consumers be happy to use recycled water for uses currently using mains water and how far would rainwater tank use be replaced?
- Does the use of recycled water increase the overall household water usage and only partially replace other water sources?
- What are the accepted uses from a customer perspective?

These questions are partially addressed in the social section of this thesis – see section 4.5.

Controversy over acceptance, particularly with regard to higher personal contact uses, and strongly held opinions can lead to social tension and feelings of disempowerment (Daniels et al 2012b p.3). There is very limited data on the social aspect, and this was a motivating factor for the survey conducted for the social aspect section of this thesis.

Recycled treated wastewater from both plants has the advantage of offering a water supply even in times of drought, as it is relatively non rainfall dependant (Daniels et al 2012b). This has an added social aspect in that public spaces, particularly recreational such as community areas and sporting venues are able to be sustained and kept in use, despite other measures such as water restrictions. As mentioned, water security was the primary motivation for the industrial use customer at MDAWTP. Drought conditions may well have served to change residential customer perceptions about the scarcity value of water.

Conversely reduction in demand on mains water supply due to the existence of alternative supply sources could allow dams to be kept at a lower level at times of risk of high rainfall, to permit greater use of these for flood mitigation. Emergency release of water from dams filled to capacity has been a recent source of controversy in Queensland and management of dams is currently under investigation by the Queensland Government (Bailey 2015). This is the result of emergency releases after excessively high rainfall such as after cyclone Marcia in February 2015, causing Callide Dam to spill water with disastrous local social, economic and environmental consequences. It should be noted however that Callide dam was designed for water storage for irrigation and industry (primarily power generation) supply, not drought mitigation (IGEM 2015). In the event of flooding an alternative water supply may also be useful to supplement shortfalls due to inundation and damage to water infrastructure, as was the case in 2011.

A relevant aspect to consider, but not quantified in this thesis is the infrastructure implications in life cycle analysis. This includes the economic and environmental costs of building and long-term maintenance of various infrastructure, and also the avoided cost of infrastructure. Large-scale infrastructure such as dams and desalination plants are likely to have a greater environmental footprint, and in the case of dams a high social cost, as evidenced by the opposition to the proposed Traveston Crossing dam and its eventual cancellation under the Environment Protection and Biodiversity Conservation Act 1999 on the grounds of ‘listed threatened species and communities’ (Department of the Environment, Water, Heritage and the Arts 2009). It is possible that alternative sources of water such as wastewater recycling could obviate the necessity for more costly large-scale infrastructure. The increased use of recycled water for higher end use such as indirect potable use would also mean that existing pipework infrastructure could be used for distribution as recycled water added to an existing dam would pass through the existing treatment and distribution processes. It is also likely that this can be used to augment water supplies in situ where the (urbanised) demand is greatest. A more local solution, provided minimum economies of scale are met, should be less expensive in terms of transportation (i.e. pumping) costs and in disinfection costs (as water cannot be transferred or stored any distance without further treatment such as chlorination). At the height of the so-called ‘Millennium drought’ various plans were mooted to create new long-distance pipe works and even to ‘ship’ water in giant bladder barges (Jacquot 2007).

Recreational use of waterways such as dams can be affected by low water levels, which could be minimised if recycled water was added for indirect potable use. The potential to add recycled water from MDAWTP to Lake Kurwongbah, for example could improve dam levels (and perhaps even water quality as some recreational uses may have a detrimental effect on the dam water, particularly at low levels). Levels at Lake Kurwongbah are planned to be reduced for maintenance works in 2014, causing the closure of a water ski club (Hayward 2014). The marginal value of water for recreational use in reservoirs has been shown to be high (Ward, Roach & Henderson 1996), with low dam levels substantially reducing their use. Recycled water from treated wastewater has the advantage of being relatively less dependent on rainfall.

There are also health risks with recycled water (many similar to STP risks) but with an added risk of close contact risk in the case of a malfunction and the potential of cross-contamination of water supply (Daniels et al (2012b)) (at source or with the use of a dual reticulation system) as was the case with Tugun desalination plant in January 2013 (Stolz 2010; 2012). In Australia no adverse health consequences relating to recycled water have been reported to date. As mentioned this risk is most often related to human error, so human management risk assessment should be undertaken. To the limited extent that this could be appraised at the time of site visits to the two plants in this study, management systems appeared modern, well-regulated and efficient.

4.5.4 Key environmental points in relation to research questions

RP 1

- **How can a triple bottom line approach be used to provide a costing model for the full cost of Class A+ recycled water for use in South East Queensland?**

Environment is one of the key aspects of a TBL model. Such considerations are not typically impounded into the economic business systems and are considered externalities. This is largely therefore related to research questions 4 (externalities) and 3 (risk).

RQ 4

- What information beyond the current economic accounting system is required to provide a full cost accounting or TBL approach? i.e. defining the scope of included externalities

- Scope 1 GHG emissions – SCWRP. Possible Methane (CH_4), Carbon Dioxide (CO_2) and Nitrous Oxide (N_2O). Even low levels of Nitrous Oxide can have large GHG significance. Research suggests emissions likely to be lower with more advanced de-nitrification and no other studies found this to be a problem at South Caboolture. Not measured but likely to be minimal compared to emissions from STP. Further research might be beneficial.
- Scope 2 GHG – highest contribution to environmental footprint. For operations, higher consumption of energy for RO significantly more than for BAC/ozonation but may be exaggerated by high fixed costs for level of output. Lack of disaggregation of electricity costs but largest component of electricity costs expected to be distribution. Lower for delivery to local commercial customer(s) or for indirect potable use than for reticulation to domestic customers via indirect potable system.

  -Best method for reduction of GHG therefore more sustainable energy source e.g. biogas recovery from STP.

- If potable water supplies restricted, then value of easing the bottleneck (substituting recycled water for potable water) should be at cost of alternative supply. Value could be quite high if alternative is desalination.

- Scope 3 GHG – supplies of chemicals: GHG footprint of manufacture (similar for both); residual chlorine in water returned to river (during timeframe of study for SCWRP only as all supply from MDWTP to customer); brine in outflow to river from MDWATP potentially harmful but mixed with treated wastewater release in low concentrations and monitored so low risk.
- Environmental benefits: reduced outflow nutrient levels; retention local industry (employment); drought resistant water supply – increase in water security & planning for population increase; improved recreational use opportunities; deferred costs of alternative potable supplies; flexibility in water policy – possible permit lower dam levels (although would need much higher levels of recycling use for this); ability to substitute in potable water supplies compromised due to flooding.
- Most beneficial the higher the level of water substitution – so indirect potable use most cost effective
- Further information needed on electricity use split; how far recycled water actually substitutes for potable water in non-potable use; customer perceptions and reasons for opposition to indirect potable use

RQ 3

- What are the risks of recycling and how can they be managed?

- Health risk: Low risk of malfunction/human error if proper management systems in place but risk greater the closer the substitution (e.g. residential use).
- Environmental risk: Low risk re. chemical spills
- Political/commercial risk due to non-acceptance of indirect potable water use due to health risk.

5. Results – customer and social perspective

5.1 Introduction

The previous chapter 4 reported the results of methods used such as site visits, interviews, research and environmental management analysis in order primarily to gain information about the economic and environmental aspects. It also reported how these methods provided the information for an initial stakeholder analysis which helped to identify TBL aspects, including key stakeholders in the social aspect. The social aspect was then explored in depth via customer survey and Chapter 5 details the results for this part of the research and then draws the strands together for the concluding chapter 6.

5.2 Social aspect

5.2.1 Introduction

The social aspect of this thesis was addressed via stakeholder analysis (section 4.3.6) and by the use of a customer survey aimed at residents in the same Moreton Bay Regional Council area as the two case study treatment plants. However, as MDAWTP at the time served only one industrial customer, respondents would either be using dual reticulation supply from SCWRP or would not have access to purified recycled water. A copy of the survey instrument is provided in Appendix A.

The survey was principally designed to address Research Questions 6 and 7: What are the perceived benefits and risks (costs) of recycled water use for customers?; and what factors influence customer acceptance of PRW for potable use? The focus was therefore on exploring customer perceptions. However RQ2 was also relevant – to identify current uses of recycled water and attitudes toward acceptable uses for levels/grades of recycled water. In this respect attitudes towards water pricing, and the question of whether any value is placed by customers on externalities such as environmental considerations, is also relevant.

The survey was in four sections (A-D), as follows:

A. respondent demographic information and questions regarding their existing water use practices and general attitudes,
B. questions relating to recycled water in general (*non-potable*),
C. questions relating to *potable* standard water, and
D. questions related to the *pricing* of recycled water (both potable and non-potable).

The following sections report the findings from the survey instrument on these four aspects A-D and the final section in each summarises the main points as they relate to the research questions.

5.2.2 Responses to the survey instrument

The response rate of 11% was low, as expected with a lengthy mail survey, although the survey respondents did appear to be generally representative of the population (see 5.2.3), with a total number of 129 responses.

The complete recycled water customer list supplied by the water authority consisted of an initial list of 917 customer accounts. The intention was to survey the entire population, however a number of accounts were excluded. As the research was directed at actual users of recycled water in the region covered by the water authority, billing addresses for vacant land, for overseas or interstate addresses, for trustees, real estate and other agents were all excluded, a total of 158 excluded billing addresses. This left a remaining population of 759 recycled water customers, and these were all sent a printed survey (with the option of a URL to complete online if they wished). Of these customers, 66 (or 8.7%) replied via mail and a further 12 (1.6%) replied online making a total response from recycled water customers of 78/759 (10.3%).

A second mail out was sent to a further 434 residents in the same water authority area, not on the recycled water customer list, chosen from the white pages telephone directory. Of these 39 (or 9%) replied via mail and a further 12 (2.8%) replied online making a total response of 51/434 (11.8%).

Total customer responses (recycled water & non-recycled water) therefore were 129/1193 surveys sent, or a 10.8% response rate and this 129 was split 60% purified recycled water billing respondents to 40% non-recycled water respondents.

Table 5.1: Response rates for the customer survey

RESPONSE RATES							
Respondents	***mail***	**%**	***online***	**%**	**Responses**	**%**	**Total sent**
PRW list	66	8.7%	12	1.6%	78	10.3%	759
Non PRW	39	9.0%	12	2.8%	51	11.8%	434
Totals	105	8.8%	24	2.0%	129	10.8%	1193

5.2.3 Respondent Information (Survey Section A)

5.2.3.1 Descriptive statistics

On the whole the demographic statistics of the respondents matched that suggested by the 2011 census data for Caboolture area, although age and education levels which were higher for the survey respondents than average for the area (MBRC 2015).

Gender

The total number of respondents was 129. Of these 62 were male and 58 female, with the remaining 9 (7%) declining to give their gender. This is only slightly more of a response from males (51.7% of those identifying) compared to the 2011 census for Caboolture district which showed the population split 49.2% male and 50.8% female.

Table 5.2: Respondent gender compared to 2011 Moreton Bay census data

Gender	***Respondents (n=120)***	***2011 Census***
Male	51.7%	49.2%
Female	48.3%	50.8%

Age

The age of respondents ranged from 17-100 years with a mean of 53.05 years (mode 57) and a standard deviation of 14.956. The average age of all Moreton Bay residents in the 2011 census was 37, but the survey average age would necessarily be higher as it would be an adult in the household completing the survey (only 1 respondent was under 18). The cut-off ages for the 2011 census results did not distinguish aged 18 and over, but grouped ages 15-19 years and then 20-24 years and so on. Excluding the one respondent under 19, the survey results were grouped in ages similar to the 2011 survey for comparison. The results showed only slightly fewer respondents in each of the younger adult age brackets compared to the census data, and slightly fewer in the 65+ age group. The main difference was the 50-64 age bracket which was more strongly represented (39.3%) in the survey respondents than in the general population per to the census data for 2011 in Moreton Bay (25.6%) (ABS 2013). The full results are shown in Table 5.3 and Figure 5.1.

Table 5.3: Respondent age compared to 2011 Moreton Bay census data

Age	*Respondents (n=122)*	*2011 Census*
65+	23.8%	26.5%
50-64	39.3%	25.6%
40-49	15.6%	20.5%
30-39	15.6%	19.1%
20-29	5.7%	8.3%

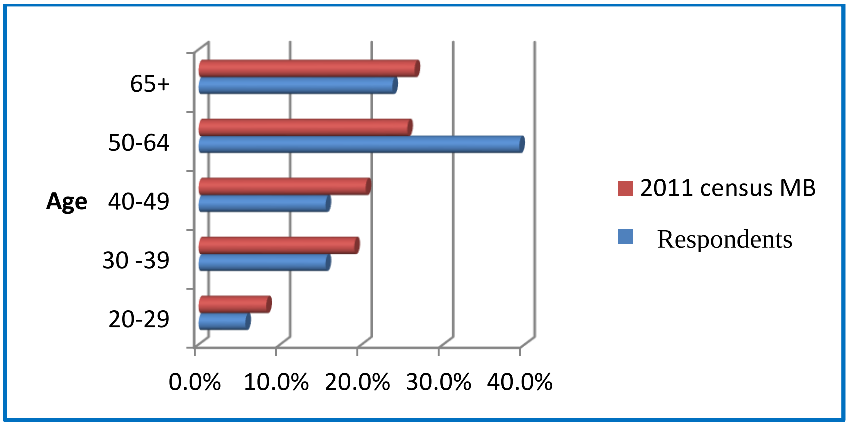


Figure 5.1: Age of Respondents compared to 2011 census

Given that the surveys were sent to the household member responsible for the water rates, then this bias is not surprising, as households with the head of the household aged between 50-64 are more likely to have young adults living in the same household (hence not appearing independently as respondents). Respondents were also asked to identify the number of people living in the household and to indicate how many were in the age groups 'under 12; child 12 or over; adults 18-29; adults 30-50; adults over

50' (Figure 5.2). The largest two groups were adults over 50 and adults 30-50. This was compared to 2011 census data, although the comparison was not exact because the age groupings were not identical in the two sources. Again the survey sample appears to have a larger proportion of members in the older categories than the 2011 census for Moreton Bay in general, although this is less pronounced for the household than for respondents themselves (Table 5.4).

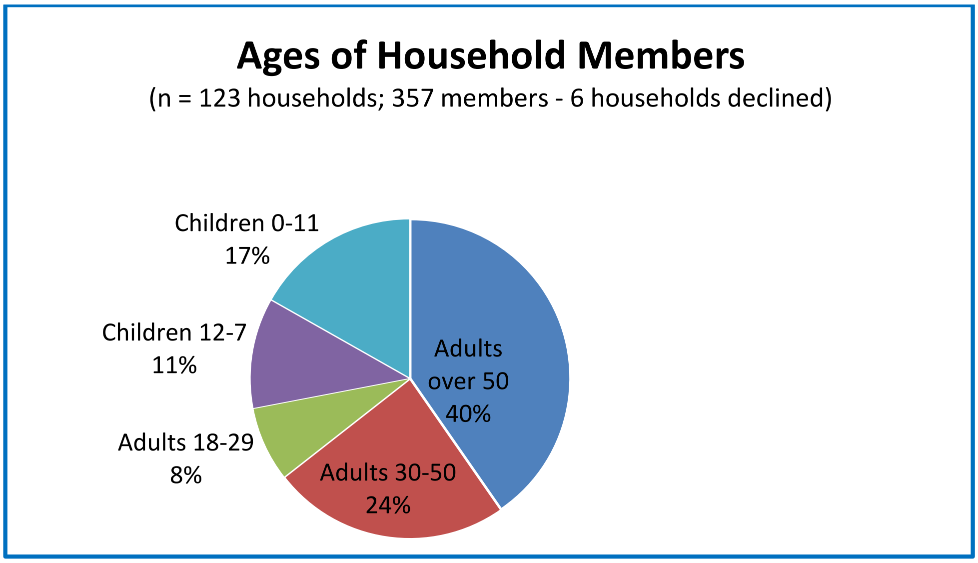


Figure 5.2: Ages of household members

Table 5.4: Household member ages compared to 2011 Moreton Bay census

Age groups	*Respondents*	*2011 Census*
51+; 50+	40.3%	31.1%
30-50; 30-49	24.1%	28.1%
18-29; 20-29	7.6%	11.7%
12-17; 10-19	11.2%	14.3%
0-11; 0-9	16.8%	14.8%
Totals	100.0%	100.0%

Prior research has provided some limited evidence that age plays a role in willingness to value the environment and to conserve natural resources (Wiernik, Ones, & Dilchert 2013) and in a willingness to pay for environmental benefits (MJA 2014b). This potential age-related bias was addressed by analysis of differences between age groups on the results for key survey questions, such as the influence of age on concern about water supply shortages (Table 5.8), however age was not found to be a major differentiating factor in environmental concerns in this study.

<u>Education level</u>

The majority of respondents were educated to high school/TAFE/ certificate level (50.4%), with a further 31% educated to undergraduate or postgraduate university level, 12.4% leaving school by year 10, and the remaining 6.2% declining to answer. This indicates higher education levels of respondents than the average for the area compared to 2011 census data. Per the census Moreton Bay had 20.1% (Caboolture 13.7%) residents who had completed higher education levels with 4.5% (3.8%) still attending; 22.2% (23.2%) completing vocational education and 27.9% (30.7%) attending school to year 10 (MBRC 2015).

Table 5.5 makes the comparison between respondents' self-declared education levels and those recorded in the 2011 census data for Moreton Bay and Caboolture. Although the education level for respondents is higher, it should be noted that as surveys were addressed to those responsible for water rates at the residence, the mean age of respondents was higher (53), whereas the census data is for all household members aged over 15, so a number of these would not yet have completed their education (27,016 or 7.1% of Moreton Bay residents were between 15-19 in 2011(MBRC 2015)).

Table 5.5: Respondent education levels compared to 2011 Moreton Bay census

Education Level	*Respondents*	*2011 Census Moreton B*	*Caboolture*
Under/post grad	31.0%	24.6%	17.5%
high school/TAFE/ certificate	50.4%	22.2%	23.2%
Year 10	12.4%	27.9%	30.7%
Survey: % of all respondents (min age 19) 2011 Census: % of total population aged 15 years or over			

As level of education was potentially another influence on attitudes towards environmental/sustainability issues, this was further investigated in the respondent analysis, such as the influence of age on concern about water supply shortages (Table 5.8). This study did find limited evidence that education level may be a differentiating factor in environmental concerns.

Households

The majority of those responding were a nuclear family living in their own house, and this is in line with the 2011 census data for the area. The mean household size was 2.9 people (mode 2), with and a standard deviation of only 1.348, and a minimum of 1 and a maximum of 7 (Figure 5.3). The vast majority of respondents were living in a house (88.4%) with a further 7.8 % living in a unit and 1.6% identifying as other (one was a unit being used as a business by a mechanic and the other a townhouse) with 2.3% declining to answer. Almost all identified as owning their own property (89.9 %) with only 6.2 % renting, one identifying as ‘other’ (unspecified – 0.8%) and 3.1% declining to answer. This was in clear parallel with the 2011 census results for the Moreton Bay Regional Council District and more specifically Caboolture. Average household size (2.69 MB; 2.7 C) and home type (separate house 84.4 % MB and 86.1% C) and ownership (65.7% MB and 62.2% C) were generally in line with 2011 census data (MBRC 2015), although there were fewer rental properties, because fewer rentals would be responsible for the water bills.

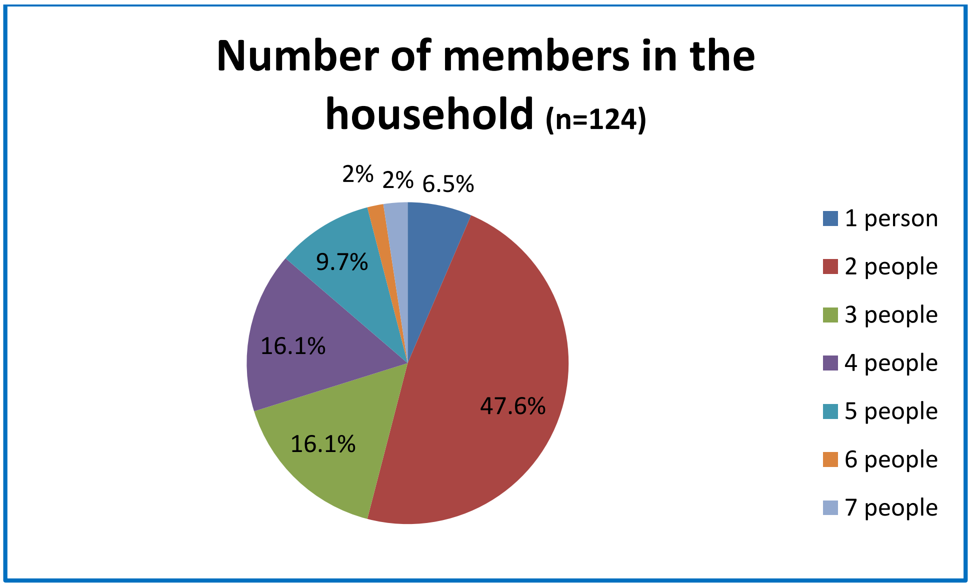


Figure 5.3: Numbers of members in each household

5.2.3.2 Existing Practices & Attitudes

Respondents were asked about their current household practices (RQ2), and some questions to reflect their attitude towards water shortages and use (RQs 6 & 7). A large majority of respondents (88%) expressed some concern about water shortages, regardless of gender or age, but results indicated that this attitude is influenced by education level. The rate of use of water-saving household devices was even higher and was normal practice.

Use of purified recycled water

The total of survey respondents were split fairly evenly between those using PRW (49.6%; n =64) and those who were not using PRW (50.4%; n=65). Despite seventy-eight (78) responses from the mail out to customers on the purified recycled water (PRW) supply list, only sixty-four (64) of these respondents identified as using purified 'purple pipe' recycled water (64; 82.1% of those with the facility available) and 14 (17.9%) did not. These last 14 were all treated as belonging to the non PRW users.

As it was considered surprising that 14 PRW respondents were not using the facility, and customer perceptions about the use of recycled water was a key research question, further analysis was done to identify the reasons for the fourteen (14) non-users within the group who had PRW available to connect to if they wished:

- Eight were identified as landlords for the properties with the PRW supply, and living in the local area, but who did not have PRW themselves, and were therefore included as part of the non-recycled water respondent group.
- Four had no need for the PRW supply as they had water from an alternative source (two from rainwater tanks and two from a dam/bore on their property). One of the respondents was using a rainwater tank but also commented about recycled water being more expensive.
- One stated that they would use the PRW if it was available, so clearly did not have the current choice to connect.
- Only one identified as making a deliberate choice not to use the PRW.

Use of water efficient devices (RQ2)

The results demonstrated that water saving practices were now usual practice, particularly the use of dual flush toilets, efficient shower heads and to a lesser extent water efficient washing machines and the use of rainwater tanks (Figure 5.4).

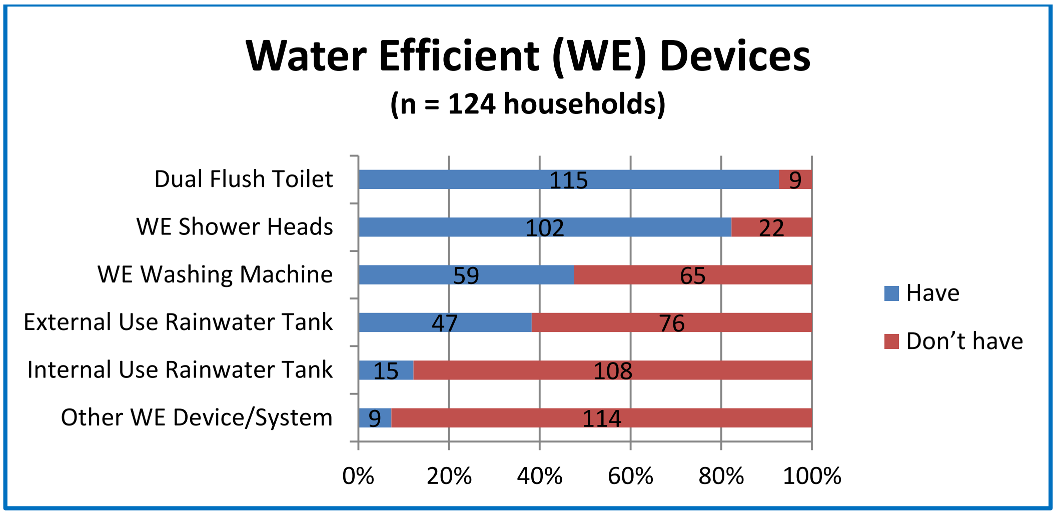


Figure 5.4: Types of water efficient devices used by households

Of the 124 respondents (5 declined) who filled in the section regarding water efficient devices, 92.7% had dual flush toilets installed, 82.3% used water efficient shower heads, 47.6% had front loading washing machines, 37.9% had a rainwater tank for external use, 12.1% had a rainwater tank for internal household water use and 7.3% (9 households) identified a further water saving device or practice other than the use of PRW (Figure 5.4). These included 2 households using spear pumps (bore water); 1 saving 'all internal water where possible'; 1 with water efficient taps; 1 using solar panels (presumably included due to an awareness of high water use in coal fired power stations); 1 using a dam; 1 with recycled water plumbed to the house; 1 using waste water from the washing machine/bath on the garden, and 1 using tank water for the toilets, garden and clothes. This last commented that 'a home should be fitted with an accessible alternative out to garden plumbing' to avoid DIY plumbing. Water efficient shower roses and dual-flush toilets were mandated for build approvals in Queensland from March 2006 (Department of Local Government, Planning, Sport and Recreation 2005).

<u>Concern regarding water shortages (RQ7)</u>

The vast majority of respondents expressed concerns regarding water shortages (88%) and had considered alternative water sources in the last five years (81%) (Figure 5.5), but few were affiliated to/donated to any environmental concern group (13.2%) (RQ 6). Concern about water supply was not affected by age or gender, although education appears to play a role in attitudes.

➢ *General concern regarding water & environmental issues*

Very few of the 129 respondents identified as being a member of, or donating to, an environmental group (13.2%; n=17), with 76.7% (99) not donating and 10.1% (13) declining to answer. However, there was an overwhelming (81%) expression of some level of concern about water supply shortages in the last five years with 29.4% indicating 'a great deal' of concern and a further 51.6% 'a little concerned', although 18.3% were 'not at all concerned' and 0.8% unsure (n=126). Similarly 83.2% of respondents had considered alternative sources of water either a great deal (26.4%) or a little (56.8%) with only 15.2% not having considered it at all and 1.6% unsure.

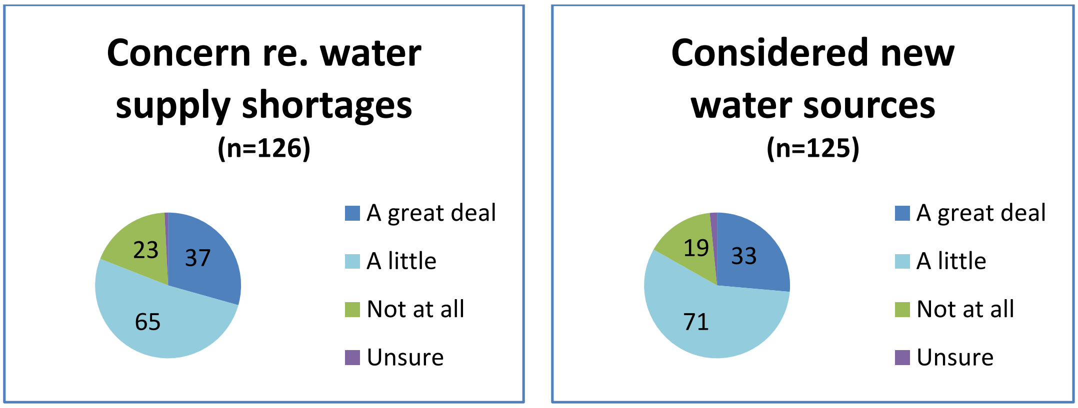


Figure 5.5: Concern about water shortages and the need for new supplies

➢ *Concerns regarding water shortages & influence of gender and age*

Further analysis confirmed that neither gender nor age played a role in concern over water supply shortages. Table 5.6 provides an overview of concerns about water supply by gender. Respondents not specifying gender were excluded leaving 120 respondents either 'Male' or 'female'. Although in each category the concern from females was marginally higher for female respondents, the Chi Square test p showed that there were no significant difference between the responses of males and females at the 5% level of significance (P= 0.72) with 30.6% of males and 31% of female respondents indicating they were concerned about water supply a great deal; 50.0% of males and 51.7% of female respondents indicating they were a little concerned; and 19.4% of males and 15.5% of female respondents indicating they were not at all concerned. The results of z-tests also indicated no differences in the proportion of male/female respondents in each of the corresponding response categories.

Table 5.6: Cross Tabulation concerns about water supply shortages by gender

Level of concern about water supply shortages (n =120)		*A great deal*	*A little*	*Not at all*	*Unsure*	*Total*
Male	Count	19	31	12	9	62
	% within category	30.6%	50.0%	19.4%	0%	100%
	% of total	15.8%	25.8%	10.0%	0%	51.7%
Female	Count	18	30	9	1	58
	% within category	31.0%	51.7%	15.5%	1.7%	100%
	% of total	15.0%	25.0%	7.5%	0.8%	48.3%
Total	Count	37	61	21	1	120
	Percentage of total	30.8%	50.8%	17.5%	0.8%	100%

However as the number of respondents was small, two of the categories had an expected count of less than 5, although these were both for the 'uncertain' responses. To be more statistically confident about the results, the test was re-calculated with fewer categories. The two categories expressing some concern regarding water supply ('a great deal' + 'a little') were combined as 'Yes' and the remaining categories combined to 'No' ('not at all' and 'unsure' -only 1 respondent was unsure).

Table 5.7 provides an overview of concerns about water supply by gender on this re-categorised basis. Again the percentage of females concerned was slightly higher but the Chi Square test p showed that there was no significant difference between the responses of males and females at the 5% level of significance (P= 0.77) with 81% of males and 83% of female respondents indicating that they are concerned about water supply.

Table 5.7: Cross Tabulation concerns about water supply shortages (revised to 2 categories) by gender

Concerned about water supply shortages (n =120)		*Concerned*	*Not Concerned*	*Total*
Male	Count	50	12	62
	% within category	81%	19%	100%
	% of total	42%	10%	52%
Female	Count	48	10	58
	% within category	83%	17%	100%
	% of total	40%	8%	48%
Total	Count	98	22	120
	Percentage of total	82%	18%	100%

Table 5.8 provides an overview of concerns about water supply by age, comparing responses from respondents placed in 5 ranges (17- 30; 31-45; 46-60; 61-75; 75-100). The Chi Square test p showed that there were no significant difference between the responses of the different age groups at the 5% level of significance (P= 0.485) regarding their degree of concern about water supply shortages. The results of z-tests also indicated no differences in the proportion of male/female respondents in each of the corresponding response categories.

Table 5.8: Cross Tabulation concerns about water supply shortages by age

Level of concern about water supply shortages (n =123)		*A great deal*	*A little*	*Not at all*	*Unsure*	*Total*
Ages 17-30	Count	2	6	2	0	10
	% within category	20.0%	60.0%	20.0%	0%	100%
	% of total	1.6%	4.9%	1.6%	0%	8.1%
Ages 31-45	Count	4	17	5	0	26
	% within category	15.4%	65.4%	19.2%	0%	100%
	% of total	3.3%	13.8%	4.1%	0%	21.1%
Ages 46-60	Count	19	19	9	0	47
	% within category	40.4%	40.4%	19.1%	0%	100%
	% of total	15.4%	15.4%	7.3%	0%	38.2%
Ages 61-75	Count	9	19	6	1	35
	% within category	25.7%	54.3%	17.1%	2.9%	100%
	% of total	7.3%	15.4%	4.9%	0.8%	28.5%
Ages 75-100	Count	3	2	0	0	5
	% within category	60.0%	40.0%	0%	0%	100%
	% of total	2.4%	1.6%	0%	0%	4.1%
Total	Count	37	63	22	1	123
	Percentage of total	30.8%	50.8%	17.5%	0.8%	100%

The results were however less reliable due to values less than 5 in a number of age categories. The test was repeated with a dichotomous division of ages into 45 and under and aged 45+ and four categories of level of concern with no significant difference between the age groups at the 5% level of significance (P= 0.163), and finally calculated again with both dichotomous age groups (adults under/over 45) and dichotomous level of concern regarding water supply 'yes' ('a great deal'/ 'a little') and 'no' ('not at all' /'unsure'). Table 5.9 provides an overview of concerns about water supply by age by comparing responses from respondents between 18-45 and those over 45 years of age. The Chi Square test indicates that there is no significant difference in the responses between the two age groups at the 5% level of significance (P= 0.892) with 81% respondents between 18 and 45 and 82% of respondents over 45 indicating they are concerned about water supply.

Table 5.9: Cross Tabulation concerns about water supply shortages by age –dichotomous groups

Concerned about water supply shortages (n=123)		*Yes*	*No*	*Total*
Age <=45 Years	Count	29	7	36
	% within category	80.6%	19.4%	100%
	% of total	23.6%	5.7%	29.3%
Age > 45 Years	Count	71	16	87
	% within category	81.6%	18.4%	100%
	% of total	57.7%	13.0%	70.7%
Total	Count	100	23	123
	Percentage of total	81.3%	18.7%	100%

➢ *Concerns regarding water shortages & influence of education*

Analysis regarding the influence of education level on concerns about water supply produced mixed results, as detailed in Table 5.10. Using only values from respondents who declared an education level (n=121), and using the aggregated answers ‘yes’ or ‘no’ regarding concern, a Pearson Chi Square test was performed. The results are significant at the 95% level (p = 0.015), and Cramer’s V (0.263) suggests a medium effect. The results of z-tests also indicated differences in the proportion of respondents answering yes/no, between respondents’ education categories.

There is some concern regarding validity given that 16.7% of cells have an expected count less than 5, but 20% is the usually accepted maximum. The main concern is the lack of fit with any logic or theory in interpretation. The two groups acting in the most similar manner are those with an education level primary-year 10 (100% ‘yes’ concerned), and those with a university level education (90% ‘yes’), with the greatest difference of opinion being in the high school/TAFE cohort (73.8% yes). So it cannot be surmised that education either increases or decreases levels of concern.

Table 5.10: Cross Tabulation concerns about water supply shortages by education

Concerned about water supply shortages (n=123)		Yes	No	Total
EDUCATION LEVEL To Year 10	Count	16	0	16
	% within category	100%	0%	100%
	% of total	13.2%	0%	13.2%
High school/ TAFE/Certificate	Count	48	17	65
	% within category	73.8%	26.2%	100%
	% of total	37.9%	14.0%	53.7%
University – Degree & post-grad	Count	36	4	40
	% within category	90.0%	10.0%	100%
	% of total	29.8%	3.3%	33.1%
Total	Count	100	23	123
	Percentage of total	82.6%	17.4%	100%

5.2.3.3 Research implications of Section A of the survey

The survey was principally designed to investigate the social/customer perspective, from current uses and attitudes to PRW to attitudes about possible future uses and willingness to pay for 'externalities' such as environmental concerns (RQ4). Section A was designed to paint a picture of the case study respondents - and find out their general attitude towards water shortages (RQ6) and the influences on this attitude (RQ7), and whether this is reflected in their current practices (RQ2).

General views about water scarcity and a willingness to conserve water suggested that externalities *do* have value in the eyes of the respondents.

- Most respondents were slightly older than the average for the area but the sample was similar to the 2011 census results for the population of the region in terms of small family size and living in their own home.
- A large majority of respondents were concerned about water shortages and open to the idea of alternative water sources and this was not - influenced by age or gender, although education played a role in attitudes.
- The vast majority had already taken steps to conserve water in the home with the use of water efficient domestic devices.

5.2.4 Recycled water –non drinking standard (Survey Section B)

Section B of the survey asked respondents about their water consumption levels and uses and their main source of drinking water and ratings for tap/mains water supply (RQ2). This then moved to awareness of, use of and source of any recycled water (RQs 2, 6 & 7). The remaining section was only completed by those with a purified recycled water (PRW) dual reticulation (purple pipe) non-potable supply.

Primarily households used mains tap water for their drinking supplies (90%) and expressed overall satisfaction with this (84%), although respondents were less certain about its safety regarding germs (61%) or chemicals (57%), indicating a possible lack of trust. Households may also underestimate their level of water use and the level of usage for different activities.

All types of recycled water were well known, although less so grey water and reclaimed stormwater. PRW respondents were marginally more likely to use storm water compared to non PRW respondents. The highest use was dual reticulation (sample bias as half were chosen specifically because they were PRW respondents) but a surprising 38% used rainwater tanks and the majority of households without PRW (55%) still use some form of recycled water. Analysis of those not using RW suggests that for a minority non-use is an active choice.

5.2.4.1 Water consumption levels and uses

Respondents were asked their water consumption levels and uses, and their main source of drinking water and ratings for tap/mains water supply. Responses indicated that householders underestimate their level of usage and misjudge the types of activities which consume the most water, particularly tap use. Ninety per cent of households primarily drank tap water, and were satisfied with this, although 26% filtered it. The next most used alternative was filtered tank water (5.4%).

- *Household level of water consumption*

The majority of respondents (n= 70; 55.1%) believed that their household's level of total water consumption, compared to other households of a similar size, was medium, 37.0% (47) thought it was low, and only 1.6% (2) considered their water consumption to be high. The remaining 6.3% were unsure (8) (total n =127 /129).

➢ *Ranking of water use activities*

The majority of respondents considered their three highest water consumption activities to be (1) shower/bath (2) clothes washing and (3) toilet flushing (Figure 5.6). Tap use tended to be underestimated (compared to actual use) and irrigation overestimated.

Respondents were asked 'what they used the most water for – ranked from 1 (most) to 7 (least) use (Figure 5.6). Three out of 127 respondents completing this question misinterpreted the question to be 'what do you use the most *mains* water for', and because they were using PRW for flushing toilets and the garden they gave '0' i.e. no use, for toilet flushing and irrigation. A further respondent only partially completed the question. These 4 responses have been excluded as it is not known what relative ranking they would have given. The category most commonly cited as having the heaviest water use was 'shower or bath' (35.8%) followed by 'clothes washing' (25.2%) and 'tap use' (14.6%) with a similar number putting 'irrigation' and 'toilet flushing' first (9.8% & 8.9%). Other water uses cited were fish ponds/aquaponics (one listing it as their main use) and washing vehicles. If the top three rankings (1-3) are combined, then the order of use is: shower/bath 27.7%; clothes washing 23%; toilet flushing 20.7%; tap use 16.8%; irrigation 9.2%; pool 2.2% & other 0.3%.

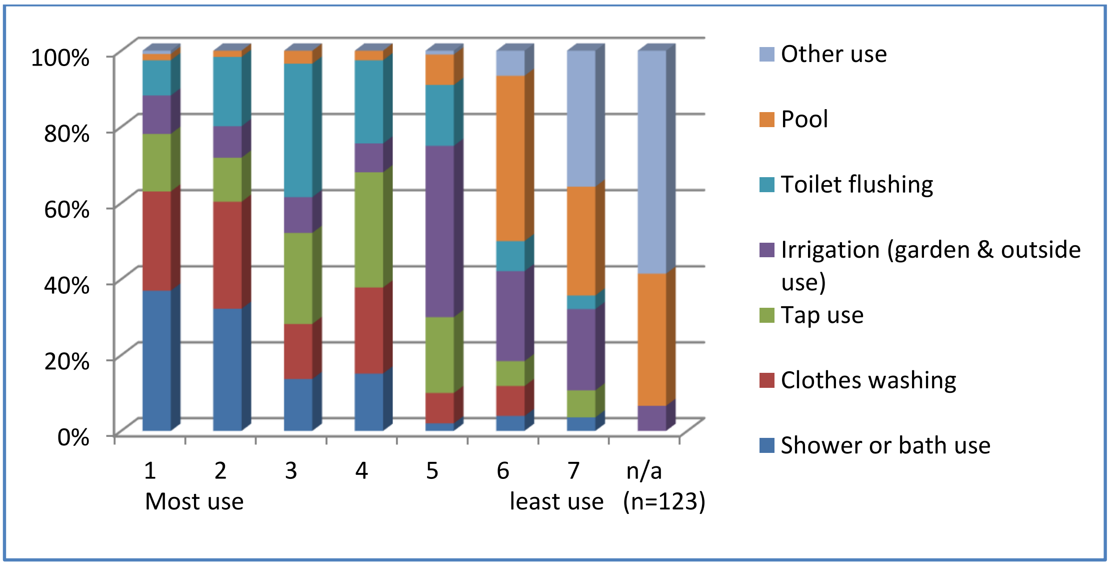


Figure 5.6: Household ranking of quantity of water used for different activities

A comparison of this perceived level of water use for each activity with actual water use recorded in a recent Queensland study by Beal and Stewart (2011) indicated that whilst households are broadly correct, two aspects of use – tap use and toilet flushing – may be underestimated by households, and one – irrigation use – isoverestimated by households. In the combined ranking in this study the top use is 'shower or bath' followed by 'clothes washing', 'toilet flushing' and then 'tap use' and next 'irrigation'. Beal and Stewart (2011) suggests shower as the top use (the same as the perception) and tap use the second use, which is perceived in this study as ranked lower in use. Irrigation and toilet flushing are perceived as having much closer ranking than reality as the actual use is much higher for toilet flushing than irrigation. This has implications for water conservation messages from water authorities where the emphasis should perhaps be on increasing awareness of tap use and promoting water efficient devices such as water efficient shower heads and dual flush toilets.

- *Primary drinking water source*

A large majority of households drink mains tap water (64%) or filtered tap water (26%) (Figure 5.7).

Householders were asked what their primary source of drinking water is. All householders completed this question (n=129) (Figure 5.7). The majority of households drink mains tap water (64.3%), but a sizeable number choose to drink filtered tap water (26.4%) and a perhaps surprising number drink filtered rainwater (5.4%) with the bottled water being the least used as a primary source (3.9%). The earlier question on water efficient devices showed that 38% of households had an external water tank and 12% had tank rainwater for internal use.

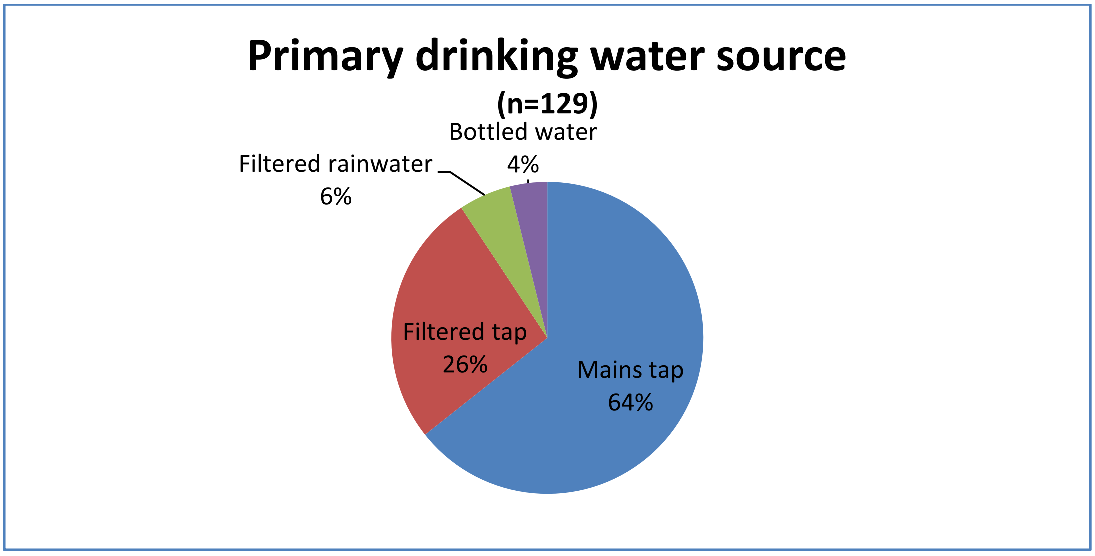


Figure 5.7: Sources used by households for their primary drinking water

5.2.4.2 Water supply satisfaction

➢ *Satisfaction with mains tap water supply quality*

The majority expressed overall satisfaction with mains tap water (84%) and were happy with the colour (91%), smell (82%) and taste (79%). However they were much more uncertain about safety as regards germs (61%) and chemicals (57%), which indicates a lack of trust in the water supply.

Respondents were further asked to ***rate*** their mains tap water supply on a 5 point scale from very good to very bad, in order to gauge their satisfaction with the supplied water source (Figure 5.8). They were asked to rank a number of attributes – overall quality; taste; colour; smell; safety (with regard to germs and also with regard to chemicals). These last two were included as previous studies suggest that suspicion regarding 'hidden' dangers in water supply and lack of trust towards water authorities and water regulation may be significant social costs/barriers of the introduction of alternative water sources.

The vast majority of respondents (83.6%; n=107) rated the *overall* quality of their mains water supply as either 'very good' (33.6%) or 'good (50%)'. Only eight respondents (6.3%) gave it a rating of either ‘bad’ (4.7%) or ‘very bad’ (1.6%). The remaining thirteen (10.2%) stated that they didn’t know.

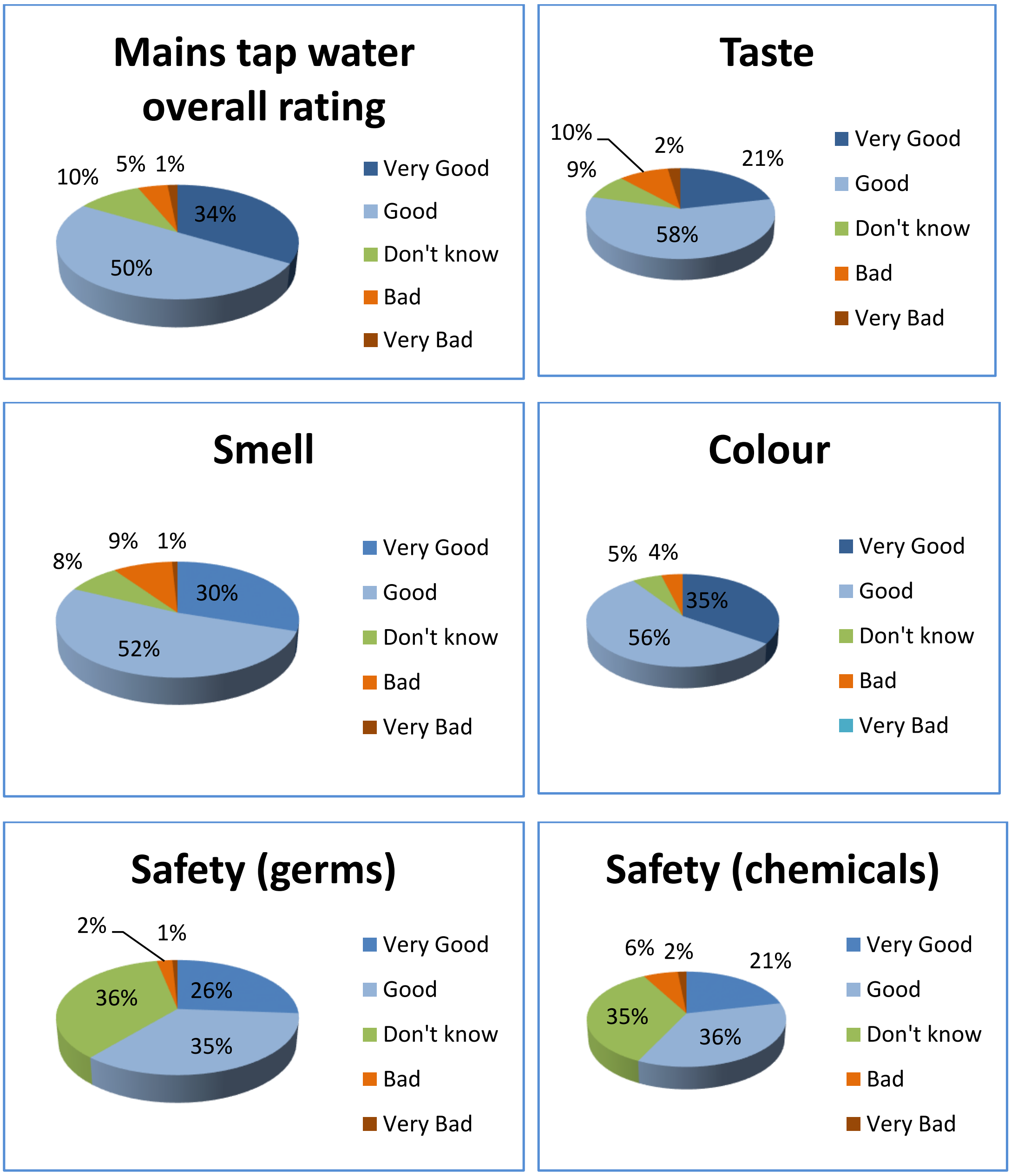


Figure 5.8: Ratings for attributes of mains water tap water

Mains water *‘colour’* was the attribute householders were most happy with, 90.6% rating this either ‘very good’ or ‘good’ (n=115) followed by *‘smell’* (82.1%; n=101) and ‘*taste’* (79.4%; n=100). Respondents rating these bad/very bad ranged from 3.9% for colour to 9.8% for smell and 11.9% for taste, with the remainder opting for ‘don’t know’ as their response. The two final attributes of mains water – *safety as regards* *germs and chemicals* - elicited a different response from householders. Householders were more sanguine as regards germs in the water – 61.1% (n=77) rating this either 'very good' or 'good' and only 3.2% rating it 'bad/very bad'. The remainder, a sizeable proportion at 35.7%, opted for 'don't know', presumably as this attribute is less obviously measurable (although experience of drinking water without ill health effects should mitigate this). This anxiety was slightly greater as regards chemicals with 57.1% of respondents considering water quality as regards this aspect 'very good/good' and an increased number at 7.9% rating it 'bad/very bad', and 34.9% unsure. This perhaps reflects earlier research findings regarding mistrust of potential centralised systems, such as large scale water recycling (Hurliman & Dolnicar 2010; Uhlmann & Head 2011; Leviston et al. 2006).

5.2.4.3 Recycled water awareness and use

The next part of section B of the survey sought to look at recycled water (RW) in general and then Purified Recycled Wastewater (PRW) in particular to discover how recycled water is being used by consumers, and how far one type of RW appears to be considered a suitable substitute for another. This was most relevant to RQ2, by painting a picture of RW uses which would lead into more detailed analysis of customer attitudes and perceptions regarding recycled water and ultimately shed light on whether it was considered acceptable for higher end use (e.g. to supplement potable supplies) by customers.

RQ 2

- How is recycled water defined and to what level should it be recycled? (substitute for industrial use/potable water added to consumer drinking supplies) What are its uses?

Most respondents *do* currently use recycled water of some sort (77.3%), and this was still the majority (55%) of householders even among non- PRW respondents. As consumers perceptions of RW risks (RQ6) and on the factors that influence the acceptance of PRW for potable use (RQ7) were of interest, reasons for non-use were also examined. No significant differences were found for use/non-use of RW, comparing respondents based on gender, age and education level. Analysis of those *not* using RW showed that whilst most were willing to use PRW (71%), a sizeable minority (29%) indicated their non-use to be an active choice. This is of interest to policy-makers, and highlights the social cost of RW use in that perceptions would need to be managed.

➢ *Awareness and use of recycled water options*

This part of Section B of the survey investigated respondents' awareness of the options for recycled water sources, and the sources of recycled water currently in use by households, if any. Table 5.11 provides an overview of the responses regarding awareness of recycled water sources and uses. All types of recycled water were well known, though less so grey water and reclaimed stormwater. PRW respondents were marginally more likely to use storm water. The highest use was dual reticulation (sample bias as half were chosen specifically because they were PRW customers) but a surprising 38% used rainwater tanks and the majority of households without PRW (55%) still use some form or recycled water.

Table 5.11: Awareness of recycled water and uses of recycled water

	Have you *heard* of this type of recycled water?				Do you *use* of this type of recycled water?					
Source of RECYLCED Water	**YES**		**NO**		**Yes**		**No**		**Don't know**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Recycled water from treated wastewater	124	97.6%	3	2.4%	64	49.6%	62	48.1%	3	2.3%
Reclaimed stormwater	94	81.0%	22	19.0%	16	13.8%	92	79.3%	8	6.9%
Grey water re-use	106	88.3%	14	11.7%	20	16.8%	92	77.3%	7	5.9%
Rainwater tank	120	100.0%	0	0.0%	45	37.8%	70	58.8%	4	3.4%
Desalinated seawater	110	93.2%	8	6.8%	1	0.8%	115	94.3%	6	4.9%

Overall the types of recycled water sources were widely recognised. All respondents had heard of recycled water from rainwater tanks (100%) and 37.8% used these. The vast majority of respondents had also heard of recycled water from treated wastewater (97.6%) and this was the most widely used recycled water at 49.6%, unsurprising as this was the targeted customer type. A high proportion had also heard of desalinated recycled water (93.2%), and only one respondent claimed to be using this, which is likely to be respondent error as such water is not available for domestic customer use in the area, with the existing local desalination plants exclusively supplying commercial customers.

Grey water re-use was slightly less well known (88.3%), although 16.8% of households were using this, and perhaps the term needed to be more fully explained. The lowest level of recognition was regarding recycled water from reclaimed stormwater, although still quite high at 81.0%, with 13.8% using this water source.

In order to investigate whether householders already using purified recycled water (PRW) are more aware of recycled water options, the responses were split between those using and those not using PRW and the percentages of respondents aware of alternative sources compared (Table 5.12). Overall the responses are similar, but there is a slight tendency for those currently using PRW to be more aware of the alternative sources of recycled water. In each instance the percentage of respondents having heard of a recycled water source type was the same or slightly higher for the respondents already using PRW.

Table 5.12: Awareness of recycled water – comparing PRW users and non-users

Do you use purple pipe PRW?	Yes -use				No - do not use				n
	Yes - Heard of		*No - Not heard of*		*Yes - Heard of*		*No - Not heard of*		
Heard of Recycled Waste water	64	100%	0	0%	60	95%	3	5%	127
Heard of Storm water re-use	43	81%	10	19%	51	81%	12	19%	116
Heard of Grey water re-use	52	91%	5	9%	54	86%	9	14%	120
Heard of Rainwater tanks	56	100%	0	0%	64	100%	0	0%	120
Heard of Desalinated water	53	96%	2	4%	57	90.5%	6	9.5%	118

To determine whether there was any significant difference between the respondent groups, other than random variation, a Pearson's Chi-Square test was performed. Table 5.13 provides an overview of respondents who have/have not heard of the various sources of recycled water, comparing responses from respondents who do and don't already use PRW. The Chi Square test p showed that there were no significant differences between the responses of the PRW and non PRW respondents at the 5%

level of significance (recycled waste water P= 0.077; storm water P= 0.98; grey water P= 0.347; rain water P= 1; desalination P= 0.204) regarding awareness of recycled water sources. Z-tests also indicated no difference in proportion of respondents in each of the corresponding categories. For recycled waste water and desalinated water 2 cells had an expected count less than 5, as all/nearly all respondents had heard of recycled rainwater/ desalination.

Table 5.13: Cross Tabulation of awareness of RW sources by PRW users/non-users

Do you have purple pipe PRW?		*Yes- use*	*No- don't use*	*Total*
RECYCLED WASTE WATER	Count	64	60	124
	% within category	100%	95.2%	97.6%
Heard of	% of total	50.4%	47.2%	97.6%
Not Heard of	Count	0	3	3
	% within category	0%	100%	2,4%
	% of total	0%	2.4%	2.4%
Total	Count	64	63	127
(n=127; p=0.077; z same)	Percentage of total	50.4%	49.6%	100%
STORM WATER RE-USE	Count	43	51	94
	% within category	81.1%	81.0%	81.0%
Heard of	% of total	37.1%	40.0%	81.0%
Not Heard of	Count	10	12	22
	% within category	18.9%	19.0%	19.0%
	% of total	8.6%	10.3%	19.0%
Total	Count	53	63	116
(n=116; p=0.98; z same)	Percentage of total	45.7%	54.3%	100%
GREY WATER RE-USE	Count	52	54	106
	% within category	91.2%	85.7%	88.3%
Heard of	% of total	43.3%	45.0%	88.3%
Not Heard of	Count	5	9	14
	% within category	8.8%	14.3%	11.7%
	% of total	4.2%	7.5%	11.7%
Total	Count	57	63	120
(n=120; p=0.347; z same)	Percentage of total	50.4%	49.6%	100%
RAINWATER TANKS	Count	56	64	120
Heard of	% within category	100%	100%	100%
	% of total	46.7%	53.3%	100%
Total	Count	56	64	120
(n=120; p=1; z same)	Percentage of total	46.7%	53.3%	100%
DESALINATED WATER	Count	53	57	110
	% within category	96.4%	90.5%	93.2%
Heard of	% of total	44.9%	48.3%	93.2%
Not Heard of	Count	2	6	8
	% within category	3.6%	9.5%	6.8%
	% of total	1.7%	5.1%	6.8%
Total	Count	55	63	118
(n=118; p=0.204; z same)	Percentage of total	46.6%	53.4%	100%

Actual use of recycled water – from any source

Householders were also asked whether or not they used *any* type of recycled water, and if not they were asked to state whether they *chose* not to use recycled water, or whether they would use recycled water if it was available. They were also given the opportunity to make additional comments if they wished. Users were also asked how long they had been using recycled water.

Most respondents *do* currently use recycled water of some sort (77.3%; n = 99), with 22.5% not using any (n=29) and only one respondent declining to answer (Figure 5.9). Excluding those respondents whose properties have recycled water supplied via the PRW purple pipe system, 55.4% of the remaining respondents (36/65 households) still used some recycled water.

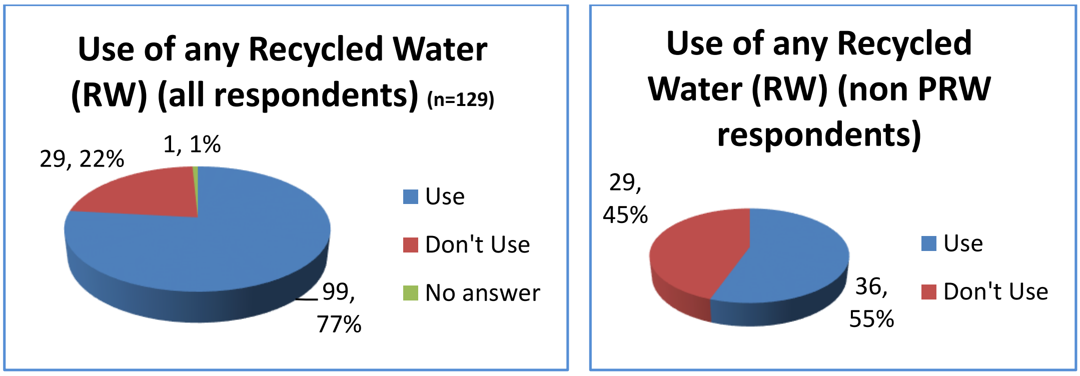


Figure 5.9: Proportion of respondents using recycled water

➢ *Reasons given for non-use*

Of the reasons given for non-use by all respondents (n= 31), a large majority (71.0%; n=22) indicated that they would use recycled water if it was available, but 29.0% (n=9) indicated that their non-use was a positive choice (Figure 5.10). This suggests a sizeable minority still with strong negative views towards use of recycled water.

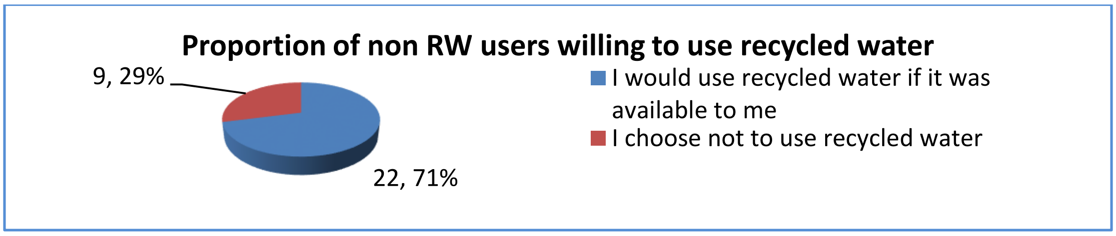


Figure 5.10: Proportion of non RW users willing to use recycled water

As the reasons for non-use of recycled water were of interest to the research as they may shed light on perceived risks (RQ6) and on the factors that influence the acceptance of PRW for potable use (RQ7), further analysis was undertaken to investigate any interactions between gender, age group or education level and the decision not to use RW.

Table 5.14 provides an overview of the reason given for not using recycled water, comparing responses from respondents based on gender, age and education level. The Chi Square test p showed that there were no significant differences between the responses of any of the different groups at the 5% level of significance (gender P= 0.69; age P= 0.976; education level P= 0.662) regarding the reason given for not using recycled water. Z-tests results also indicated no differences in the proportion of respondents in each of the corresponding response categories. Due to the small sample size, however, some cells had expected counts less than 5 in all tests.

Table 5.14: Cross Tabulation of reasons for non-use of RW by gender/age/ education

Why don't you currently use RW?		***Choose not to use***	***Would use if available***	***Total***
GENDER (n=30) **Male**	Count	5	10	15
	% within category (m)	55.6%	47.7%	50%
	% of total	16.7%	33.3%	50%
Female	Count	4	11	15
	% within category (f)	44.4%	52.4%	50%
	% of total	13.3%	36.7%	50%
Total	Count	9	21	30
	Percentage of total	30.0%	70.0%	100%
AGE (n=29) **Less than 45**	Count	3	8	11
	% within category	37.5%	38.1%	37.9%
	% of total	10.3%	27.6%	37.9%
Over age 45	Count	5	13	18
	% within category	62.5%	61.9%	62,1%
	% of total	17.2%	44.8%	62.1%
Total	Count	8	21	29
	Percentage of total	27.6%	72.4%	100%
EDUCATION LEVEL (n=29) **To Year 10**	Count	0	2	2
	% within category	0%	9.5%	6.9%
	% of total	0%	6.9%	6.9%
High school/ TAFE/Certificate	Count	6	14	20
	% within category	75%	66.7%	69%
	% of total	20.7%	48.3%	69%
University – Degree & post-grad	Count	2	5	7
	% within category	25%	23.8%	24.1%
	% of total	6.9%	17.2%	24.1%
Total	Count	8	21	29
	Percentage of total	27.6%	72.4%	100%

- *Respondent comments*

There were nine other comments made (Table 5.15). Six respondents expressed the view that they would use recycled water for non-drinking outside use. One expressed concerns about the source, another about bacteria in mains supply, and another about the energy consumption and salt waste from desalination. Another expressed disappointment at the lack of plumbing in house building providing for toilet flushing etc. using recycled water.

Table 5.15: Other comments made by respondents regarding RW use

- Would use but depends on what type/source
- Would use to water my plants
- I have a house at Caboolture that uses recycled water for toilet flushing & gardens/car wash. GREAT IDEA!
- I object to desalination of water - it wastes energy & pollutes the ocean where it dumps salt into the ocean.
- I would like to use toilet flushing & garden use
- I would use RW for non-drinking purposes. I have my doubts in the main water supply. I am sure there are bacteria in the main because a lot of us have chronic cough. Tap water is not enjoyable to drink at all. There is room to test the purification of our mains tap water supply.
- Technology not clear. Do yourself plumbing a nuisance factor. A home should be fitted with accessible alternative out to garden plumbing. Use tank for toilet, garden & clothes.
- Use grey water from washing machine & container under taps for garden & lawn.
- Would use for washing of clothes & outside use & toilet flushing

- *Types of RW used*

Taking all respondents (which includes those selected because they have PRW available), the most commonly used recycled water was PRW from treated wastewater (44%), closely followed by rainwater tanks (31%), then grey water (14%) and stormwater (11%) (Figure 5.11)

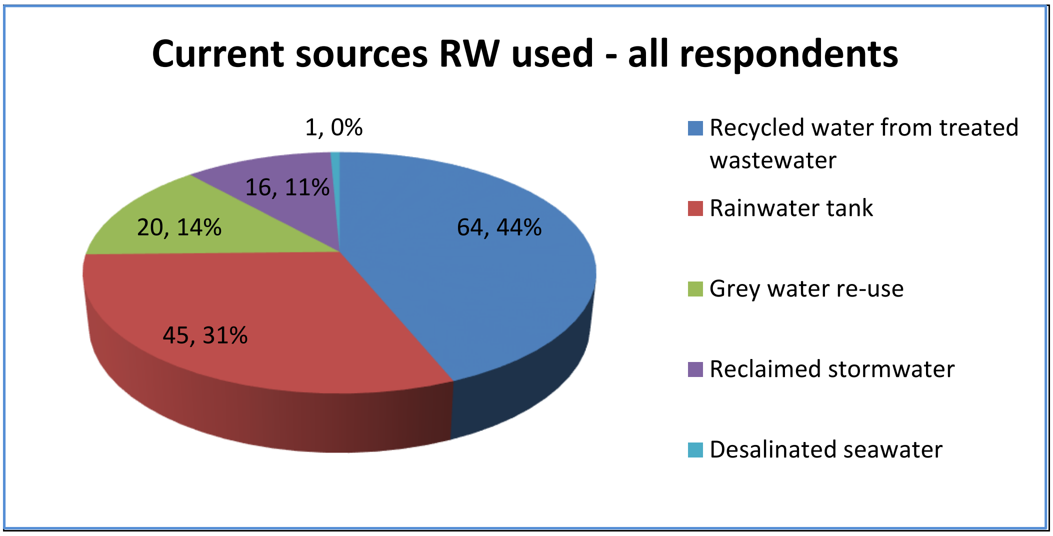


Figure 5.11: Current sources of recycled water used - all households

Looking separately at the respondents for whom PRW from treated wastewater was available (n=64; 49.6%) (Table 5.16) and those for whom it was not (n=65; 50.4%), (Table 5.17), some PRW respondents also used storm water (n = 11; 20.3% of those responding to that question; 17.2% of the 64 PRW households), and an equal number had rainwater tanks (n =11; 19.6% of answers) and some used recycled grey water (n =8; 14% of answers). For those not able to use PRW, most had rainwater tanks (n = 34; 53.4% of those responding to that question; 52.3% of the 65 non PRW households); and many used recycled grey water (n=11; 17.7% of answers), and some used stormwater (n=5; 8.1% of answers). One respondent identified as using desalinated water (not available in the area).

Table 5.16: Sources of recycled water used –PRW user respondents only

Do you have PRW supplied?	yes (n = 64; 49.6%)									TOTAL
Do you use the following:	Yes			No			Total	declined/ unsure		PRW
	n	% ans	% total	n	% ans	% total	no. ans	n	%	n
use recycled waste water	64	100%	100%	0	0.0%	0.0%	64	0	0.0%	64
use recycled storm water	11	20.3%	17.2%	43	79.6%	67.2%	54	10	25.0%	64
use recycled grey water	8	14.0%	12.5%	49	86.0%	76.6%	57	7	10.9%	64
use rainwater tanks	11	19.6%	17.2%	45	80.4%	70.3%	56	8	12.5%	64
use desalinated water	0	0.0%	0.0%	58	100%	90.6%	58	6	9.4%	64

Table 5.17: Sources of recycled water used –non PRW respondents only

Do you have PRW supplied?	NO (n = 65; 50.4%)									TOTAL
Do you use the following:	yes			no			Total	declined/ unsure		Non PRW
	n	% ans	% total	n	% ans	% total	no. ans	n	%	n
use recycled waste water	0	0.0%	0.0%	65	100.0%	100%	65	0	0%	65
use recycled storm water	5	8.1%	7.7%	57	91.9%	87.7%	62	3	4.6%	65
use recycled grey water	11	17.7%	16.9%	51	82.3%	78.5%	62	3	4.6%	65
use rainwater tanks	34	53.4%	52.3%	29	46.0%	44.6%	63	2	3.1%	65
use desalinated water	1	1.6%	1.5%	63	98.4%	96.9%	64	1	1.5%	65

The respondent group is small, but suggested that respondents already using PRW were more inclined to also use reclaimed stormwater.

Results using a Chi-Square partially confirmed this. Table 5.18 provides an overview of respondents using/not using various recycled water sources, comparing responses from respondents who do and don't already use PRW. Naturally PRW respondents answered that they were using PRW and those without PRW purple pipes replied that they did not. This has been included in the table merely to suggest the robustness of the survey instrument. The Chi Square test p showed that there were no significant differences between the responses of the PRW and non PRW respondents at the 5% level of significance for grey water use (P= 0.581), but at the same level of significance for storm water it was marginal (P= 0.055), which provides weak evidence that there is a difference between the two groups. For rainwater tank use the difference was significant (p= 0.00), as might be expected with less incentive to install a rainwater tank if you already have a PRW supply. However the PRW does not - entirely replace rainwater tank water use, with 19.6% of PRW respondents also using rainwater. Presumably this is for higher end uses not permitted for PRW.

Table 5.18: Cross Tabulation of use of sources of RW by PRW users/non-users

Do you have purple pipe PRW?		*Yes*	*No*	*Total*
RECYCLED WASTE WATER **Use**	Count	64	0	64
	% within category	100%	0%	49.6%
	% of total	49.6%	0%	49.6%
Don't Use	Count	0	65	65
	% within category	0%	100%	62.1%
	% of total	0%	50.4%	62.1%
Total	Count	64	65	129
(n=129; p=0.000; z diff)	Percentage of total	49.6%	50.4%	100%
STORM WATER RE-USE **Use**	Count	11	5	16
	% within category	20.4%	8.1%	13.8%
	% of total	9..5%	4.3%	13.8%
Don't Use	Count	43	57	100
	% within category	79.6%	91.9%	86.2%
	% of total	37.1%	49.1%	86.2%
Total	Count	54	62	116
(n=116; p=0.055; z same)	Percentage of total	46.6%	53.4%	100%
GREY WATER RE-USE **Use**	Count	8	11	19
	% within category	14.0%	17.7%	16%
	% of total	6.7%	9.2%	16%
Don't Use	Count	49	51	100
	% within category	86.0%	82.3%	84%
	% of total	41.2%	42.9%	84%
Total	Count	57	62	119
(n=119; p=0.581; z same)	Percentage of total	47.9%	52.1%	100%
RAINWATER TANKS **Use**	Count	11	34	45
	% within category	19.6%	54.0%	37.8%
	% of total	9.2%	28.6%	37.8%
Don't Use	Count	45	29	74
	% within category	80.4%	46.0%	62.2%
	% of total	37.8%	24.4%	62.2%
Total	Count	56	63	119
(n=119; p=0.000; z diff)	Percentage of total	47.1%	52.9%	100%

5.2.4.4 Respondent uses for all forms of recycled water

This section of the survey, having established the level of RW use and the main sources, turned to look at the actual use RW water was being put to by respondents (RQ2) and examine attitudes to 'acceptable' uses (RQs 6 & 7). Current PRW use respondents were generally established customers who ranked their drinking water use and consumption of recycled water as low. Non PRW respondents used their recycled water primarily for garden watering, and PRW respondents used it more for toilet flushing, plumbing issues being cited by non PRW respondents as the main issue for not using recycled water for toilets.

- *How long had respondents been using recycled water?*

Respondents *currently using* recycled water were asked how long they had been using it and to self-assess their level of drinking water and recycled water consumption. The majority of respondents had been using recycled water for more than 2 years (n=69; 71.9%); with another 25% (n=24) using recycled water for 1-2 years, and only 3.1% using recycled water for less than a year. Use of recycled water in some form therefore is well established among users.

- *Level of use of drinking water and recycled water*

Most households ranked their volume of consumption of drinking water as low (68%), with a further 20.6% ranking themselves as medium users, and only 4.1% as high use of drinking water. A further 5% were unsure. Given that mean household size in the sample is 2.9 people (mode 2), this appears realistic.

Most households ranked their volume of consumption of recycled water as low, but at a lesser percentage (56.4%), with a further 24% ranking RW use as medium, and only 4.3% as high use with 6.4% unsure. This would reflect a ranking of outside water use as slightly higher than drinking water use.

- *How are respondents currently using their recycled water?*

The most common uses of any recycled water were for garden, car washing and toilets followed by other non-recommended uses for PRW, but this did *not* necessarily mean inappropriate use as many respondents also had rainwater tanks. PRW respondents were more likely to use recycled water for toilet flushing, and other RW users to use it primarily for gardening.

Respondents were asked to indicate what their recycled water was used for (Figure 5.12 and Table 5.19). Class A+ PRW is *not* recommended or intended for clothes washing, drinking, cooking, or showering, or pool top up, however households may be using rainwater tanks for these purposes. Almost all households used recycled water (RW) for garden watering (94.8%), and most also for car washing (82.1%) and toilet flushing (72.9%). A smaller but substantial number also used it for clothes washing (18.9%), and for drinking (10.6%), cooking (7.4%) and the least use was for showering (5.3%). Other uses (5.2%) consisted of pool use (3.9%) and the last was boat washing (1.3%).

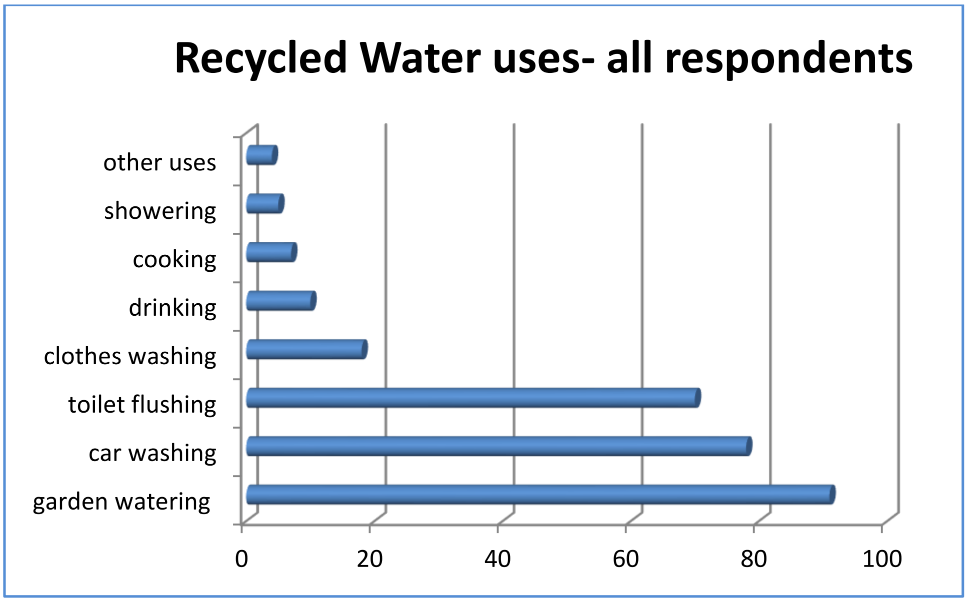


Figure 5.12: Uses made by all households of their recycled water

Table 5.19: Uses made of recycled water – all respondents

Do you use RW for:	yes		no		don't know		TOTAL
	n	% ans	n	% ans	n	%	no.
toilet flushing	70	72.9%	25	26.0%	1	1.0%	96
garden watering	91	94.8%	4	4.2%	1	1.0%	96
car washing	78	82.1%	16	16.8%	1	1.1%	95
clothes washing	18	18.9%	75	78.9%	2	2.1%	95
drinking	10	10.6%	83	88.3%	1	1.1%	94
cooking	7	7.4%	86	91.5%	1	1.1%	94
showering	5	5.3%	87	92.6%	2	2.1%	94
other uses	4	5.2%	72	93.5%	1	1.3%	77

The two groups (those with PRW access and those without) were again analysed separately, to examine any difference in the pattern of RW use, and then the results compared (Figure 5.13). The highest RW use for respondents with PRW available was toilet flushing (93.8% of those responding to the question), closely followed by garden watering (93.8%) and car washing (87.5%). More of the PRW users were using their RW for toilet flushing than the total group. RW was also being used for purposes not permitted for PRW such as (12.7%) clothes washing; (4.76%) drinking; (3.2%) cooking and (1.5%) showering. This does not necessarily mean that these respondents customers are misusing the PRW, given that 20.4% of PRW respondents stated that they also has rainwater tanks.

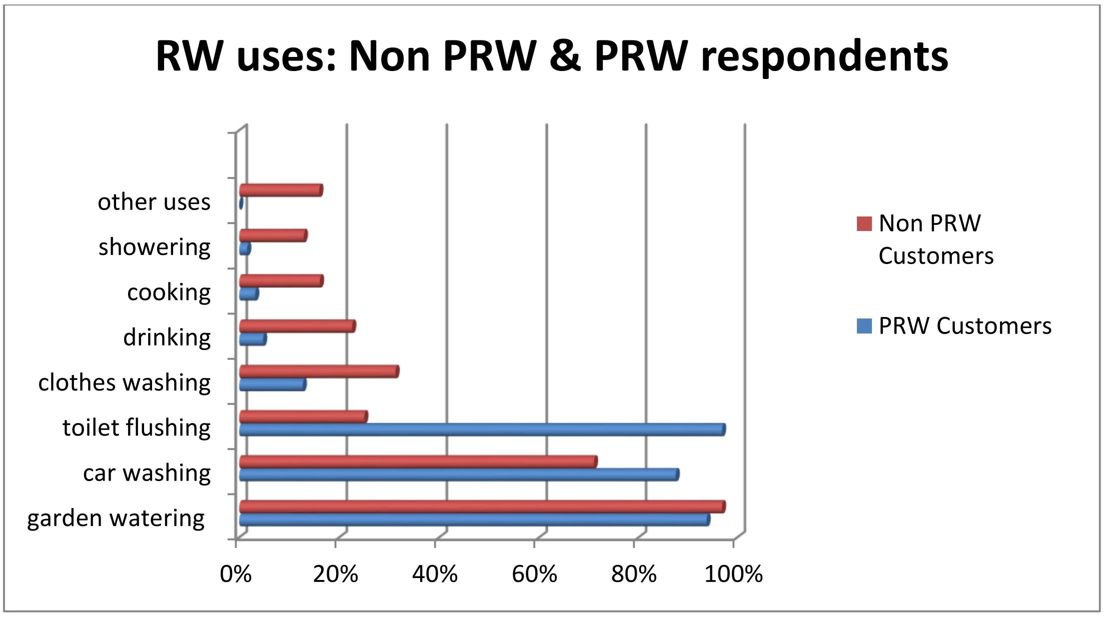


Figure 5.13: Comparison of recycled water uses between PRW/non PRW respondents

The ranking of uses was different for highest RW use for respondents without PRW available (Figure 5.13). The highest use was overwhelmingly garden watering (96.9% of those responding to the question); followed by car washing (71.0%) then clothes washing (31.3%) with toilet flushing only (25.0%), closely followed by drinking (22.6%), then to a lesser extent cooking (16.1%) and showering (12.9%). All other uses are attributable to these respondents (16%). As 55.7% of these respondents reported having rainwater tanks, it indicates that this is primarily used for garden watering, but is also used for higher physical contact uses such as clothes washing and drinking.

➢ *Reasons for not using recycled water for toilets*

Respondents *not* using their RW for either garden or toilet-flushing use were also asked to comment on the non-use for these purposes. Twenty-two comments were made (3 from PRW respondents and the remainder from non PRW respondents) (Table 5.20). All of the comments regarding toilet flushing use concerned lack of plumbing to toilets and the cost and difficulty of this (20 comments – only one from a PRW respondent). Plumbing for toilet use from PRW must be more readily accessible. The only comments about garden use were from PRW respondents. One reason for lack of RW use was because the tap was on the wrong side of the garden, and the other reason given (which would apply to toilet non-use as well) was that the PRW was too expensive: 'Recycled water is too expensive Drinking water 0.176 p/kl? RW 0.800 p/kl'.

RQ 1

- What are the characteristics of the recycled water supply chain in SE Queensland, including key stakeholders, and specifically the stakeholders in the 2 AWTPs studied

An examination of the current uses or recycled water in the area serviced by PRW is relevant to research question one as it sheds light on characteristics of the current supply chain and highlights opportunities and problems. Respondents are aware of recycled water options. Greater use would be made by recycled water users with rainwater tanks of toilet flushing if plumbing support was provided. The use of rainwater tanks as a preferred recycling method is evidenced by their use by PRW and non PRW respondents alike. However prior research has indicated that rainwater tank use often has high electricity costs (and carbon footprint) due to pump use (Hall et al 2009). This study did not specifically ask respondents about this, but as it is not mentioned in any comment it seems that respondents are unaware of this cost.

Table 5.20: Respondent comments regarding non-use of RW for garden or toilets

Comments from PRW respondents	
Garden non- use	**Toilet non-use**
Garden - because the tap is on the other side of the garden and can't reach. Recycled water is too expensive Drinking water 0.176 p/kl? RW 0.800 p/kl	Our recycled water source is not connected to the toilets but we have them outside so it is convenient for us to use this for gardening and for the purpose of washing the car
Comments from non PRW respondents	
	-Cost & difficulty of connection -Current plumbing of house does not allow it. -Have not yet plumbed toilets to rainwater tanks -Household is plumbed into the water system -It is not plumbed in for toilet flushing -My house is not plumbed for this type of recycling. although when I built my house in 2005 I did want to install this type of unit but it was illegal at that time. -not connected - Not connected to recycle system - Not hooked up for recycled in the house - Not plumbed in - our toilet is hooked up to town water -Tank not plumbed into toilet cistern -This is not plumbed in. - Toilet not hooked up to tank (too dear) Toilets not connected to tank We are only connected to mains water We don't have facility to use recycled water in our toilet

5.2.4.5 PRW ('purple pipe') respondent satisfaction

The next section explored PRW respondents' attitudes, and was most relevant to RQ6, customer perceived benefits and risks of RW. A total of sixty-four households identified as having a PRW supply (49.6%) and were asked to complete this section.

RQ 6

• What are the perceived benefits and risks (costs) of recycled water use for customers?

➢ *Overall satisfaction with Purified Recycled Water (PRW) Supply*

Significantly above average levels of overall satisfaction (79%) with PRW supply were expressed by PRW respondents (Figure 5.14), regardless of gender. However, there was still a lack of trust regarding its safety on terms of germs and chemicals.

Respondents were asked to rate their *overall* satisfaction with their recycled water supply on a scale of 0-10 where 0 = 'not at all satisfied'; 5 = neither satisfied nor dissatisfied and 10= extremely satisfied. There were sixty-three (63) responses and they were significantly favourable with 79.4% (n= 50) expressing satisfaction with the PRW, including 31.8% (n=20) extremely satisfied. Seven respondents (11.1%) were neutral ('neither satisfied nor dissatisfied') and 6 (9.52%) expressed dissatisfaction, with two (3.2%) of these 'not at all satisfied' (Figure 5.14). One sample t-test analysis showed that participants' level of satisfaction is significantly above average (M = 7.57, SD 2.519) $p < 0.05$. On average male respondents (M=7.23, SD 2.741) had lower satisfaction than their female counterparts (M=8.04, SD 2.028). However the difference between them was not significant t (56) = -1.265, $p > .05$. The effect size was low r = 0.17. This analysis indicates that the level of satisfaction does not differ between the genders.

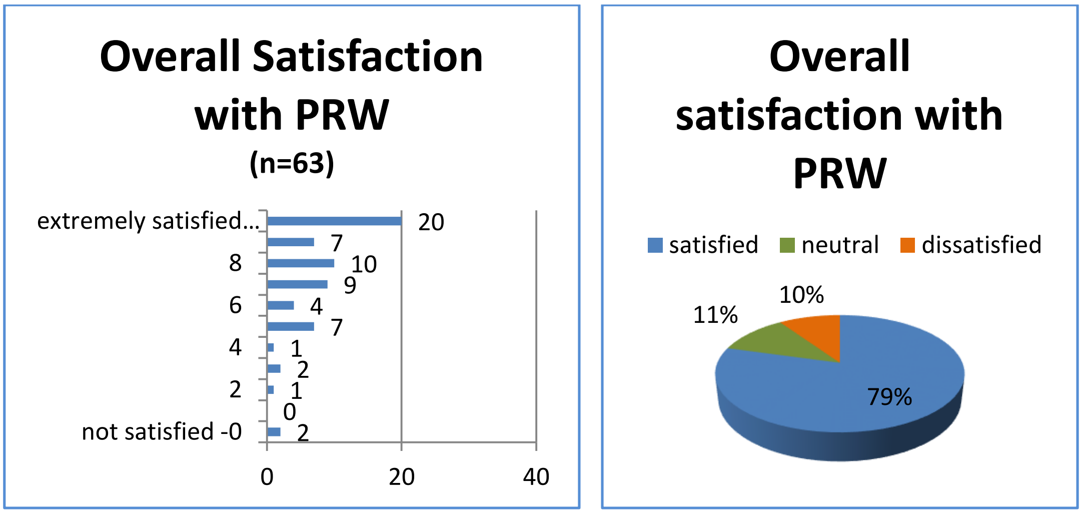


Figure 5.14: Level of overall satisfaction with Purified Recycled Water (PRW)

➢ *Satisfaction with PRW quality*

Respondents were also asked the same questions regarding rating of water supply attributes asked previously about mains supply drinking water (Figure 5.8), but this time in relation to their PRW supply in terms of overall quality and attributes such as taste, smell, colour and safety (Table 5.21). In summary, the majority expressed overall satisfaction with PRW quality water (76%) and were happy with the colour (79%), and smell (69%), although these were lower ratings than for mains water. Uncertainty increased about safety as regards germs (18%) and chemicals (18%), with low levels of satisfaction (and trust). Spearman's Rho was calculated for the demographic information respondent age, number of household members, and education level to examine possible correlations with PRW respondents' rating of the quality of the PRW supply, but no significant correlation coefficients results were found at the 95% confidence level.

Looking in more detail, although 76% of PRW respondents (n=47) gave positive ratings for the *overall* quality of their PRW supply (a slight fall from overall mains water positive rating of 84%), the fall is all from the higher ratings. Satisfaction ratings of 'good' are 50% for both water sources, but ratings for 'very good' PRW (25.8%) were lower than for mains water (34%) (Figures 5.15 and 5.8). On the other hand, only three respondents (4.8%) rated the PRW 'bad' (the same percentage as for mains water) but none gave it a rating of 'very bad' (1.6% for mains water). The level of uncertainty expressed is the main differential with the remaining twelve respondents for PRW (19.4%) stating that they didn't know about the overall quality - compared to 10.2% for mains water.

As with mains water, for PRW the attribute *'colour'* was the one householders were most happy with (Figure 5.15), as 79% (n=49) rated it either 'very good' or 'good', but again compared to mains supply (90.6%) the level of satisfaction was less. The majority of PRW respondents were satisfied with the *'smell'*, but this was a fall to 69.4% compared to 82.1% for mains water. PRW is supplied strictly as non-potable (non-drinking) water, and for the attribute '*taste'* the majority (79.7%) indicated that they did not know. However this means that 20.3% (n=12) *did* rate the water for taste, 15.3% rating it 'very good' (6.8%) or 'good' (8.5%) and 5.1% rating it 'bad' (3.4%)/ 'very bad' (1.7%). It is unclear whether this reflected their expectations about what it might taste like, or whether they had actually tasted the water at some point. This should be of some concern to the water suppler/authority.

Table 5.21: PRW respondents' rating of the quality of the PRW supply

Rating current recycled water supply (PRW) from 1 'very good' to 5 'very bad'											
	Very good		Good		Don't know		Bad		Very bad		n
	n	%	n	%	n	%	n	%	n	%	
Overall quality	16	26%	31	50%	12	19%	3	5%	0	0%	62
Taste	4	7%	5	8%	47	80%	2	3%	1	2%	59
Colour	17	27%	32	52%	11	18%	1	2%	1	2%	62
Smell	12	19%	31	50%	7	11%	11	18%	1	2%	62
Safety (germs)	6	10%	5	8%	45	73%	4	6%	2	3%	62
Safety (chemicals)	5	8%	6	10%	45	74%	2	3%	3	5%	61

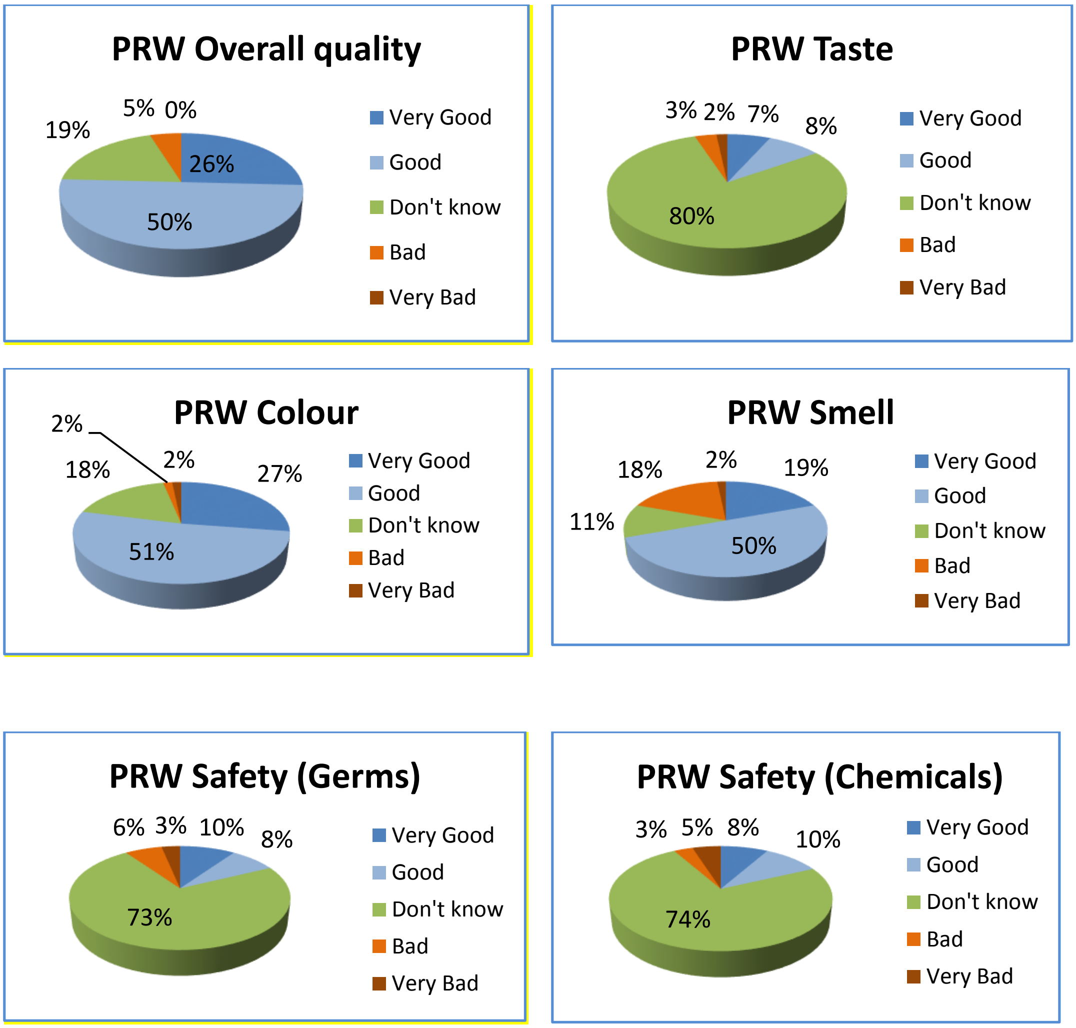


Figure 5.15: Respondent ratings for attributes of Purified Recycled Water (PRW)

Again, the two final attributes of for PRW – *safety as regards germs and chemicals* - elicited a doubtful response from householders. Only 17.7% (germs) and 18% (chemicals) of respondents rated the safety as either 'very good' or 'good', a much lower rating than for the mains water where the majority were happy with these attributes. It is interesting that these are rated similarly, whereas in the scientific community the concern is greater about chemicals. This reflects the negative media coverage which has tended to concentrate on biological concerns and label recycled water from treated wastewater 'poo water', the so-called 'yuk factor' (Price et al. 2010). Most householders expressed uncertainty as their answer to these attributes, with marginally greater uncertainty about chemicals (73.8%) than germs (72.6%). Slightly more respondents rated safety regarding germs (9.7%) as 'bad' (6.5%)/ 'very bad' (3.2%) than safety regarding chemicals (8.2%) but the difference is again slight. On the other hand, this is a lower proportion than the satisfied respondents.

➢ *PRW respondent comments*

PRW respondents were also given the opportunity to make any positive comments/express any concerns regarding various uses of PRW (Table 5.22). The majority of comments were positive, mostly regarding toilet flushing, garden watering and car washing (also lack of restrictions and better than wasting drinking water supplies). Most negative comments regarded concerns over chemicals or germs, smell and staining of toilet bowl or residue left after cash washing, and there were mixed comments regarding price.

Toilet flushing

The clear majority (76.1%) of comments regarding PRW used for 'toilet flushing' were positive, although three of these qualified their comment with a minor concern (and in such cases comments are listed in Table 5.22 as concerns as well). Positive comments ranged from simply 'no concerns' to 'excellent' and four commented that it was an appropriate use for this water e.g. 'drinking water should not be wasted for this purpose'. Two respondents commented that they enjoyed the lack of restrictions, one that it was cheap, and one that it kept the toilet clean. The remainder (23.9%)

expressed concern/made a negative overall comment, most frequently about staining of the bowl (8.7%) and smells (6.5%) and supply issues (4.3%).

Garden watering

An even larger number of the forty-five comments regarding PRW used for 'garden watering' were positive compared to toilet flushing (82.2%) with 18% negative comments. Again positive comments ranged from simply 'no concerns' or 'does the job' to 'excellent' (24.4%) with comments such as 'great way to use the water supply' and 'the best use of PRW'. Two respondents commented that they enjoyed the lack of restrictions (4.4%), three that it was cheap (6.7%), and three (6.7%) noticed a positive effect on the garden. The remainder (18%) expressed concern/made a negative overall comment. The most frequent complaints were adverse effects on plants (6.7%; n=3 – oddly the same number as reported a positive effect on the garden!) and smells (4.4%). Other concerns raised by individual respondents included: initial supply issues, a trust issue - uncertainty regarding the effect of its use & chemicals, too expensive (though 3 said it was cheaper), and another found it hard to get timers (presumably to do with the system).

Car washing

Of the forty-four comments regarding PRW used for 'car washing' 75% were positive and 25% were negative concerns. Positive comments ranged from simply 'does the job' or 'can't see any difference in colour/smell etc.' to 'excellent '(15.9%) with comments including 'ideal use for car and does no harm'. Two respondents commented that they enjoyed the lack of restrictions (4.5%) and two that it was cheap. The most common concern was that it did not leave the car fully clean (9.1%) by leaving a white residue or 'blotches on the windows'. The same number expressed a lack of trust in its use, two being specifically concerned about the effect on paintwork, one of whom avoided using it on this part of the car, and of the other two one just stated generally 'I don't trust it' and the other person was anxious about chemicals: 'not wish to use re. chemicals.' If the person is included who was positive about the use, but who still had longer tem doubts about its effects, 'unsure of effect – looks clean', then this becomes the largest category of concern (11.4%). This - supports the research that building trust is important, as this last respondent, for example, was successfully using PRW to wash a car, but was still doubtful of the evidence, and concerned about longer term effects. The last three concerns each came from only one respondent and concerned the smell (chlorine), the expense and simply an aversion to using PRW.

Non-recommended uses: Clothes washing, Drinking, Cooking, Showering and Swimming Pool

In all of these categories there were fewer responses and most recognised that for current PRW sources it was not a recommended use. For each there was a significant minority who expressed a definite aversion to PRW use for these activities, but others also expressed some support and some seemed possibly to be already using their PRW for the activity, provided additional conditions were met. A few comments expressed uncertainty and there was one respondent concern over cost and another (incorrectly) concerned about fluoride in the PRW.

Clothes washing

One respondent commented that the inability to use it for this purpose was 'unfortunate'. Four (11.4%) expressed a definite aversion to its use for this: 'yuk'; 'definitely not'; 'would not do'; 'would not use recycled'. Despite the prohibition, seven responses (20%) were positive. Two (5.7%) responded that it was excellent or great. One commented 'good: no different (recycled H2O)' another 'no concerns' and a third 'better than greywater – that has smell/germs'. Three respondents were willing to support its use for this, provided conditions were met.

Drinking

There are specific warnings/signage on installation of the PRW that it is not to be used for potable/drinking use and 97.2% appropriately gave a negative response regarding PRW used for 'drinking', given the question was about their *current* PRW supply which is not for potable use. One stated: 'Happy to use it for other areas if given proof of quality'. Five (13.9%) expressed a definite aversion to its use for this: 'definitely not'; 'don't want myself or my dog drinking it'; 'People – rainwater- no chemicals; pets – recycled'; 'would not do'; 'would not use recycled'. Two were not sure (5.6%) and two mildly objected 'probably wouldn't feel comfortable'; 'concerned'.

Cooking

All but one (97%) appropriately gave a negative response. The one positive comment was the same as for drinking: 'Happy to use it for other areas if given proof of quality'. Six (18.2%) expressed a definite aversion to its use for this: 'definitely not'; 'Rainwater- sweeter & no chemicals; 'would not do' (2); 'would not use recycled'; 'yuk'. Two were not sure (6.1%) and two mildly objected 'probably wouldn't feel comfortable'; 'concerned'.

Showering

91.4% appropriately gave a negative response. There were however three (8.6%) qualified positive comments: 'yes, as long as it's clean'; 'Happy to use it for other areas if given proof of quality'; 'water is prone to feel greasy & leaves a slippery feeling on the floor' (suggesting the respondent *had* actually used it for showering). Four (11.4%) expressed a definite aversion to its use for this: 'definitely not'; 'would not do'; 'would not use recycled'; 'yuk'. Two (5.7%) noted it was not used due to lack of plumbing: 'It's not hooked up to the shower I don't think'; 'not connected to them'. Again two were not sure and two stated 'probably wouldn't feel comfortable'; 'concerned'.

Swimming pool

Of the twenty-eight respondents who answered this and had a pool 87.5% appropriately gave a negative response, as PRW is not intended for pool use. There were however four (12.5%) qualified positive comments: 'Happy to use it for other areas if given proof of quality'; 'If bacteria doesn't build up in pool'; 'might use after testing by me'; 'would like to be able to use recycled water to fill the pool'. Only two (6.3%) expressed a definite aversion to its use for this: 'definitely not'; 'yuk'. Of the prohibited categories, therefore, pool owners do seem more likely to accept PRW for this use were it of an approved quality.

Table 5.22: PRW respondents' positive comments and concerns

PRW Use	**Positive comments**	**Concerns**
Toilet flushing	***35 (76.1%)*** *-Excellent/great (6) 'great way to manage current water supply'* *-Good (12) 'drinking water should not be wasted for this purpose'; 'everyone should use it'; 'seems like a sensible use'* *-No concerns/problems (6)* *-ok/acceptable (7) 'can't see any difference'; 'does the job'* *-Unlimited use (2) 'can use as much as we want'; 'Love it – kids can use whenever'* *-'cheap' (1)* *-'seems to keep toilet cleaner'(1)*	***11 (23.9%)*** ***+ 3 qualified comments from positive respondents*** *-stains bowl (4)* *-smells(3) 'chlorine smell'(2); 'smell in ensuites'* *-supply issues(2) 'Occasionally pressure is low or supply not forthcoming'; 'some days there will be no supply to flush toilets'* *-'choose not to use PRW' (1)* *-'don't want if too expensive' (1)* *-'have you seen what goes down the plug hole & they want us to drink it. You got to be joking'(1)* *-'can block refill pipe'(1)* *-'there is algae growth'(1)*
Garden watering	***37 (82.2%)*** *-Excellent/great (11) 'excellent idea'(2); 'great use of water'; 'great way to manage current water supply'* *-Good (6)* *-No concerns/problems (5); 'the best use of PRW'* *-ok/acceptable (7) 'can't see any difference'; 'does the job'* *-Unlimited use (2) 'can use as much as we want'; 'great with no restrictions'* *-cheap (3) 'cheaper alternative: works well usually advised some plants have problems'; 'saves some money'* *-Positive effect on garden (3) 'great, I like green grass'; 'Ideal to use for gardens & doesn't harm plants'; 'notice no side effects on garden/lawn'*	***8 (17.8%)*** ***+ 2 qualified comments from positive respondents*** *- adverse effect on plants (3) 'good to water garden but turns plants yellowish'; 'next door killed their grass with this and you want us to drink it'; water kills gardenias, azaleas and several other plant species'* *-smells(2) 'smells very high in chemicals; 'sometimes strong chlorine smell'* *-resolved supply issues(1) 'problems with pressure when first started using, pressure now is good'* *- trust issue 'unsure of effect' (1)* *-'don't want if too expensive' (1)* *-'use but concerned re. chemicals'(1)* *-'hard to get timers etc.'(1)*
Car washing	***33 (75%)*** *-Excellent/great (7) 'excellent idea'; 'great use of water'; 'great way to manage current water supply'; 'ideal to use for car and does no harm'* *-Good (7)* *-No concerns/problems (8); 'the best use of PRW';* *-ok/acceptable (7) 'can't see any difference'; 'does the job' 'can't notice any difference in colour/smell etc.'* *-Unlimited use (2) 'can use as much as we want'; 'great with no restrictions'* *-cheap (2) 'saves money'*	***11 (25%)*** ***+ 1 qualified comment from positive respondents*** *- leaves residue/marks (4) 'leaves a thick white residue on car (3)'; leaves blotches on the windows',* *-smells(1) ' 'sometimes strong chlorine smell'* *-bad for paint (2) 'not good for paint – only use for tyres and under car'; 'some concerns about how it may affect paintwork'.* *-trust issue (3) 'don't trust it'; 'not wish to use re. chemicals'; 'unsure of effect – looks clean'* *-'don't want if too expensive' (1)* *-'would not use recycled'(1)*

Clothes washing	***7 (20%)*** *-Excellent/great (2) 'excellent idea'; 'great'* *-Good (1) 'Good – no different (recycled H22O)'* *-No concerns/problems (1); 'no concerns';* *-ok/acceptable (1) 'better than greywater – that has smell/germs'* *-Potential support if conditions met (3) 'as long as it's clean water'; 'Happy to use it for other areas if given proof of quality'; 'Unfortunately not allowed to connect as per regulations'*	***28 (80%)*** *- not a valid option: (21) these stated (correctly) that it was not a valid option, though one of these was potentially interested if it was permitted* *- aversion (4): 'yuk'; 'definitely not'; 'would not do'; 'would not use recycled'.* *-unsure (2)* *-cost: (1) 'don't want if too expensive'*
Drinking	***1 (2.8%)*** *-Potential support if conditions met (1) 'Happy to use it for other areas if given proof of quality'*	***35 (97.2%)*** *- not a valid option: (24) these stated (correctly) that it was not a valid option* *- aversion (5): 'definitely not'; 'don't want myself or my dog drinking it'; 'People – rainwater- no chemicals; pets – recycled'; 'would not do'; 'would not use recycled'.* *- mild aversion (2): 'probably wouldn't feel comfortable'; 'concerned'* *-unsure (2)* *-trust issue (1) 'I don't like that we have fluoride in our water supply'* *-cost: (1) 'don't want if too expensive'*
Cooking	***1 (3%)*** *-Potential support if conditions met (1) 'Happy to use it for other areas if given proof of quality'*	***32 (97%)*** *- not a valid option: (20) these stated (correctly) that it was not a valid option* *- aversion (6): 'definitely not''; 'Rainwater- sweeter & no chemicals'; 'would not do'(2); 'would not use recycled'; 'yuk'* *- mild aversion (2): 'probably wouldn't feel comfortable'; 'concerned'* *-unsure (2)* *-trust issue (1) 'I don't like that we have fluoride in our water supply'* *-cost: (1) 'don't want if too expensive'*
Showering	***3 (8.6%)*** *-Potential support if conditions met (3) 'yes, as long as it's clean'; 'Happy to use it for other areas if given proof of quality'; 'yes, as long as it's clean';*	***32 (91.4%)*** *- not a valid option: (20) these stated (correctly) that it was not a valid option* *- aversion (4): 'definitely not'; 'would not do'(2); 'would not use recycled'; 'yuk'* *- plumbing issue (2): 'It's not hooked up to the shower I don't think'; 'not connected to them'* *- mild aversion (2): 'probably wouldn't feel comfortable'; 'concerned'* *-unsure (2)* *-trust issue (1) 'I don't like that we have fluoride in our water supply'* *-cost: (1) 'don't want if too expensive'*
Swimming pool	***4 (8.6%)*** *-Potential support if conditions met (4): 'Happy to use it for other areas if given proof of quality'; 'If bacteria doesn't build up in pool'; 'might use after testing by me'; 'would like to be able to use recycled water to fill the pool'.*	***28 (87.5%)*** *-no pool: (3)* *- not a valid option: (21) these stated (correctly) that it was not a valid option* *- aversion (2): 'definitely not'; 'yuk'* *-unsure (1)* *-cost: (1) 'don't want if too expensive'*

This section provided more detailed information about attitudes towards various PRW uses (RQ2) and about the perceived benefits and risks (costs) of recycled water use for customers (RQ6). Respondents are generally satisfied with the system and can see benefits (toilet flushing, garden watering, car washing, lack of restrictions, avoid wasting potable water supplies). Pool owners generally expressed a desire to be able to use PRW for this purpose. Respondents still have some concerns about water quality (smell, residue) and more particularly regarding perceived risk of chemicals and germs in the supply that should be addressed, relevant to Research Question 6.

5.2.4.6 PRW respondent motivations & perceptions

This section of the survey explored both customer perceptions of risk and also the motivations/benefits behind using/not using PRW (RQ6), which would influence its acceptance as a substitute for higher end use such as indirect potable water substitution (RQ7). The vast majority of PRW respondents valued living in a PRW supply area (89%) and agreed that it had environmental benefits (and so valued externalities RQ4). Although generally happy with the system (84%) they did express some trust issues and were less happy with the water authority (66%) and regulations (63%), and particularly regarding perceived health risks (45%). Lack of restrictions (73%) and costs savings (69%) were the prime motivations for using PRW and 42% agreeing that PRW added value to their property. Although most respondents also expressed concern about climate change (68%), that concern was not fully translated into support for PRW with only 42% valuing environmental benefit over cost for PRW.

The PRW respondents were asked to indicate whether they agreed or disagreed on a 5 point Likert scale with eighteen (18) questions designed to indicate their attitudes towards recycled water, their motivations for using it, and to explore their attitudes 'Agree' (A) (5) through 'Somewhat agree'(SA) (4); 'Neither agree nor disagree' or Neutral (N)(3); 'Disagree somewhat' (DS) to 'Disagree' (D) (1) (Table 5.23).

<u>Attitudes towards the PRW system in general</u>

Initial analysis showed that the majority of users had a 'positive' attitude towards the use of recycled water and the results are internally consistent.

- *Attitude towards living in a PRW area:* 74.2% of respondents 'agreed', and 14.5% 'somewhat agreed' (total agreement 88.7%) that they enjoyed 'living in a community that actively contributes to environmental sustainability' (with only 1.6% disagreeing). (Mean 4.60 A; Standard Deviation 0.799).

- *PRW and the environment:* Given the general approval of living in a PRW community, it would be expected that most would *disagree* to some extent with the suggestion that 'the dual water scheme may have a negative impact on the environment'. This was found to be the case with 69.8% disagreeing to some extent and only 11.1 % agreeing. (Mean 1.92 DS; SD 1.154).

- *Support for dual pipe system:* Consistent with this, 74.2% disagreed to some extent that they would 'prefer it if the water system was standard – no dual water supply' (11.3% agreeing) (Mean 1.82 DS; SD 1.153). and the vast majority at 88.7% disagreed to some extent (74.2% fully) that they 'avoid using the lilac/purple (PRW) pipes' (8.1% agreed). (Mean 1.48 DS; SD 1.004).

Responses to these questions did provide some support for the idea that customers have concern for the environment and see added value in water recycling (a preference for retaining the system and added property premiums), relevant to Research Questions 4 (what externalities should be included in the RW value beside economic) and 6 (customer perceptions of benefits and risks).

<u>Exploring concepts of trust in the system</u>

A number of questions were aimed at exploring the trust (or lack of it) in the *safety* of the PRW supply and the *trust* in the authorities providing it. This indicated general satisfaction with the current operation of the system but also some trust issues regarding the water authority, regulations and particularly health risks. These are issues relevant to Research Questions 6 and 3 (managing risk e.g. social risk).

Operation of the system: 83.9% of respondents agreed to some extent (53.2% fully) that they were 'happy with the operation of the recycled water system' with 11.3% unsure and 4.8% disagreeing to some extent. (Mean 4.29 SA; SD 0.965)
Water authority: Most were also happy with the water authority as 66.1% indicated that they 'trust the water authority to ensure recycled water quality' although for most

(33.9%) this was ‘somewhat agree’, with 14.5% unsure and 19.4% expressing some disagreement. (Mean 3.68 SA; SD 1.315)

Existing regulations: Slightly fewer, but still a majority, were happy with the regulations, with 62.9% indicating that they thought that there is ‘adequate regulation to ensure safe use of recycled water’ although again for most (32.3%) this was ‘somewhat agree’, and 24.2% were unsure with 12.9% expressing some disagreement. (Mean 3.73 SA; SD 1.19)

Health risks: Most agreed that ‘I am confident there are no health risks associated with the dual water supply system’ at 45.2% but a substantial number were not sure (29%) and 25.8% disagreed to some extent, so this appears the greatest concern. (Mean 3.37 N; SD 1.346)

As these questions were designed to examine a particular attribute, in this case trust in the system, Cronbach’s alpha was calculated in order to gauge the scale reliability. The Cronbach’s α for these four questions was calculated at .843, which demonstrated strong question reliability.

Exploring possible motive for supporting/opposing the PRW system

Some questions were aimed at exploring the possible **motives** for supporting (or not) the PRW scheme. Lack of water restrictions and costs savings seemed the most likely, but not the only, motivations:

- *Climate change*: 67.7% agreed to some extent that ‘the threat of climate change is a concern to me’, and although 22.6% were unsure, only 9.7% disagreed that it was a concern. (Mean 3.87 SA; SD 1.138)

- *Environmental benefits and cost*: Environmental concern does not translate as readily into willingness to pay, however, as a much lower percentage at 41.9% agreed to some extent that ‘environmental benefits of dual water supply are more important than financial benefits’, and 33.9% were unsure, whilst 24.2% disagreed. (Mean 3.4 N; SD 1.336)

- *Property value*: Most (46.8%) were unsure whether ‘the dual water system adds value to my property’ but almost as many (41.9%) agreed to some extent that it did add value and the minority at 11.3% disagreed that it added value. (Mean 3.52 SA; SD 1.052)

- *Lack of water restrictions*: 72.6% agreed to some extent that ‘recycled water should not be subject to water use restrictions’ with 12.9% uncertain and 14.5% disagreeing. (Mean 4.06 SA; SD 1.304)

- *Cost savings*: 69.4% agreed to some extent that ‘I save money by using recycled water’ with 9.7% uncertain but a sizeable number at 21% disagreeing. (Mean 3.81 N; SD 1.491) However cost seems to have been less of a reason for choosing that area to live in as 35.5% (25.8% only somewhat) agreed that ‘The potential to save money associated with the dual water supply system contributed to my decision to live here’ with almost as many (25.8%) unsure and 38.7% disagreeing to some extent with the statement. (Mean 2.74 N; SD 1.409)

These questions were most relevant to RQ6, as they identified the strongest respondent motivations/perceived benefits as lack of water restrictions and costs savings, and some value to externalities such as the environment (research question 4).

<u>Exploring attitudes towards water pricing/costing</u>

As water pricing has been an ongoing issue in Queensland, and in the geographical area of this study in particular, a number of the questions sought to examine PRW respondent attitudes relating to this.

- *Cost of potable versus non-potable PRW:* The majority of respondents agreed to some extent (56.5% with 38.7% fully) that the ‘cost of non-drinking recycled water should be *slightly* less than drinking water’ with 6.5% unsure and 37.1% disagreeing (Mean 3.35 N; SD 1.641). Those disagreeing with this statement did so because they think the price gap should be greater. This is borne out by the results of the next question to which almost all agreed (87.1% with 75.8% fully) that the ‘cost of non-drinking recycled water should be *significantly* less than drinking water' with only 8.1% uncertain and 4.8% disagreeing. (Mean 4.53 A; SD 1.004)

- *Quality of PRW and price:* Respondents were split and less certain about paying for high quality non-potable recycled water, as only 37.7% agreed to some extent with the statement 'I prefer my supply of non-drinking recycled water to be high quality and therefore cost only slightly less than drinking water', with quite a large proportion uncertain (26.2%) and almost as many in disagreement as agreement (36.1%). (Mean 3.02 N; SD 1.360)

- *Charging full cost for PRW:* Marginally more respondents were in favour of just paying for treatment and delivery of PRW than those also agreeing to pay for the necessary infrastructure, and although for both of these questions there were more agreeing than disagreeing, a large proportion were also uncertain. It is also possible that those uncertain were not entirely sure what the question was asking. 48.4% agreed to some extent (though 35.5% of this only somewhat) with the statement 'Charging for recycled water should be based on treating the wastewater to a high (Class A) standard & transport or delivery via pipe work to customers' with the largest proportion remaining uncertain at 38.7% but still only 12.9% disagreeing (Mean 3.45 SA; SD 0.953). When the statement was changed to include capital costs - 'Charging for recycled water should be based on treating the wastewater to a high (Class A) standard & transport or delivery via pipe work to customers, plus part of the cost of building the treatment plant' – the proportion in agreement reduced to 42.4% (25.8% somewhat) and uncertain was 31.8% and disagreeing was 25.8%. The inclusion of capital costs therefore polarises opinions more, although still with a sizeable proportion uncertain. (Mean 3.20 N; SD 1.255)

The evidence from the price-related questions indicates that most respondents expect recycled water to be significantly cheaper than potable water supplies, and are unwilling to pay full cost. However, this is of course relative to the price charged for potable water, which has not historically been charged at full cost either.

Table 5.23: Attitudes to Recycled Water - PRW respondents (n=61-66)

	Statements	A n	A %	SA n	SA %	A Total %	N N	N %	DS n	DS %	D n	D %	D Total %	M	SD
1	I enjoy living in a community that actively contributes to environmental sustainability	46	74.2	9	14.5	88.7	6	9.7	0	0.0	1	1.6	1.6	4.60	0.799
2	I believe that the dual water scheme may have a negative impact on the environment	2	3.2	5	7.9	11.1	12	19.0	11	17.5	33	52.4	69.8	1.92	1.154
3	The threat of climate change is a concern to me	22	35.5	20	32.3	67.7	14	22.6	2	3.2	4	6.5	9.7	3.87	1.138
4	I would prefer it if the water system was standard – no dual water supply	2	3.2	5	8.1	11.3	9	14.5	10	16.1	36	58.1	74.2	1.82	1.153
5	I avoid using the lilac/purple (recycled water) taps whenever possible	2	3.2	3	4.8	8.1	2	3.2	9	14.5	46	74.2	88.7	1.48	1.004
6	I save money by using recycled water	30	48.4	13	21.0	69.4	6	9.7	3	4.8	10	16.1	21.0	3.81	1.491
7	I am confident there are no health risks associated with the dual water supply system	18	29.0	10	16.1	45.2	18	29.0	9	14.5	7	11.3	25.8	3.37	1.346
8	Environmental benefits of dual water supply are more important than financial benefits	20	32.3	6	9.7	41.9	21	33.9	9	14.5	6	9.7	24.2	3.4	1.336
9	I am happy with the operation of the recycled water system	33	53.2	19	30.6	83.9	7	11.3	1	1.6	2	3.2	4.8	4.29	0.965
10	I think there is adequate regulation to ensure safe use of recycled water	19	30.6	20	32.3	62.9	15	24.2	3	4.8	5	8.1	12.9	3.73	1.19
11	I trust the water authority to ensure recycled water quality	20	32.3	21	33.9	66.1	9	14.5	5	8.1	7	11.3	19.4	3.68	1.315
12	The cost of non-drinking recycled water should be slightly less than drinking water	24	38.7	11	17.7	56.5	4	6.5	9	14.5	14	22.6	37.1	3.35	1.641
13	The cost of non-drinking recycled water should be significantly less than drinking water	47	75.8	7	11.3	87.1	5	8.1	0	0.0%	3	4.8	4.8	4.53	1.004
14	Recycled water use should not be subject to water use restrictions	35	56.5	10	16.1	72.6	8	12.9	4	6.5%	5	8.1	14.5	4.06	1.304
15	The potential to save money associated with the dual water supply system contributed to my decision to live here	6	9.7	16	25.8	35.5	16	25.8	4	6.5%	20	32.3	38.7	2.74	1.409
16	The dual water system adds value to my property	15	24.2	11	17.7	41.9	29	46.8	5	8.1%	2	3.2	11.3	3.52	1.052
17	I prefer my supply of non-drinking recycled water to be high quality and therefore cost only slightly less than drinking water	11	18.0	12	19.7	37.7	16	26.2	11	18.0 %	11	18.0	36.1	3.02	1.360
18	Charging for recycled water should be based on treating the wastewater to a high (Class A) standard & transport or delivery via pipe work to customers	8	12.9	22	35.5	48.4	24	38.7	6	9.7%	2	3.2	12.9	3.45	0.953
19	Charging for recycled water should be based on treating the wastewater to a high (Class A) standard & transport or delivery via pipe work to customers, plus part of the cost of building the treatment plant	11	16.7	17	25.8	42.4	21	31.8	8	12.1	9	13.6	25.8	3.20	1.255

Note: The answer with the highest percentage of responses has been highlighted (yellow), as has the second most common response (beige). Blue indicates that either the total 'agrees' or 'disagrees' have 50% or more responses.

5.2.4.7 Exploratory Factor Analysis (EFA) PRW respondent perceptions

A key contribution of this study is the social aspect and exploration of customer perceptions, particularly the perceived benefits and risks/costs of recycled water (RQ6) and the influence of these on the acceptance of PRW for non-potable and potable use (RQs 2 and 7). This social aspect is crucial for planning for alternative water supply sources. Customer attitudes towards externalities – such as perceived environmental benefits – may be reflected in willingness to pay for such sources. Consequently further analysis of the nineteen questions on PRW respondent attitudes (Table 5.23) was undertaken using factor analysis.

The factor analysis identified six components of the survey results and explained 70% of the total variance (Table 5.26). The results suggested largely positive attitudes to PRW use (45.5% of the explained variance), but also indicated a polarisation of views, with minority but significant component attitudes in direct contradiction to the largest positive component grouping. Positive views are characterised by trust in the system, environmental concerns, and value for money. Negative views are influenced primarily by cost, but also lack of belief in the environmental benefits, and the most strongly opposed respondents have a lack of trust in the system and have concerns about health risks (Table 5.24).

Table 5.24: Component groupings with positive/negative attitudes towards PRW

Label	Positive	Var Expl	Label	Negative	Var Expl
1. POS Trust	* Positive towards PRW * trust its safe operation (low health risk) * pro environmental benefits	30%	2. TRAD	* 'traditional' view *plentiful use permitted * significantly lower cost PRW (*not negative if price low?*)	11%
3. QUAL	* Positive towards higher quality PRW * willingness to pay for quality (pro environmental benefits)	8.5%	4. NEG EnvC	* Negative towards environmental issues * slightly lower cost PRW	7.5%
5. POS Invest	* improved property value * saves money	7%	6. NEG UseEnvC	* negative towards any use of PRW * believe has negative environmental impact (no trust in system – concern re. health risks /cost)	6%
	Variance explained:	**45.5%**			**24.5%**
TOTAL Variance Explained 70%					

Research Question 7 had the objective if identifying factors that may influence customer acceptance of PRW for potable use. Further analysis was therefore undertaken using independent-samples t-tests to see if any of the components identified were associated with a willingness to accept/reject using PRW for indirect potable use. The analysis found evidence to support the view that PRW respondents with the 'POSTust' attribute are more likely to accept PRW for indirect potable use (Figure 5.17), but there were no other significant associations with this and other attribute/components. As might be expected, the respondents with the most negative component attribute 'NEGUseEnvC' who were opposed to PRW use for non-potable purposes, who distrusted the regulatory system, doubted the environmental benefits and expressed concern regarding cost and health risks, were significantly more likely to reject PRW for indirect potable use as well.

The following sections outline the rationale and methodology of the factor analysis; give the details of the results for this; and then provide details of the further analysis regarding a willingness to accept/reject PRW for indirect potable use.

Factor Analysis rationale and approach

Factor analysis and Principal component analysis (PCA) are commonly used variable/dimension reduction techniques, used to reduce a data set to a manageable size and to identify clusters of variables that may be driven by the same underlying variable. As this section on PRW Respondent Attitudes contained nineteen questions, for parsimony factor analysis was used to identify clusters of correlated variables, or 'to reduce a set of variables into a smaller set of dimensions (called 'factors' in factor analysis and 'components' in PCA)' (Field 2013, p.667). This approach was used to analyse data in the survey for each large set of Likert scale questions (here questions on PRW respondents' attitudes to recycled water (Table 5.23).

In a survey of human participants correlation of factors is to be expected, and this was confirmed by the correlation matrix (numerous correlations >0.3), therefore the direct oblimin oblique rotation method was used, to allow for factor correlation (Field 2013; Pallant 2011). The 19 items were subjected to EFA using both principal components analysis (PCA) and principal axis factoring (PAF). Results for both methods produced similar component/factor groupings of the underlying questions, with each analysis using Kaiser’s Criterion revealing the presence of six eigenvalues greater than 1. The PAF methodology was however unable to extract more than five factors due Heywood cases (improper factor solutions with communalities greater than 1.0). McDonald (1985) suggests that each factor should be defined by at least three variables with large loadings, so this is a likely problem with smaller sample sizes. McDonald notes that Heywood cases may be avoided by fitting fewer factors (in this case extracting five rather than 6 factors), but notes that this may give an unacceptably small fit to the data. In light of this, and given the similarity of the groupings comparing 5 factors under PAF and 6 components using PCA (Table 5.25), the PCA method was preferred as it produced six components, based on all eigenvalues greater than one.

Table 5.25: Comparison of PCA and PAF

	6 FACTORS - PCA: Pattern matrix: 70.329%						5 FACTORS - PAF: Pattern matrix: 64.293%				
	1	2	3	4	5	6	1	2	3	4	5
QU	POSTrust	TRAD	QUAL	NEGEnvC	POSInvest	NEGUseEnvC	POSTrust	TRAD	NEGUseEnvC	NEGEnvVal	QUAL
1				-0.729						-0.402	
2						0.73			0.566		
3		-0.348		-0.601						-0.705	
4						0.843			0.999		
5						0.603			0.633		
6					0.335	-0.744			-0.571		
7	0.554			0.377			0.457		-0.414	0.448	
8	0.645		0.302			-0.379	0.619				0.338
9	0.553				0.329		0.546				0.329
10	0.983						0.895				
11	0.777						0.727				
12				-0.527							
13		0.85						0.935			
14	0.323	0.835					0.323	0.619			
15					0.709		0.322				
16					0.803					-0.364	
17			0.773								0.516
18		-0.359	0.689								0.598
19			0.705								0.671
Qu	7,8,9,10,11	13,14	17,18,19	-1,-3,-12	15,16	2,4,5,-6	7,8,9,10,11,15	13,14	2,4,5,-6	-1,-3,-16	17,18,19

Note: Differences in groupings are highlighted in orange.

The additional component extracted in PCA concerned statements 15 and 16 which were both concerning the reasons for picking the community with PRW – that the potential to save money contributed to the decision to live there (15) and that the PRW system adds value to the property. The only other difference was regarding cost of PRW in statement 12, ‘the cost of non-drinking recycled water should be slightly less than drinking water’. In the PCA analysis disagreement with statement 12 was associated with a negative attitude towards the environment. In the PAF analysis statement 12 was not significant in any of the factors.

Catell's scree plot test (Figure 5.16) suggested extracting either 2 factors or eight factors. Extraction of two components resulted in only 41.707% of total variance explained, so six components were again preferred.

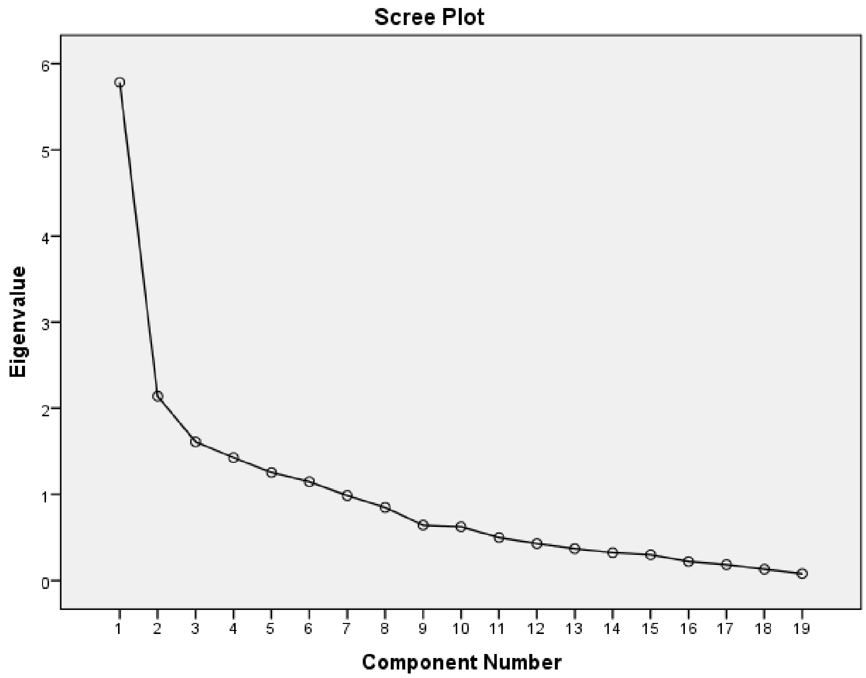


Figure 5.16: Catell's Scree plot of PCA components on Respondent Attitudes

Given a mean sample size of only sixty-two purified recycled water respondents across the questions, the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy was calculated and at 0.682 it was not ideal, but was greater than the minimum acceptable of 0.5 suggested by Hutcheson & Sofroniou (1999). Bartlett's Test of Sphericity was also significant ($p = .000$).

<u>Outliers</u>

Outliers can be problematic with factor/component analysis, and can exacerbate a problem with Haywood cases (McDonald (1985)). In order to detect potential outliers, the factor scores were also examined to identify any scores greater than +/- 3 (as recommended in SPSS). One such score was identified, and the survey responses were examined to check for data entry errors. The analysis was re-run without this respondent and the results compared. As the omission did not change the results the survey response was retained.

PCA results

Under principal component analysis the cumulative of the six components explained 70.329% of the total variance, with component one explaining 30.449%, component two 11.258% and the remaining components each between 6-8% (using PFA the five factors explained 53.405% of the total variance, 28.477% of the total variance being explained by factor 1) (Table 5.26). Analysis of the reproduced correlation residuals suggest that the model is not ideal as there are 42.0% non-redundant residuals with absolute values greater than 0.05 (32% for PFA), but this is still less than a generally accepted benchmark of less than 50% (Field 2013 p. 700).

Table 5.26: Principal Component Analysis (PCA) – total variance explained

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	5.785	30.449	30.449	5.785	30.449	30.449	4.419
2	2.139	11.258	41.707	2.139	11.258	41.707	1.907
3	1.610	8.475	50.182	1.610	8.475	50.182	2.289
4	1.426	7.507	57.689	1.426	7.507	57.689	1.856
5	1.255	6.604	64.293	1.255	6.604	64.293	2.213
6	1.147	6.035	70.329	1.147	6.035	70.329	3.831
7	.986	5.192	75.520				
8	.847	4.459	79.979				
9	.643	3.384	83.363				
10	.624	3.286	86.649				
11	.499	2.626	89.275				
12	.429	2.258	91.533				
13	.369	1.944	93.477				
14	.324	1.704	95.180				
15	.300	1.576	96.757				
16	.221	1.163	97.919				
17	.184	.968	98.887				
18	.132	.695	99.582				
19	.079	.418	100.000				

Extraction Method: Principal Component Analysis.

Identification and analysis of components – attitudes of existing PRW respondents

The six components identified using PCA made theoretical sense and suggest that the survey instrument is robust. Only loadings above 0.3 were extracted, and where a statement/variable loaded on more than one component only the higher loading was used. All loadings are reported in Table 5.33 below. On analysis of the results of the *Pattern Matrix* the components were labelled as follows:

1. POSTrust.

The statements that loaded on this component all reflected a positive attitude towards regulation and the safe operation of the current water supply, and a positive attitude towards its environmental benefits. This attribute label therefore reflects Positive Trust in the system (POSTrust).

Five statements loaded strongly positive (from 0.983 to 0.553) on this component, namely (in descending order of strength) statements 10, 11, 8, 7 and 9 (Table 5.27).

Table 5.27: PCA - Statements loading on POSTrust component 1

10 - I think there is adequate regulation to ensure safe use of recycled water (0.983) 11 - I trust the water authority to ensure recycled water quality (0.777) 8 - Environmental benefits of dual water supply are more important than financial benefits (0.645) 7 - I am confident there are no health risks associated with the dual water supply system (0.554) 9 -I am happy with the operation of the recycled water system (0.553) Statement 14 - Recycled water use should not be subject to water use restrictions - also loaded on this component (0.323), but as it loaded far more strongly on component 2 (0.835) it was included in that component.

2. TRAD

Two statements, 13 & 14, loaded strongly positive on this component (0.85 & 0.835) and seemed to reflect the 'traditional' view towards water use in Australia prior to more recent climate change concerns, with a long history of subsidised water supply and liberal use of the resource (Table 5.28).

Table 5.28: PCA - Statements loading on TRAD component 2

13 - The cost of non-drinking recycled water should be significantly less than drinking water (0.85) 14 - Recycled water use should not be subject to water use restrictions (0.835) Two further statements loaded negatively on the component (i.e. the respondents did not agree with the statements) but are not included in this component because they load with greater strength in other components and have been included there. Statement 18 - Charging for recycled water should be based on treating the wastewater to a high (Class A) standard & transport or delivery via pipe work to customers - (-0.348) and statement 3- The threat of climate change is a concern to me- (-0.359)

3. QUAL

The statements that loaded on this component all reflected a positive desire for quality recycled water, and a positive attitude towards willingness to pay for this. Three statements loaded strongly positive on this component - statements 17, 19 and 18 (Table 5.29).

Table 5.29: PCA - Statements loading on QUAL component 3

17 - I prefer my supply of non-drinking recycled water to be high quality and therefore cost only slightly less than drinking water (0.773) 19 - Charging for recycled water should be based on treating the wastewater to a high (Class A) standard & transport or delivery via pipe work to customers, plus part of the cost of building the treatment plant (0.705) 18 - Charging for recycled water should be based on treating the wastewater to a high (Class A) standard & transport or delivery via pipe work to customers (0.689) Statement 8 - Environmental benefits of dual water supply are more important than financial benefits - also loaded on this component (0.302), but as it loaded more strongly on component 1 (0.645) it was included in that component.

4. NEGEnvC

Three statements all loaded *negatively* on the component (i.e. the respondents did not agree with the statements) and reflected a negative attitude towards environmental issues and a lack of willingness to pay for PRW. NEGEnvC therefore denotes a negative attitude towards the environment and the Cost of PRW (Table 5.30).

Table 5.30: PCA - Statements loading on NEGEnvC component 4

1 - I enjoy living in a community that actively contributes to environmental sustainability (-0.729) 3 - The threat of climate change is a concern to me (-0.601) 12 - The cost of non-drinking recycled water should be slightly less than drinking water (-0.527) Statement 7 - I am confident there are no health risks associated with the dual water supply system - also loaded *positively* on this component (0.377), but as it loaded more strongly on component 1 (0.554) it was included in that component.

5. POSInvest

Two statements, 15 & 16, loaded strongly positive on this component (0.709 & 0.803) and reflected a positive attitude towards the financial investment choice of moving into a community with a PRW or 'purple pipe' system (Table 5.31).

Table 5.31: PCA - Statements loading on POSInvest component 5

15 - The potential to save money associated with the dual water supply system contributed to my decision to live here (0.709) 16 - The dual water system adds value to my property (0.803) Two further statements loaded positively on the component but are not included in this component because they load with greater strength in other components and have been included there. Statement 6 - I save money by using recycled water (0.335) and statement 9- I am happy with the operation of the recycled water system - (0.329)

6. NEGUseEnvC

Three statements loaded positively (agreement with the statements) and one loaded *negatively* on this component (i.e. the respondents did not agree with the statement). These respondents agreed that they would prefer a standard system with no dual water supply and that they avoided using the PRW system. They agreed with the statement that the PRW system had a negative effect on the environment and they disagreed with the statement that its use saved them money. NEGUseEnvC therefore denotes a reluctance to Use PRW and a negative attitude towards the Environmental benefits and Cost saving potential of PRW. In some ways this is similar to component 4 attitudes, but component 4 was related to a *positive* attitude to health risk (positive 0.377 on statement 7 - 'I am confident there are no health risks associated with the dual water supply system'). The PCA Structure matrix (Table 5.33) seems to suggest that the reluctance of respondents in component 6 may be more to do with fear of health risks (strong *negative* loading on statement 7) and a lack of trust in the water authority (negative loadings on 9, 11 and 10) (Table 5.32).

Table 5.32: PCA - Statements loading on NEGUseEnvC component 6

4 - I would prefer it if the water system was standard – no dual water supply (0.709) Negative to 6 - I save money by using recycled water (-0.744) 2 – I believe that the dual water scheme may have a negative impact on the environment (0.73) 5 - I avoid using the lilac/purple (recycled water) taps whenever possible (0.603) Statement 8- Environmental benefits of dual water supply are more important than financial benefits - also loaded *negatively* on this component (-0.379), but as it loaded more strongly on component 1 (+0.645) it was included in that component. In addition per *Structure Matrix*: 7 - I am confident there are no health risks associated with the dual water supply system (-0.555) 9 -I am happy with the operation of the recycled water system (-0.462) 11 - I trust the water authority to ensure recycled water quality (-0.378) 10 - I think there is adequate regulation to ensure safe use of recycled water (-0.351)

Table 5.33: Principal Components Analysis (PCA) – pattern matrix and structure matrix

Principal Components analysis (PCA): Pattern matrix

	1	2	3	4	5	6
QU	POSTrust	TRAD	QUAL	NEGEnvC	POSInvest	NEGUseEnvC
1				-0.729		
2						0.73
3		-0.348		-0.601		
4						0.843
5						0.603
6					0.335	-0.744
7	0.554			0.377		
8	0.645		0.302			-0.379
9	0.553				0.329	
10	0.983					
11	0.777					
12				-0.527		
13		0.85				
14	0.323	0.835				
15					0.709	
16					0.803	
17			0.773			
18		-0.359	0.689			
19			0.705			
Qu	10,11,8,7,9	13,14	17,19,18	-1,-3,-12	16,15	4,-6,2,5

Rotation method: Oblimin with Kaiser Normalization

PCA: Structure matrix

	1	2	3	4	5	6
QU	POSTrust	TRAD	QUAL	NEGEnvC	POSInvest	NEGUseEnvC
1				-0.729		
2						0.73
3		-0.348		-0.601		
4						0.843
5						0.603
6					0.335	-0.744
7	0.668					-0.555
8	0.735		0.469			
9	0.676				0.487	-0.462
10	0.926					-0.351
11	0.842				0.315	-0.378
12				-0.527		
13		0.85				
14	0.323	0.835				
15					0.709	
16					0.803	
17			0.773			
18		-0.359	0.689			
19			0.705			
Qu	10,11,8,9,7	13,14	17,18,19	-1,-3,-12	15,16	2,4,5,-6

Note: Items highlighted in blue have the highest loading for that question, those in beige load on that factor for that question, but not at the highest value.

Note: For scale reliability analysis and calculation of Cronbach's alpha, a number of the reverse-phased statements, initially recording a negative correlation, were reverse recoded (Field 2013).

Further component analysis

Having identified components, further analysis was undertaken with the composite components to test relationships between PRW respondents with these 6 characteristics and the responses to other aspects of the survey instrument. Composite component variables were calculated by adding the results from the statements in that component and then averaging by the number of statements to achieve a score/5. For the purpose of this analysis all negative scoring statements were reversed scored and this transformed variable used.

Willingness to accept PRW for indirect potable (drinking) use (PRW respondents)

One key consideration is to identify attributes related to the willingness to accept (or reject) the idea of PRW for indirect potable (drinking) use. How important is a respondent's trust in the system for determining if he/she will accept PRW for potable use? Are PRW respondents with the attribute 'POSTust' more or less likely to accept the use of PRW for potable water?

The **POSTrust** variable was analysed in relation to the answers to the question 'would you support the use or recycled water for indirect drinking water use (recycled water added to the dam)?' in times of water restrictions. The respondents could answer 'yes', 'no', or 'unsure' to this question, so for these purposes the question was recoded to make it dichotomous. To be conservative, those answering 'yes' were counted as yes and 'no' and 'unsure' answers were both coded as 'no'.

Initial analysis showed that PRW respondents with the attribute 'POSTust' *are* more likely to accept the use of PRW for potable water. Boxplots revealed that the median for those PRW respondents exhibiting trust and responding 'yes' to the use of PRW for drinking is higher than for those answering 'no' and the middle quartiles (25^{th}-75^{th} percentiles) are noticeably higher for those responding 'yes' (Figure 5.17).

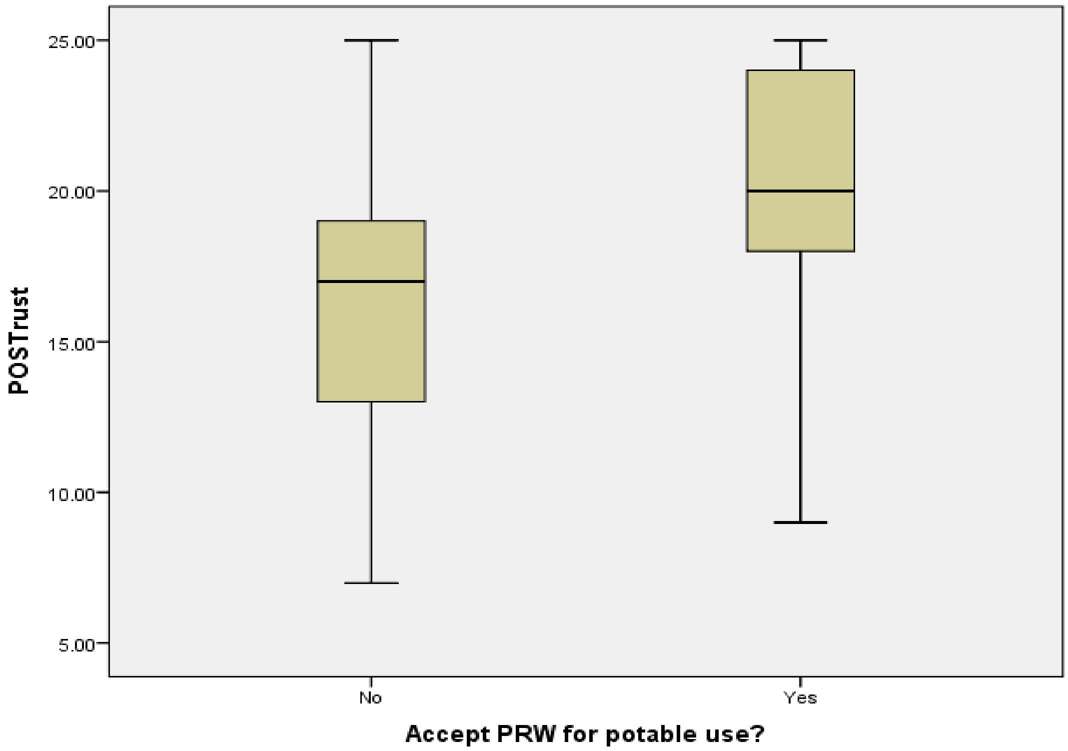


Figure 5.17: PRW respondents exhibiting positive trust (POSTrust) – response to accepting PRW for potable use

An independent-samples t-test was conducted to compare the averaged 'POSTrust' scores for PRW respondents responding 'yes' to support the use or recycled water for indirect drinking water use and those responding 'no' or 'unsure'. There was a significant increase in scores for 'yes' respondents (M = 3.9943, SD 0.90552) and 'no/unsure' respondents (M = 3.2923, SD 0.92474; *t* (59) = -2.967, p = 0.004, two-tailed). The magnitude of the differences in the means (mean difference = .702, 95% Cl: -1.17535 to -.22861) was large (eta squared = 12.983). On average PRW respondents with the attribute 'POSTrust' were more likely to respond 'yes' to support the use or recycled water for indirect drinking water use than to respond 'no' or 'unsure'.

As this is a small data set, a non-parametric test was also undertaken with similar results. A Mann-Whitney U Test revealed a significant difference in the average POSTrust levels of PRW respondents responding 'yes' for PRW indirect potable use (Md = 4, n =35) and RW respondents responding 'no/unsure' (Md = 3.4, n = 26), U = 261, z = –2.845, p=.004, r =.364. Again on average PRW respondents with the attribute ‘POSTrust’ were more likely respond ‘yes’ to support the use or recycled water for indirect drinking water use.

The Mann-Whitney U test was repeated for all of the other component variables.
For the **TRAD** variable a Mann-Whitney U Test revealed no significant difference in the average TRAD levels of PRW respondents answering ‘yes’ for PRW indirect potable use (Md =5, n =35) and RW respondents answering ‘no/unsure’ (Md = 5, n = 26), U = 452.5, z = –.040, p=.968, r =.005.

For the **QUAL** variable, although the mean in the average QUAL levels of PRW respondents responding ‘yes’ for PRW indirect potable use (3.3824) was higher than for RW respondents responding ‘no/unsure’ (2.9861), a Mann-Whitney U Test again revealed no significant difference in the average QUAL levels of PRW respondents responding ‘yes’ for PRW indirect potable use (Md =3.5, n =34) and RW respondents responding ‘no/unsure’ (Md = 3, n = 24), U = 290.5, z = –1.868, p=.062, r =.245.

For the **NEGEnvC** variable once again a Mann-Whitney U Test revealed no significant difference in the average NEGEnvC levels of PRW respondents responding ‘yes’ for PRW indirect potable use (Md =2, n =35) and RW respondents responding ‘no/unsure’ (Md = 2, n = 26), U = 415, z = –.589 p=.556, r =.07.

Similarly for the **POSInvest** variable a Mann-Whitney U Test revealed no significant difference in the average POSInvest levels of PRW respondents responding ‘yes’ for PRW indirect potable use (Md =3, n =35) and RW respondents responding ‘no/unsure’ (Md = 3, n = 26), U = 442, z = –.193 p=.847, r =.025.

However for the final component variable **NEGUseEnvC** a Mann-Whitney U Test revealed a significant difference in the average NEGUseEnvC levels of PRW respondents responding ‘yes’ for PRW indirect potable use (Md = 1.25, n =35) and RW respondents responding ‘no/unsure’ (Md = 2.125, n = 26), U = 308.5, z = –2.168, p=.030, r =.278. On average PRW respondents with the attribute ‘NEGUseEnvC’ were more likely respond ‘no’ to oppose the use or recycled water for indirect drinking water use. In other words existing respondent customers who are currently reluctant to use the dual pipe system on grounds that they believed it had a negative effect on the environment, did not save money, and had potential health concerns, were less likely to support the extension of PRW use to potable/drinking water use.

5.2.4.8 Research implications of Section B of the survey

In relation to the model, this section B of the survey explores the social aspect. Following is a summary of the additional information from this section in relation to the research questions.

Section B sheds some light on the water customers as stakeholders, relevant to RQ1:

RQ 1

- What are the characteristics of the recycled water supply chain in SE Queensland, including key stakeholders, and specifically the stakeholders in the 2 AWTPs studied

- Primarily households used mains tap water for their drinking supplies (90%) and expressed overall satisfaction with this (84%), although 26% filtered it. There was some suggestion that some respondents lacked trust even in the supply of mains water, with uncertainty expressed regarding its quality with regard to germs and chemicals. The second most used drinking water is filtered tank water (5.4%).
- Households estimated the highest use of water for (1) shower/bath (2) clothes washing and (3) toilet flushing, but may underestimate their level of overall water use and the level of usage for different activities (tap use underestimated and irrigation overestimated).

The focus of section B was however to ascertain information about sources and uses of recycled water and to explore customer perceptions about the benefits and risks of recycled water use. Customer awareness of recycled water sources, RW sources in use, and uses for the recycled water were examined first. This has most relevance for RQ2.

RQ 2

- How is recycled water defined and to what level should it be recycled? (substitute for industrial use/potable water added to consumer drinking supplies) What are its uses?

- Most respondents used some form of RW (77%), and had generally done so for more than two years, even the majority of non PRW respondents (55%). A sizeable proportion had rainwater tanks (31% of all respondents; 56% of non PRW respondents), even if they had PRW as well (20%). This may have greenhouse gas emissions implications as respondents may be unaware of the higher electricity costs (and carbon footprint) of these due to pump use.
- All types of recycled water seemed well known, although less so grey water and reclaimed stormwater. PRW respondents may be marginally more likely to use storm water compared to non PRW respondents.
- The most common uses of any recycled water were garden watering (highest use category for non PRW respondents), car washing, toilet flushing (highest use for PRW) and clothes washing (primarily re. non PRW respondents).
- RW water toilet use is not widespread among non PRW respondents due to the cost of plumbing (from tanks).
- Most respondents currently not using RW would be willing to do so (71%) although reasons for non-use also suggested a sizeable minority (29%) making a positive choice not to use RW. The choice to use/not use RW does not seem to be influenced by gender, age or education level.

Customer perceptions about recycled water were examined next, which had most relevance for RQ6:

RQ 6

- What are the perceived benefits and risks (costs) of recycled water use for customers?

- Overall respondent satisfaction with the PRW system was high (79%) and respondents were generally happy with the quality of water for non-potable permitted uses, although as with satisfaction with mains water supply satisfaction over quality was least concerning germs and chemicals, and this was much more pronounced for PRW, indicating increased trust issues. The majority responded 'don't know' about quality in these categories, and rated them similarly. This distrust was expressed in respondent comments, even for areas where they had used the PRW for an activity with low human contact and observed no ill effects, such as car washing e.g. 'unsure of effect – looks clean.' However, the large majority of comments made about PRW permitted uses were positive (75-82%).

- The vast majority of PRW respondents valued living in a PRW supply area (89%) and agreed that it had environmental benefits (and so valued externalities RQ4).

RQ 4

- What information beyond the current economic accounting system is required to provide a full cost accounting or TBL approach? i.e. defining the scope of included externalities

- Identified Benefits: Lack of water restrictions (73%); cost savings (69%); to a lesser extent environmental benefits (being sustainable/avoid using potable water supply) and 42% agreeing that PRW added value to their property.
- Although most respondents also expressed concern about climate change (68%), that concern was not fully translated into support for PRW with only 42% valuing environmental benefit over cost for PRW.
- Respondents value the existence of the PRW supply but willingness to pay is limited with reference to potable supply
- Risks/costs: Perceived health risks re .chemicals and germs in PRW. Lesser complaints re. smell and residue left after car washing. Trust issue to some extent with water authority and more so with regulations
- Factor analysis identified six components/attitudes. The results suggested largely positive attitudes to PRW use (45.5% of the explained variance), but also indicated a polarisation of views, with minority but significant attitudes in direct contradiction to the largest positive component grouping. Positive views seem characterised by trust in the system, environmental concerns, and value for money. Negative views seem influenced primarily by cost, but also lack of belief in the environmental benefits, and the most strongly opposed respondents have a lack of trust in the system and have concerns about health risks.

- Factor analysis

  1.-Respondents positive in their trust of the water authority and regulations also more likely to value the environment over financial benefits

  2. -Respondents who favour fewer restrictions also unwilling to pay (situation pre drought)

  3. -Desire for quality water linked to willingness to pay

  4. -Lack of belief in climate change/environment linked to unwillingness to pay

  5. -Desire to save money and add value to the property linked

  6. -Respondents not wanting PRW, believe it has a negative environmental impact and unwilling to pay (also distrust regulators and fear health risks)

Further analysis was undertaken to examine the influence these attitudes may have on acceptance of PRW for indirect potable use, most relevant to RQ7.

RQ 7 •What factors influence customer acceptance of PRW for potable use?

The acceptance or otherwise of PRW for potable use seems to hinge primarily on trust as the only significant relationship is with the first group - respondents trusting the water authority/regulations, who perceived environment benefits of RW more likely to support indirect and the last group - Respondents wanting no PRW use, perceiving a negative environmental impact & unwilling to pay and concerned about poor regulation and health risks – rejecting PRW for indirect potable use.

From a policy-making point of view, this has relevance to RQ3, as social cost/risk and lack of trust/perception are identified as a risk of introducing recycled water.

RQ 3 •What are the risks of recycling and how can they be managed?

- Need to manage actual risk (to promote trust) particularly in light of a negative minority that could act as a lobby group 'NEGUseEnvC'(negative views on RW use, environment and prices and lacking trust over regulations/health issues).

5.2.5 Recycled water – drinking standard (potable) (survey Section C)

Section C was similarly designed to explore Research Questions 2, 6, 7 and additionally RQ5 (investigating attitudes about preferred methods of producing PRW). It was designed to be answered by ***all*** households, whether or not they already had an existing recycled water supply via a 'purple pipe' scheme. The intention regarding customer perceptions was to explore -:

- the extent to which PRW should be refined – is it acceptable for indirect potable use? (RQ2)
- -customer preferences for processing method – RO or BAC/ozone? (RQ5)
- -customer perceived risks and benefits for all water customers (and are these different to PRW existing customers) (RQ6)
- -factors that influence customer acceptance of PRW for potable use (RQ7)

In this section respondents were given a definition of the term 'Purified Recycled Water' (PRW) and a brief explanation of the terms 'Reverse osmosis' (RO) and 'Biologically activated carbon' (BAC). The difference between direct and indirect (i.e. via a dam) PRW drinking water supply was also explained. For this section respondents were also asked to assume that the PRW was drinking (potable) standard, and that water restrictions were in place due to water shortages. They were then asked for their views on a number of issues.

5.2.5.1 Views on indirect potable use

- *Household views regarding the use of PRW for indirect potable use*

When asked a majority of all water respondents (59.1%) said yes they would support indirect potable use, but there was a significant proportion undecided (15%) and a sizeable minority against (26%).

The QLD government intended the investment in water infrastructure to be a method of 'drought proofing' the water supply or at least creating a drought resilient water supply for the increasing population of the region. It was the intention of government to use recycled water in the future to boost water supply in times of drought and population expansion. There is some research evidence to suggest that the experience of drought and water restrictions has increased customer awareness regarding the need to save water, and has raised the profile of water as a scarce resource (AAP 2009; Beal, Stewart & Huang 2010). However, public acceptance of PRW remains a critical aspect of successful implementation.

Support for potable use of PRW (RQ7)

In this section respondents were first asked if, during water restrictions, they would support the use of PRW for indirect drinking water use (recycled water added to the dam). Of the 127 households responding to this question, a majority at 75 (59%) said yes that they would support it, with 19 (15%) undecided and 33 (26%) saying no that they would not support it (Figure 5.18). This again shows that although PRW may have majority support, there remain significant proportions of the population both undecided and opposed to the scheme.

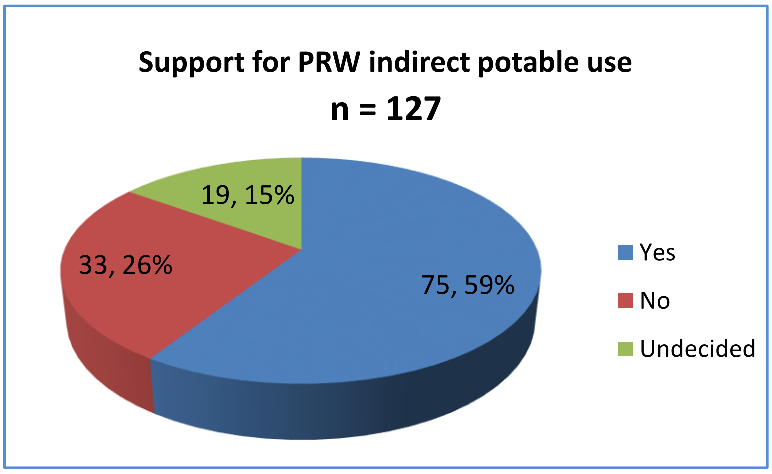


Figure 5.18: Strength of support for the indirect potable use of purified recycled water (PRW)

- *Attitudes regarding the risk of various uses of potable standard PRW*

Respondents were asked to rate their view of the risk of using drinking standard PRW for various uses, using a Likert scale from ‘not at all risky’ (0) through ‘medium risk’ (5) to ‘extremely risky’ (10) (Table 5.34). No use received a mean rating higher than a medium risk, but again opinions were polarised.

In common with previous studies (Hurlimann 2007; Marks, Martin & Zadoroznyj 2006; 2008), the results demonstrated that respondents were increasingly reluctant to use even potable standard PRW the more personal that use became. That said, for all but the two drinking uses, the largest proportion of respondents indicated that they saw no risk in the other uses of PRW. For the six more remote uses of PRW the second largest proportion of respondents indicated a '1' or minimal risk. The two drinking uses are the only two categories with a mean above 5 (medium risk) at 5.23 for indirect and 5.9 (marginally above medium risk) for direct potable use. The next closest category was showering with a mean of 4.6.

This begs the question why has the proposed introduction of potable PRW historically met with such opposition? Analysis of the *dispersion* of the results suggests a reason. Although the means do not go further than suggest 'medium' perceived risk, the dispersion of views about perceived risk (standard deviation) increases with the increase in personal contact. Looking at the scores with the two highest proportions of answers, highlighted in Table 5.34 below, views begin to polarise. For vegetable growing, the second largest category (which for the first six PRW uses remained only one step up at a risk level of '1') now becomes '10' or 'extreme risk'. So the two major categories for vegetable growing are '0'(37.4%) and '10' (11.4%) respectively. There is a less severe split for clothes washing with categories '0' (37.9%) and '3' (9.7%). However the dichotomy is evident again with washing hands ('0':23% & '10':16.4%) and with showering the proportions are almost equal ('0':22.4% & '10':20.8%). For the two drinking uses these proportions are reversed, with the same two categories having the largest proportion of answers, but this time the majority picking '10': drinking indirectly ('10':25% & '1':16.9%) and drinking directly ('10':32.8% & '1':12.8%) . The spread of opinions is greatest for these four close contact categories as well – shower standard deviation 3.929, drink directly SD 3.835, drink indirectly SD 3.824 and wash hands SD 3.724. Perceptions of risk are therefore both more diverse and more polarised on these categories.

- *Differences between existing dual-pipe PRW respondents and other respondents*

This survey found no significant difference between the perceptions of existing PRW respondents and other respondents, contrary to suggestions from previous research, and perhaps surprising given the overall satisfaction with the PRW system expressed by existing respondent customers.

In order to investigate whether experience using non-potable recycled water in the dual-pipe domestic scheme changed perceptions regarding the risk of using of potable PRW for drinking use, the results from the two categories of respondents were compared.

An independent samples t-test was conducted to compare the risk assessment of potable PRW being used for indirect drinking purposes between respondents currently using non-potable recycled water in the dual-pipe domestic scheme and those who did not have the dual pipe scheme available. On average respondents currently using a dual reticulation scheme (M=5.37, SD 3.997) had a slightly higher perception of the risk associated with using potable PRW for indirect drinking use than those not currently using non potable PRW (M=5.10, SD 3.670). However there was no significant difference between the two respondent groups t (122) = .398, p = .689, two tailed. The magnitude in the differences in the means (mean difference = .27, 95% *Cl*: -1.090 to 1.638) was very small (eta squared = .001).This analysis indicates that the level of assessment of risk in using potable PRW for indirect drinking use does not differ between the respondent groups.

Table 5.34: Perceptions of risk regarding potable standard PRW uses: all respondents

Use of RECYLCED (PRW) Water			0 - no risk		1		2		3		4		5 - medium		6		7		8		9		10 - extreme		n
	mean	sd	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%	
Garden watering – public e.g. parks/golf courses	0.83	1.54	79	64.2%	22	17.9%	8	6.5%	5	4.1%	0	0.0%	7	5.7%	1	0.8%	0	0.0%	1	0.8%	0	0.0%	0	0.0%	123
Garden watering – private	0.94	1.64	77	62.1%	18	14.5%	14	11.3%	5	4.0%	2	1.6%	5	4.0%	0	0.0%	2	1.6%	1	0.8%	0	0.0%	0	0.0%	124
Toilet flushing	0.80	1.77	86	69.4%	19	15.3%	8	6.5%	2	1.6%	0	0.0%	4	3.2%	1	0.8%	1	0.8%	2	1.6%	1	0.8%	0	0.0%	124
Street cleaning	0.69	1.5	85	69.1%	20	16.3%	10	8.1%	1	0.8%	0	0.0%	4	3.3%	1	0.8%	0	0.0%	2	1.6%	0	0.0%	0	0.0%	123
Car washing	0.96	1.68	76	61.3%	20	16.1%	13	10.5%	4	3.2%	1	0.8%	7	5.6%	1	0.8%	0	0.0%	2	1.6%	0	0.0%	0	0.0%	124
Public fountains and water features	2.04	3.05	62	50.4%	17	13.8%	10	8.1%	8	6.5%	1	0.8%	9	7.3%	2	1.6%	1	0.8%	3	2.4%	2	1.6%	8	6.5%	123
Vegetable growing	3.41	3.61	46	37.4%	6	4.9%	14	11.4%	7	5.7%	6	4.9%	9	7.3%	5	4.1%	8	6.5%	3	2.4%	5	4.1%	14	11.4%	123
Clothes washing	3.22	3.47	47	37.9%	10	8.1%	8	6.5%	12	9.7%	5	4.0%	9	7.3%	5	4.0%	5	4.0%	9	7.3%	5	4.0%	9	7.3%	124
Wash hands	4.47	3.72	28	23.0%	11	9.0%	12	9.8%	4	3.3%	5	4.1%	16	13.1%	5	4.1%	7	5.7%	7	5.7%	7	5.7%	20	16.4%	122
Drink – indirectly	5.23	3.82	21	16.9%	10	8.1%	11	8.9%	9	7.3%	2	1.6%	11	8.9%	6	4.8%	8	6.5%	10	8.1%	5	4.0%	31	25.0%	124
Shower	4.60	3.93	28	22.4%	14	11.2%	11	8.8%	9	7.2%	1	0.8%	12	9.6%	4	3.2%	6	4.8%	4	3.2%	10	8.0%	26	20.8%	125
Drink – directly	5.90	3.84	16	12.8%	11	8.8%	6	4.8%	9	7.2%	5	4.0%	11	8.8%	4	3.2%	6	4.8%	8	6.4%	8	6.4%	41	32.8%	125

(pink)	indicates category with largest proportion of responses/largest value
(green)	indicates category with second largest proportion of responses/second largest value

➢ *Preferences for PRW processing*

Most respondents who accepted indirect potable use were willing to accept any method approved by Australian standards, but those expressing a preference preferred RO. This may be related to the higher media profile of RO.

All participants were asked, again on the assumption that water restrictions were in place due to water shortages, 'how would you prefer that the PRW had been processed'? The response options were:

A multi barrier process including reverse osmosis (RO)	A multi barrier process including biologically activated carbon (BAC)	It does not matter provided the PRW meets the Australian standards	It should be decided on cost provided both meet Australian standards	I would not drink any PRW	I am unsure /don't know

As mentioned, Section C gave respondents definitions of the terms 'Purified Recycled Water' (PRW) 'Reverse osmosis' (RO) and 'Biologically activated carbon' (BAC). It is possible that these explanations were not always read, or not clearly understood, as one respondent added the comment 'How many people know what RO and BAC are!' However respondents were given the opportunity to respond 'I am unsure/don't know.'

Six participants did not answer the question, but of the remaining one hundred and twenty-three, thirty-seven (30.1%) had no real preference as long as Australian standards were met with only twelve respondents (9.8%) being of the opinion that the method should be decided on cost. Twenty (16.3%) were unsure. Nineteen expressed a preference for RO (15.4%) and three for BAC (2.4%). Once again a significant minority of thirty-two (26%) stated that they would not drink *any* PRW. Most of those who would consider drinking PRW were therefore willing to be guided by Australian standards, with RO the most favoured process of those who expressed a preference (Figure 5.19).

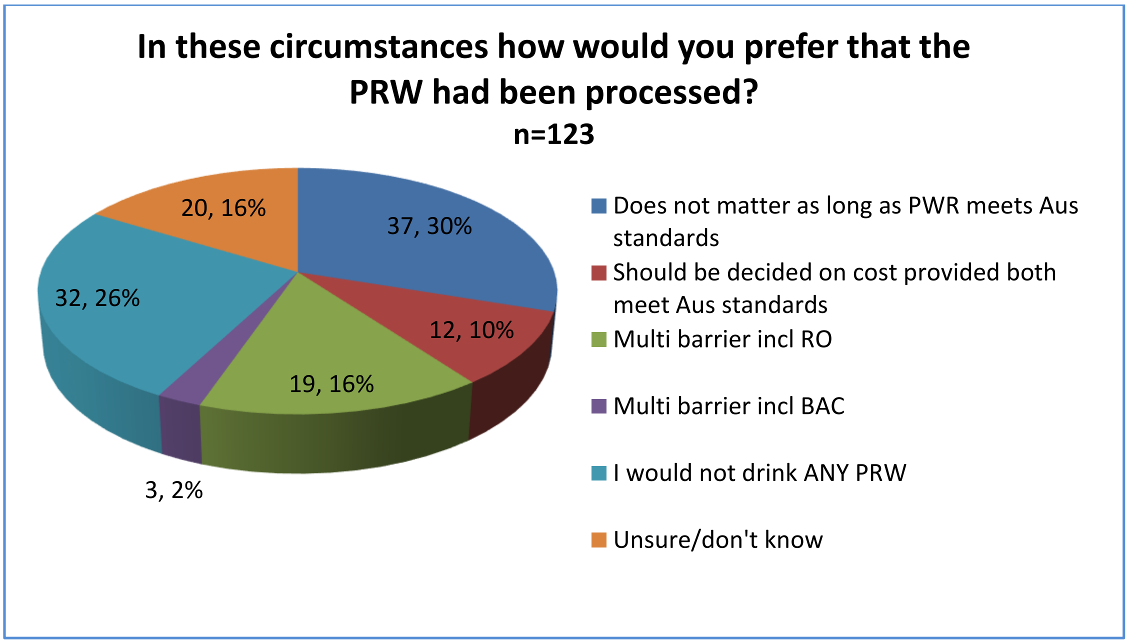


Figure 5.19: Respondents preferences regarding the preferred processing method for indirect potable use of purified recycled water (PRW)

5.2.5.2 Environmental concerns

- *Attitudes about recycled water and motivations – ALL respondents*

All respondents were then asked - to indicate whether they agreed or disagreed on a 5 point Likert scale with twenty-four (24) questions designed to indicate their attitudes and views in a number of areas including environmental issues, attitudes about recycled water, water management, water and health, water costs, the role of the media, and their water usage (Table 5.35). This was partly exploratory and partly suggested by previous research. The scale ranged from 'Agree' (A) (5) through 'Somewhat agree'(SA) (4); 'Neither agree nor disagree' or Neutral (N)(3); 'Disagree somewhat' (DS) to 'Disagree' (D) (1).

- *Environmental concerns (RQ4)*:

Some questions examined attitudes to environmental issues in general terms (Figure 5.20) and were most relevant to Research Question 4:

- *QLD and drought:* 49.6% of respondents 'agreed', and 27.6% 'somewhat agreed' (total agreement 77.2%) with the statement 24 'I think that there will be droughts in SE QLD again in the near future' (with only 5.5% disagreeing and the rest unsure). (Mean 4.20 SA; SD 0.968). It seems most respondents accepted recurring drought as a 'norm' in the QLD weather scheme.

- *Climate change*: 64.1% agreed to some extent that 'the threat of climate change is a concern to me', while 13.3% were unsure, and 22.7% disagreed that it was a concern. (Mean 3.67 SA; SD 1.346). This was a question that was also asked of the existing PRW use respondents (i.e. repeated here). The PRW answers were: agree 67.7%, unsure 22.6% and disagree 9.7%. (Mean 3.87 SA; SD 1.138). This question permitted comparison between the two groups and assessment of the consistency of answers.

Other questions looked more specifically at environmental issues concerning water (Figure 5.20):

- *The natural water system:* 27% of respondents 'agreed', and 21.4% 'somewhat agreed' (total agreement 48.4%) with the statement 15 'All water is recycled', but the largest single proportion at 27.8% were unsure while 23.8% disagreed to some extent (12.7 DS, 11.1%D). (Mean 3.4 N; SD 1.31). This was a statement provoking uncertain responses and a wide range of responses. The statement may not have been clearly understood.
- *Floods and water supply:* The vast majority agreed (86.6%) that 'floods also cause water supply problems because they damage infrastructure' (A 42.5%; SA 44.1%) with only 7.1% unsure and 6.3% disagreeing to some extent. (Mean 4.21 SA; SD 0.888). This was the statement with the largest percentage of agreement and least polarisation or variation in responses. The impact of floods on water supply is appreciated.
- *Energy and water:* These questions were prompted by interest in whether respondents were aware of the connection between energy and water use. Most energy in QLD is generated by coal fired power stations with heavy water use. Statement 1 was 'Saving energy is more important than saving water' and 33.1% of respondents answered neutral/neither agree nor disagree with a total of 42.5% disagreeing to some extent and 24.4% agreeing to some extent (Mean 2.71 N; SD 1.203). Again this was a statement provoking uncertain responses and a wide range of responses. The responses to Statement 2 'Saving energy is

a way of saving water' suggest that most respondents are aware of the link between these two resources. For this statement most respondents (55.9%) agreed to some extent (although 38.6% SA; 17.3% A) with still a sizeable number neutral (28.3%) and a minority disagreeing to some extent (15.7%) (Mean 3.5 SA; SD 1.097).

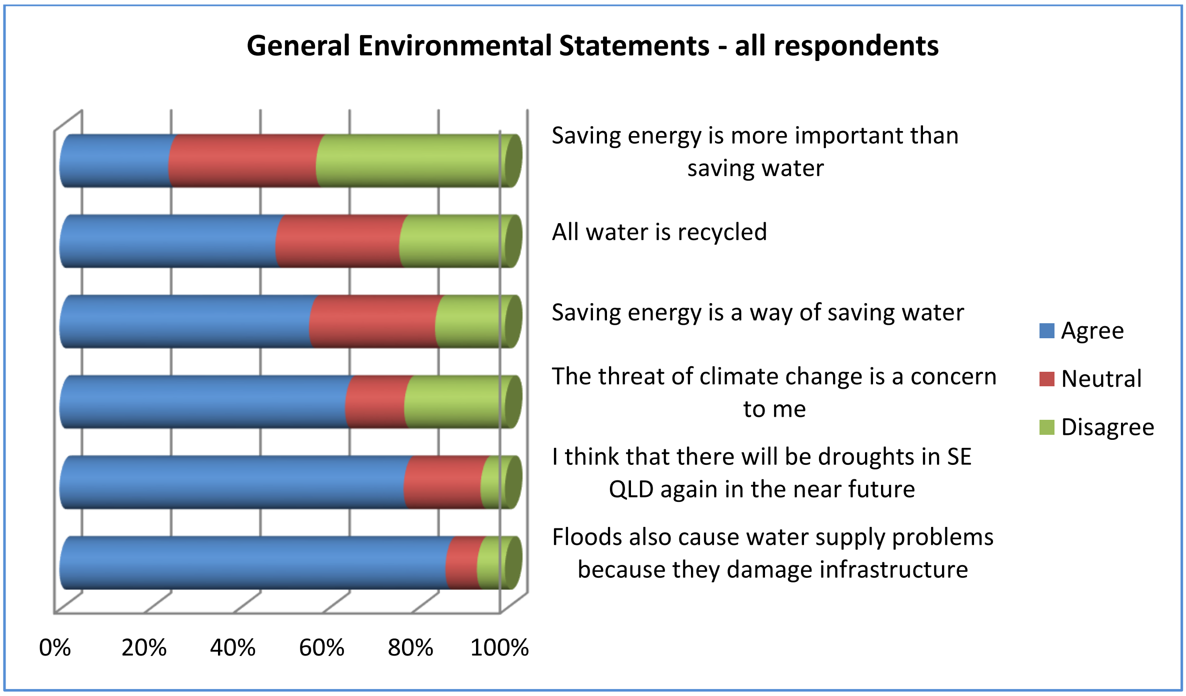


Figure 5.20: Responses regarding general environmental statements

➢ *Questions regarding the use of recycled water more specifically*

These statements were aimed at exploring attitudes towards recycled water, relevant to Research Question 6 (Figure 3.5).

Need for water recycling: The vast majority of respondents (75.8%) agreed to some extent that 'We need to use recycled water for the future's sake' (46.9% A; 28.9% SA) with only 10.2% Neutral and 4.7 disagreeing at all. ((Mean 4.04 SA; SD 1.173).

Recycled water and natural water recycling: Respondents were uncertain about the statement 'The Purified Recycled Water treatment just speeds up the natural water recycling process' with 46% Neutral and 41.3% agreeing to some extent (18.3% A; 23% SA) but only12.7% disagreeing at all. (Mean 3.43 N; SD 1.015).

Advantages of water recycling: Three statements concerned potential advantages of PRW. The first concerned the ready supply: 'An advantage of using Purified Recycled Water is that there is a constant supply'. This was the most strongly supported statement with 66.4% agreement (29.6% A; 36.8% SA), 23.2% neutral and only 10.4% disagreeing at all. (Mean 3.81 SA; SD 1.075).

The second statement concerned savings in infrastructure: 'An advantage of using Purified Recycled Water is that it may mean less need to build dams'. This was also a strongly supported statement with 64.5% agreement (30.6% A; 33.9% SA), 23.1% neutral and even fewer disagreeing at 5.8%. (Mean 3.77 SA; SD 1.131).

The third statement regarded the use of dams for flood mitigation: 'An advantage of using Purified Recycled Water is that it may allow more dam capacity to be used for flood mitigation'. The theory is that dams need not be kept at such high capacity if there are alternative water supplies, thereby leaving spare capacity to absorb higher rainfall at crucial times. Respondents were less aware of this or less convinced by this as 33.3% were Neutral with 47.6% agreeing to some extent (15.9% A; 31.7% SA) and 19% disagreeing to some extent. (Mean 3.39 N; SD 1.081).

5.2.5.3 Trust issues

Trust & satisfaction with the system:

Some questions were aimed at exploring the trust (or lack of it) in the *safety* of the mains water and PRW supply and the *trust* in the authorities providing it (relevant to perceived risks in research question 6) (Figure 5.21):

- *Operation of the water system*: Approval of current water quality appears high with 73.8% agreement (34.9% A; 38.9% SA) with the statement 'I think the present water quality system in Queensland is good', and a further 19% were neutral and with only 7.1% disagreeing to some extent (Mean 3.97 SA; SD 1.035).
- *Interference in the water cycle*: The majority of respondents did *not* agree with the statement that 'I feel uneasy about human interference in the natural cycle', but there was some uncertainty. The largest section at 41.7% disagreed to some

extent (18.1% DS; 23.6% D), but 23.6% gave a Neutral response, and a still sizeable proportion at 34.6% agreed to some extent (12.6% A; 22% SA). Worries about the risks involved - persist and divide views. (Mean 2.82 N; SD 1.354)

- *Trust in the science:* A clear majority of respondents do trust the scientific evidence with 57.5% agreement (27.6% A; 29.9% SA) with the statement 'I trust the scientific evidence about the safety of Purified Recycled Water', but opinion is still divided with 21.3% being neutral and the same number (21.3%) disagreeing to some extent (Mean 3.54 SA; SD 1.271).
- *Health risk- general:* A majority of respondents did not think PRW presented a large health risk with again 57.5% agreement (26.8% A; 30.7% SA) with the statement 'The likelihood of an incident leading to a health risk from Purified Recycled Water is small', but with similar divided opinion with 20.5% being neutral and slightly more (22%) disagreeing to some extent (Mean 3.52 SA; SD 1.284).
- *Health risk- Australia:* Surprisingly when talking about *PRW in Australia* specifically a smaller number of respondents agreed with the statement 'I do not think it likely in Australia that there would be an incident using Purified Recycled Water that would lead to a serious health risk', with 44.1% agreement (18.9% A; 25.2% SA) and 26.8% remaining neutral and with slightly more (29.1%) disagreeing to some extent regarding Australia compared to the more general question. (Mean 3.2 N; SD 1.303).

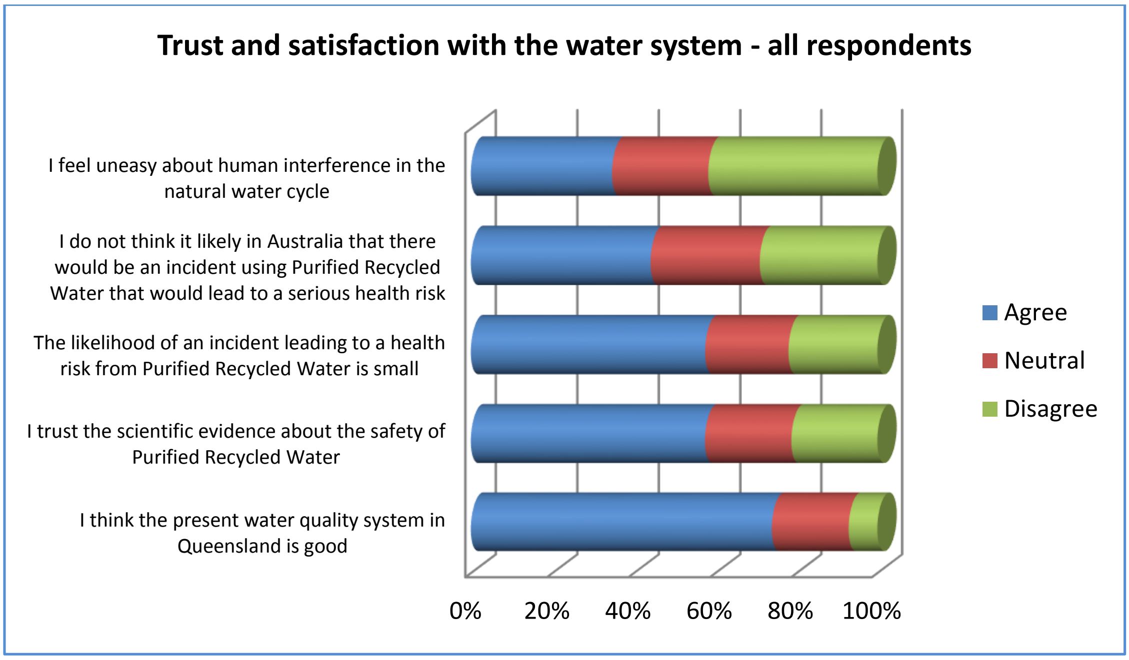


Figure 5.21: Responses regarding trust & satisfaction with the water system

5.2.5.4 Water use

Water use:

Some questions were aimed at exploring perceptions about water use and PRW use restrictions:

- *PRW Water restrictions*: The majority clearly agreed to some extent that 'Recycled water use should not be subject to water use restrictions' at 63.8%, while 15% were neutral, and 21.3% disagreed to some extent. (Mean 3.69 SA; SD 1.226). This was a question that was also asked of the existing PRW use respondents (i.e. repeated here). The PRW answers were: agree 72.6%, unsure 12.9% and disagree 14.5%. (Mean 4.06 SA; SD 1.304). This question permitted comparison between the two groups and assessment of the consistency of answers.

- *Level of Water use:* Three statements concerned the respondent's perception of his/her household's level of water use i.e. whether or not they agreed the use to be average, more than average or less than average compared to other households in the area. Clearly householder perceptions are that they use less than they do in reality, inasmuch as the vast majority agreed that they used less than average (which they cannot *all* do, assuming a respondent group representative of the poulation). The statement: ‘My household uses *less than* the average amount of water per day for my area’ had 63% agreement (38.6% A; 24.4% SA), 29.1% neutral (indicating some uncertainty) and only 7.9% disagreeing at all. (Mean 3.93 SA; SD 1.017). The statement: ‘My household uses *an average amount* of water per day for my area’ had by contrast 36.5% agreement (17.5% A; 19% SA), with also some uncertainty at 26.8% neutral and more respondents disagreeing at 29.1%. (Mean 3.2 N; SD 1.303). The statement: ‘My household uses *more than the average* amount of water per day for my area’ received least support with only 7.1% agreement (0.8% A; 6.3% SA), with also some uncertainty at 23.6% neutral but the clear majority of respondents disagreeing at 69.3%. (Mean 2.02 DS; SD 0.968). This -indicates a - disparity between perception and practice regarding water use. This also appears to be the case regarding the influence of media coverage (discussed in the next section).

5.2.5.5 Media and information and cost

Media influence:

As suggested by previous research on the ‘third-person effect’ (Davison 1983; McLeod, Eveland & Nathanson 1997) respondents tend to believe that others are influenced by the media, but that they personally are not. This was explored with two statements:

- *General Media influence*: A clear majority of respondents did agree that negative media coverage regarding PRW influenced the public, as 66.4% agreed to some extent that ‘People in SE QLD are influenced by the negative messages about Purified Recycled Water in the media’ (36.7% A; 29.7% SA), with some uncertainty at 24.2% neutral but very few in disagreement at 9.4% (Mean 3.91 SA; SD 1.068).
- *Personal influence by the Media*: Most respondents by contrast did *not* agree that negative media coverage regarding PRW influenced them personally, as only 23.4% agreed to some extent that ‘I am influenced by the negative messages about Purified Recycled Water in the media’ (8.6% A; 14.8% SA), with again some uncertainty at 29.7% neutral but a larger proportion in disagreement at 46.9% (10.2% DS; 36.7% D)(Mean 2.48 N; SD 1.346).

Information:

As many responses to questions included a large proportion of 'neutral' answers, which suggests uncertainty, it was useful to also ask respondents whether they thought that they had sufficient information regarding PRW. Just over half of the respondents (52%) - believe that they have enough information, which naturally means that almost half did not:

- *Information about PRW*: A majority of respondents (51.6%) agreed with the statement that 'I feel that I have enough information to make a decision about using PRW' (30.3% A; 21.3% SA), but with significant uncertainty at 31.1% neutral and 17.2% disagreeing to some extent (Mean 3.59 SA; SD 1.197).

Cost:

One question in this section explored customer willingness to pay the full cost of PRW.

- *PRW cost structure*: Half of the respondents (50%) agreed to some extent that 'Charging for recycled water should be based on treating the wastewater to a high (Class A) standard & transport or delivery via pipe work to customers, plus part of the cost of building the treatment plant' but 20.6% were neutral, and 29.4% disagreed to some extent. (Mean 3.25 N; SD 1.302). This is a question that again divides opinion. This was a question that was also asked of the existing PRW use respondents. The PRW answers were: agree 42.4%, unsure 31.8% and disagree 25.8%. (Mean 3.20 N; SD 1.255). It should be noted that in section B the PRW were also given other options regarding the cost (e.g. excluding capital costs).

Table 5.35: Attitudes to Recycled Water -All respondents (n=121-128)

	Statements	A		SA		A Total	N		DS		D		D Total		
		n	%	n	%	%	N	%	n	%	n	%	%	M	SD
1	Saving energy is more important than saving water	11	8.7	20	15.7	24.4	42	33.1	29	22.8	25	19.7	42.5	2.71	1.203
2	Saving energy is a way of saving water	22	17.3	49	38.6	55.9	36	28.3	11	8.7	9	7.1	15.7	3.50	1.097
3	I trust the scientific evidence about the safety of Purified Recycled Water	35	27.6	38	29.9	57.5	27	21.3	15	11.8	12	9.4	21.3	3.54	1.271
4	The threat of climate change is a concern to me	46	35.9	36	28.1	64.1	17	13.3	16	12.5	13	10.2	22.7	3.67	1.346
5	I think the present water quality system in Queensland is good	44	34.9	49	38.9	73.8	24	19.0	3	2.4	6	4.8	7.1	3.97	1.035
6	We need to use recycled water for the future's sake	60	46.9	37	28.9	75.8	13	10.2	12	9.4	6	4.7	14.1	4.04	1.173
7	People in SE QLD are influenced by the negative messages about Purified Recycled Water in the media	47	36.7	38	29.7	66.4	31	24.2	8	6.3	4	3.1	9.4	3.91	1.068
8	I am influenced by the negative messages about Purified Recycled Water in the media	11	8.6	19	14.8	23.4	38	29.7	13	10.2	47	36.7	46.9	2.48	1.346
9	The likelihood of an incident leading to a health risk from Purified Recycled Water is small	34	26.8	39	30.7	57.5	26	20.5	15	11.8	13	10.2	22.0	3.52	1.284
10	An advantage of using Purified Recycled Water is that it may mean less need to build dams	37	30.6	41	33.9	64.5	28	23.1	8	6.6	7	5.8	12.4	3.77	1.131
11	I feel that I have enough information to make a decision about using PRW	37	30.3	26	21.3	51.6	38	31.1	14	11.5	7	5.7	17.2	3.59	1.197
12	My household uses less than the average amount of water per day for my area	49	38.6	31	24.4	63.0	37	29.1	9	7.1	1	0.8	7.9	3.93	1.017
13	Recycled water use should not be subject to water use restrictions	40	31.5	41	32.3	63.8	19	15.0	20	15.7	7	5.5	21.3	3.69	1.226
14	The Purified Recycled Water treatment just speeds up the natural water recycling process	23	18.3	29	23.0	41.3	58	46.0	11	8.7	5	4.0	12.7	3.43	1.015
15	All water is recycled	34	27.0	27	21.4	48.4	35	27.8	16	12.7	14	11.1	23.8	3.40	1.31
16	An advantage of using Purified Recycled Water is that it may allow more dam capacity to be used for flood mitigation	20	15.9	40	31.7	47.6	42	33.3	17	13.5	7	5.6	19.0	3.39	1.081
17	Charging for recycled water should be based on treating the wastewater to a high (Class A) standard & transport or delivery via pipe work to customers, plus part of the cost of building the treatment plant	23	18.3	40	31.7	50.0	26	20.6	20	15.9	17	13.5	29.4	3.25	1.302
18	My household uses more than the average amount of water per day for my area	1	0.8	8	6.3	7.1	30	23.6	41	32.3	47	37.0	69.3	2.02	0.968
19	I feel uneasy about human interference in the natural water cycle	16	12.6	28	22.0	34.6	30	23.6	23	18.1	30	23.6	41.7	2.82	1.354
20	Floods also cause water supply problems because they damage infrastructure	54	42.5	56	44.1	86.6	9	7.1	6	4.7	2	1.6	6.3	4.21	0.888
21	I do not think it likely in Australia that there would be an incident using Purified Recycled Water that would lead to a serious health risk	24	18.9	32	25.2	44.1	34	26.8	19	15.0	18	14.2	29.1	3.20	1.303
22	An advantage of using Purified Recycled Water is that there is a constant supply	37	29.6	46	36.8	66.4	29	23.2	7	5.6	6	4.8	10.4	3.81	1.075
23	My household uses an average amount of water per day for my area	22	17.5	24	19.0	36.5	40	31.7	19	15.1	21	16.7	31.7	3.06	1.31
24	I think that there will be droughts in SE QLD again in the near future	63	49.6	35	27.6	77.2	22	17.3	5	3.9	2	1.6	5.5	4.20	0.968

Note: The answer with the highest percentage of responses has been highlighted (yellow), as has the second most common response (beige). Blue indicates that either the total 'agrees' or 'disagrees' have 50% or more responses.

5.2.5.6 Exploratory factor analysis (EFA) of respondent perceptions

Since a key contribution of this study is the exploration of customer perceptions, particularly the perceived benefits and risks/costs of recycled water (RQ6) and the influence of these on the acceptance of PRW for non-potable and potable use (RQs 2 and 7), further analysis was undertaken for these questions asked of *all* respondents. Factor analysis was applied to the twenty-four questions on customer attitudes (Table 5.35 above).

The factor analysis identified five components of the survey results and explained 43% of the total variance (Table 5.37). The results indicated positive attitudes to PRW use (30% of explained variance), but again a significant minority (8%) took a negative stance. It also indicated some respondent uncertainty (4% of the explained variance) and a large unexplained variance is consistent with the conclusion that other respondents also have mixed views. Positive views were characterised by trust in the system regarding health safety and scientific evidence, and the need to ensure future water supplies and concern about climate change and the high water costs of energy. Negative views were associated primarily with climate/drought scepticism (Table 5.36).

Table 5.36: Component groupings of attitudes towards PRW – all respondents

Label	Positive	Neutral	Negative	% Var Expl
1. Trust Health Need	* PRW low health risk * trust science re PRW *Wary of negative media influence * RW necessary for future			23.4
2. High Use			* higher than average water use * doubt droughts will recur	8.2
3. Media Info		* negative media infleunce * want more information		4.4
4. Energy RWCC	* concerned re. climate change * linked energy & water use * water restrictions may be necessary			3.6
5. Pro Adv	* pro advantages of PRW * PRW must cover costs * floods damage water infrastructure *approve of QLD water quality system (Trust)			3.4
Totals	**30.4%**	**4.4%**	**8.2%**	**43%**

The following sections outline the rationale and methodology of the factor analysis and the details of the results.

Factor analysis rationale and methodology

As this section on (all) Respondents Attitudes contained twenty-four questions (Table 5.35), for parsimony factor analysis was again used to identify clusters of correlated variables. In a survey of human participants correlation of factors is to be expected, therefore the direct oblimin oblique rotation method was used, to allow for factor correlation (Field 2013; Pallant 2011). The 24 items were subjected to EFA using principal axis factoring (PAF) using Kaiser's Criterion revealing the presence of nine eigenvalues greater than 1 (57.06% cumulative explanation).

An examination of Catell's scree plot (Figure 5.22 below) shows that the curve begins to flatten at Factor 3, suggesting a two factor analysis (31.01% cumulative explanation). An examination of 2 factors demonstrated that this resulted in no useful information as the second factor consisted of only 2 statements concerning water use – a correlation between respondents disagreeing with the statement that they use less than the average amount of water and those respondents agreeing that they used more than the average amount of water. All other statements were in factor 1. An examination of the full nine factors revealed that some of the factors were trivial. Although only factors greater than 0.3 were considered, some of the statements loaded on more than one factor and if only the highest loading was taken, one of the factors consequently had no high loading statements in it and others had only relatively low loadings. The best explanatory model was therefore a cut off at five factors (43.02% cumulative explanation) (Table 5.37).

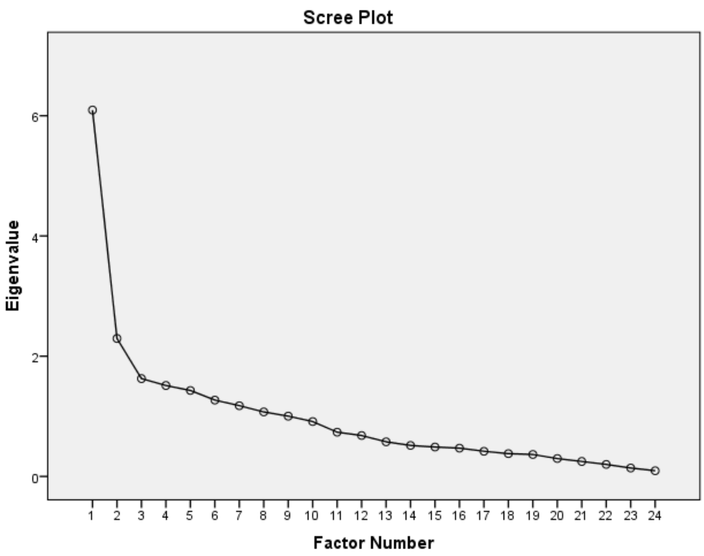


Figure 5.22: Catell's Scree plot of PAF factors on (all) Respondents' Attitudes

Table 5.37: Principal Axis Factoring (PAF) – total variance explained

Total Variance Explained

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	6.094	25.392	25.392	5.612	23.384	23.384	4.399
2	2.295	9.561	34.952	1.979	8.248	31.632	2.044
3	1.627	6.778	41.730	1.064	4.434	36.066	1.949
4	1.512	6.300	48.031	.864	3.601	39.666	.956
5	1.430	5.959	53.990	.806	3.357	43.023	3.663
6	1.270	5.291	59.280				
7	1.177	4.903	64.183				
8	1.073	4.470	68.653				
9	1.003	4.179	72.832				
10	.912	3.801	76.633				
11	.736	3.067	79.700				
12	.680	2.834	82.534				
13	.576	2.400	84.933				
14	.515	2.146	87.080				
15	.489	2.037	89.117				
16	.471	1.961	91.078				
17	.418	1.743	92.820				
18	.379	1.580	94.400				
19	.365	1.520	95.921				
20	.297	1.238	97.158				
21	.249	1.036	98.195				
22	.199	.830	99.025				
23	.140	.584	99.608				
24	.094	.392	100.000				

Extraction Method: Principal Axis Factoring.

a. When factors are correlated, sums of squared loadings cannot be added to obtain a total variance.

The mean sample size was one hundred and twenty-six (126) purified recycled water respondents across the questions, however the Kaiser-Meyer-Olkin (KMO) measure verified the sampling adequacy for the analysis (KMO= 0.682), greater than the minimum acceptable of 0.5 suggested by Hutcheson & Sofroniou (1999). Bartlett's Test of Sphericity was also significant ($p = .000$).

Outliers

Outliers can be problematic with factor/component analysis. In order to detect potential outliers, the factor scores were also examined to identify any scores greater than +/- 3 standard deviations from the mean (as recommended in SPSS). One such score was identified, for factor 5 for one respondent, and that survey was examined to check for data entry errors. The analysis was re-run without this respondent and the results compared. As the omission did not change the results the survey response was retained.

PFA/PAF results

Under principal axis factoring the cumulative of the five factors explained 43.023% of the total variance, with component one explaining 23.384%, component two 8.248% and the remaining components each between 3-4.5% (Table 5.37 above). Analysis of the reproduced correlation residuals suggest that the model is acceptable as there are 26.0% non-redundant residuals with absolute values greater than 0.05, much less than the maximum of 50% suggested by Field (2013).

Table 5.38: Principal Axis Factoring (PAF) – pattern matrix and structure matrix

	5 FACTORS - PAF: Pattern matrix: 43.02%					5 FACTORS - PAF: Structure matrix				
	1	2	3	4	5	1	2	3	4	5
QU	TrustHealthNeed	HighUse	MediaInfo	4. EnergyRWCC	ProAdv	TrustHealthNeed	HighUse	MediaInfo	4. EnergyRWCC	ProAdv
1	NO LOADING above 0.3					NO LOADING above 0.3				
2				0.517					0.518	
3	0.777					0.826		-0.345		0.395
4				0.381					0.402	0.304
5					0.332	0.397				0.431
6	0.635					0.686				0.373
7	0.659					0.719				0.485
8			0.679					0.675		
9	0.502					0.643		-0.369		0.503
10					0.554	0.373		-0.342		0.642
11			-0.628					-0.671		
12		-0.933					-0.930			
13				-0.431					-0.436	
14	0.323				0.465	0.520		-0.362		0.618
15	NO LOADING above 0.3					NO LOADING above 0.3				
16					0.640	0.438				0.723
17					0.592					0.574
18		0.835					0.827			
19	-0.556					-0.535				
20					0.351					0.368
21	0.510					0.644		-0.368		0.505
22	0.491					0.616				0.544
23	NO LOADING above 0.3					NO LOADING above 0.3				
24	0.371	-0.358		0.327		0.386	-0.376		0.332	
Qu	3,7,6,-19,21,9,22,24,14	-12,18, -24	8,-11	2,-13,4, 24	16,17,10,14,20,5	3,7,6,21,9,22,-19,24, 16,10,14,5	-15,18, -24	8,-11,-9,-21,-14,-3,-10	2,-13,4, 24	16,10,14,17,22,21 ,9,7,5,3,6,20,4

Note: Items highlighted in blue have the highest loading for that question, those in beige load on that factor for that question, but not at the highest value.

Identification and analysis of factors – attitudes of all respondents

The five factors identified using PAF made theoretical sense and suggest that the survey instrument is robust. Only loadings above 0.3 were extracted, and where a statement/variable loaded on more than one component only the higher loading was used. All loadings are reported in Table 5.38 above. On analysis of the results of the *Pattern Matrix* the components were labelled as follows:

1. TrustHealthNeed

The statements that loaded on this component reflected a positive attitude towards recycled water (Table 5.39). PRW was considered a low health risk by these respondents who trusted the scientific evidence (statement 3), and thought the likelihood of an incident leading to a health risk small in Australia and in general (21, 9). They believed people in SE Qld were influenced by negative media coverage about RW. They agreed that recycled water was necessary for the future (6), were *not* uneasy about interference in the water cycle (-19), agreed that PRW offered a constant supply (22) and that future droughts were likely in QLD (24). This attribute label therefore reflects positive Trust and low Health risk in the system and a need for RW use to meet needs (TrustHealthNeed). Seven statements loaded strongly positive on this component (from 0.777 to 0.371) and one negatively (i.e. disagreed with the statement -.556), namely (in descending order of strength) statements 3, 7, 6, -19, 21, 9, 22 and 24.

Table 5.39: PCA – Statements loading on TrustHealthNeed component 1

3 - I trust the scientific evidence about the safety of Purified Recycled Water (0.777)
7 - People in SE QLD are influenced by the negative messages about Purified Recycled Water in the media (0.659)
6 - We need to use recycled water for the future's sake (0.635)
-19 - I feel uneasy about human interference in the natural water cycle (-0.556)
21 - I do not think it likely in Australia that there would be an incident using Purified Recycled Water that would lead to a serious health risk (0.510)
9 - The likelihood of an incident leading to a health risk from Purified Recycled Water is small (0.502)
22 - An advantage of using Purified Recycled Water is that there is a constant supply (0.491)
24 - I think that there will be droughts in SE QLD again in the near future (0.371)
Statement 14 - The Purified Recycled Water treatment just speeds up the natural water recycle - also loaded on this factor(0.323), but as it loaded more strongly on factor 5 (0.465) it was included in that component.

2. HighUse

One statement loaded strongly positive on this component, (18) & one strongly negative (-12) both regarding volume of water uses indicating that these respondents were high volume users. These respondents also doubted that droughts would recur in QLD (Table 5.40).

Table 5.40: PCA – Statements loading on HighUse component 2

-12 - My household uses less than the average amount of water per day for my area (-0.933) (disagreed)
18 - My household uses more than the average amount of water per day for my area (0.835)
Statement 24- I think that there will be droughts in SE QLD again in the near future - loaded negatively on this factor (-0.358) but also loaded positively and to a slightly greater extent on factor 1 (0.371) and has been included there.

3. MediaInfo

One statement loaded positive on this component (8) & one negative (-11) and both related to sources of information. These respondents agreed that they were influenced by negative media about RW and also thought that they had insufficient information to make a decision on the subject (Table 5.41).

Table 5.41: PCA – Statements loading on MediaInfo component 3

8 - I am influenced by the negative messages about Purified Recycled Water in the media (0.679)
-11 - I feel that I have enough information to make a decision about using PRW (-0.628)

4. EnergyRWCC

Two statements loaded positive (2, 4) and one negative on this factor (-13) and reflected a concern for climate change, an awareness of the link between energy generation and water use, and a desire to conserve water. These respondents also thought further droughts in QLD likely (Table 5.42).

Table 5.42: PCA – Statements loading on EnergyRWCC component 4

2 - Saving energy is a way of saving water (0.517)
-13 - Recycled water use should not be subject to water use restrictions (-0.431)
4 - The threat of climate change is a concern to me (0.381)
Statement 24- I think that there will be droughts in SE QLD again in the near future - loaded positively on this factor (0.327) but loaded positively to a slightly greater extent on factor 1 (0.371) and has been included there.

5. ProAdv

Six statements loaded strongly positive on this component and reflect a positive attitude towards the advantages of PRW, an acceptance that PRW needs to cover its costs, agreement that floods damage water infrastructure and approval of the current QLD water quality system (Table 5.43).

Table 5.43: PCA – Statements loading on ProAdv component 5

16 - An advantage of using PRW is that it may allow more dam capacity to be used for flood mitigation (0.640)
17 - Charging for recycled water should be based on treating the wastewater to a high (Class A) standard & transport or delivery via pipe work to customers, plus part of the cost of building the treatment plant (0.592)
10 - An advantage of using Purified Recycled Water is that it may mean less need to build dams (0.554)
14 - The Purified Recycled Water treatment just speeds up the natural water recycling process (0.465)
20 - Floods also cause water supply problems because they damage infrastructure (0.351)
5 - I think the present water quality system in Queensland is good (0.332)

5.2.5.7 Research implications of Section C of the survey

Following is a summary of the main points gleaned from Section C of the survey on customer attitudes of all respondents towards PRW related issues, as applied to the Research Questions. This survey section provided information for Research Questions 3, 4, 5, 6 & 7

RQ 3 • What are the risks of recycling and how can they be managed?

Stakeholder management & political risk:

- Media influence – most agreed media influenced public about PRW, but not personally
- Potential lobby groups (many questions polarised opinions so that even questions with majority support has also a sizeable ‘opposition’)
- Most thought that they had sufficient information, but with a significant amount of uncertainty. This presents an opportunity to provide clearer information.

RQ 4 • What information beyond the current economic accounting system is required to provide a full cost accounting or TBL approach? i.e. defining the scope of included externalities

- Respondents are concerned about environmental issues such as climate change and drought and are aware that floods may damage water infrastructure; most showed some awareness of the link between electricity supply and water; and agreed PRW use could defer cost of dams/infrastructure
- most did not agree that 'all water is recycled' via the natural water system; did not think it would help keep dams at a lower level for flood mitigation

RQ 5 • Are the two method of producing Class A+ recycled water identified in the two case studies equivalent in terms of costs, or is there a preferred method?

- of those willing to accept potable PRW most not expressing a preference , but more support for RO as the preferred process from those that did

RQ 6 • What are the perceived benefits and risks (costs) of recycled water use for customers?

- Benefits: RW needed for the future; ensures constant supply; defers costs of infrastructure e.g. dams; should not have restrictions (higher agreement among PRW respondents);
- Risk: Agree that current QLD water quality system good; do not object to human interference in natural cycle (less certain); majority trust science & think health risk from a PRW incident in QLD small (but don't agree with this Australia wide);
- respondents assessing risk of various uses for potable PRW rating higher risk with more personal use and huge dispersion of results – both ends of scale even though median ranking 'medium risk'
- did not think PRW use would help keep dams at a lower level for flood mitigation & unsure about a statement that it just speeds up the natural process
- Respondents underestimate their household water use – most 'less than average'

- Unlike PRW sample, majority of all respondents agreed in principle with the idea of charging costs including part of the capital cost but large number unsure and 29% disagreed.

RQ 7

- What factors influence customer acceptance of PRW for potable use?

- Majority support for indirect RPW use but still uncertainty and a dichotomy between views
- Factor analysis identified 5 sets of respondents with similar attributes– respondents who consider PRW a low health risk, trust the science and agree with future need to ensure supply with future droughts likely, also thought media a negative influence ('TrustHealthNeed')

  -Respondents who were high use and doubted that drought would recur ('HighUse')

  -Respondents who thought that they were negatively influenced by the media and needed more information ('MediaInfo')

  -Respondents who believe in climate change and are aware of the link between energy generation and water and wish to conserve water (restrictions) ('EnergyRWCC')

  - Respondents in favour of a number of advantages of PRW – flood mitigation; less dams; part of natural process; floods damage water infrastructure; water quality in QLD good; charge for PRW should include capital cost 'ProAdv'

5.2.6 Prices for recycled and drinking (potable) water (Survey Section D)

Section D of the customer survey contained an explanation of the calculation of the then current water charges followed by questions exploring customer attitudes regarding the scarcity of water and water pricing, and questions exploring the possible motivations for agreeing to use PRW for non-drinking and drinking/potable use. This was primarily concerned with Research Questions 3 (risk – here the risk to the water provider regarding price recovery), 6 (customer perceived benefits and risks) and 7 (factors influencing acceptance of potable PRW).

A large majority of respondents agreed that water was a scarce resource (76%) and most agreed that subsidising water costs would increase usage (58%) and strongly supported the idea of increased variable costs (83%) (not surprising as nearly all respondents previously self-assessed themselves as ‘below average’ usage), and there was some confusion as to whether respondents believed that this would discourage water use (Figure 5.24). A large majority (83%) believed that PRW should be significantly cheaper than mains tap water, reducing to 70% agreement to paying ‘actual’ costs and a further reduction (56%) in those agreeing to paying the ‘full cost’ (Figure 5.25). Despite agreeing that water transport costs are high, the majority (64%) of respondents were in favour of a universal/standard charge for the region. Most (58%) wanted further information on water costing.

- *Attitudes about recycled water pricing and motivations – ALL respondents*

All respondents were asked to indicate whether they agreed or disagreed on a 5 point Likert scale with nineteen (19) questions designed to indicate their attitudes and views in a number of areas including water scarcity, pricing and motivations for accepting PRW. This was largely exploratory. The scale ranged from ‘Agree’ (A) (5) through ‘Somewhat agree’(SA) (4); ‘Neither agree nor disagree’ or Neutral (N)(3); ‘Disagree somewhat’ (DS) to ‘Disagree’ (D) (1) (Table 5.44 at the end of section 5.2.6.2).

5.2.6.1 Water scarcity, usage and pricing

Water scarcity:

- *Australia and water:* 44.9% of respondents 'agreed', and 31.5% 'somewhat agreed' (total agreement 76.4%) with the question 'Historically, do you agree that water in Australia is a scarce resource?' (with 14.2% disagreeing and 9.4% neutral/unsure). (Mean 4.05 SA; SD 1.112). Most respondents agreed that water is a scarce resource (Figure 5.23)

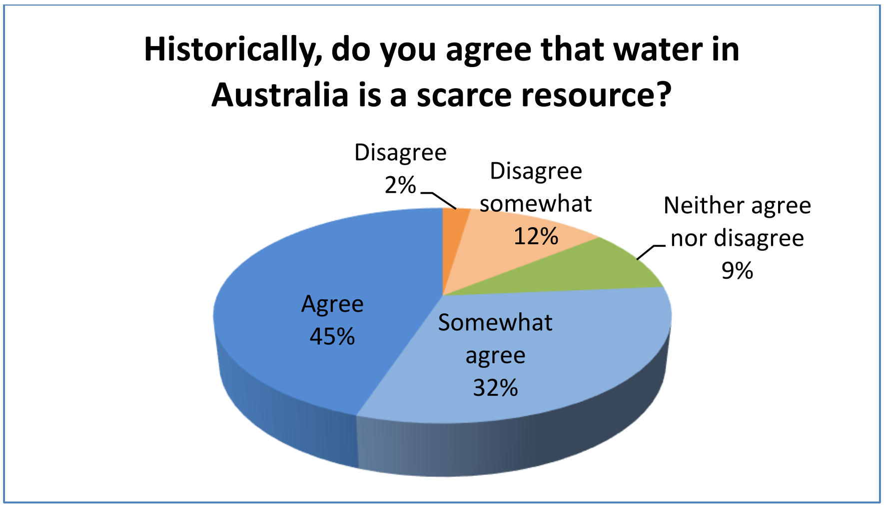


Figure 5.23: Respondents' attitudes towards water scarcity in Australia

Water usage and pricing: Five questions explored beliefs about the relationship between costs and volume of water use, and about the preferred cost structure between fixed charges and charges based on water use (Figure 5.24).

- *Subsidisation and water use:* Respondents were asked 'If water prices are subsidised, do you agree that residential customers will use more water?' The majority at 58.3% agreed to some extent (23.6% A; 34.6% SA) (total agreement 58.3%) although 27.6% still disagreed (18.9% DS; 8.7% D) with 14.2% neutral/unsure. (Mean 3.46 SA; SD 1.277).

- *Fixed or variable rates for water*: Two statements explored views on this, with a slight variation in wording. The first statement 'I think it is a good idea to have different rates (tiers) for water usage, so that people using more water are charged more' and was strongly supported with 84.3% agreement (57.5% A; 26.8% SA), with 6.3% neutral and 9.4% disagreeing to some extent. The second statement 'I think it is a good idea to charge less for fixed water charges and more for water usage to encourage people to save water' was also strongly supported with 79.2% agreement (50.4% A; 28.8% SA) with 15.2% neutral and 5.6% disagreeing to some extent. There is the possibility that support for this split between fixed and variable costs may derive from a belief that their household water usage is comparatively low and that they would therefore be charged less if the variable component was given greater emphasis than the fixed.

- *Increased variable rates and water use*: In response to: 'I think people will use less water if they are charged more for usage' 57.1% agreed to some extent (29.4% A; 27.8% SA), with a substantial 18.3% neutral/unsure and 24.6% disagreeing to some extent (19% DS; 5.6% D) (Mean 3.56 SA; SD 1.249). This is a smaller proportion than those agreeing with charging more for water usage. The second related statement, expressed in reverse 'I don't think people will use less water even if they are charged more for usage', surprisingly met with 49.6% *agreement* (22.4% A; 27.2% SA), with 12% neutral and 38.4% disagreeing to some extent (22.4% DS; 16% D) (Mean 3.18 SA; SD 1.420). This seems to suggest that even though a large majority are if favour of emphasising variable charges, they are not convinced that it will change the behaviour of water users.

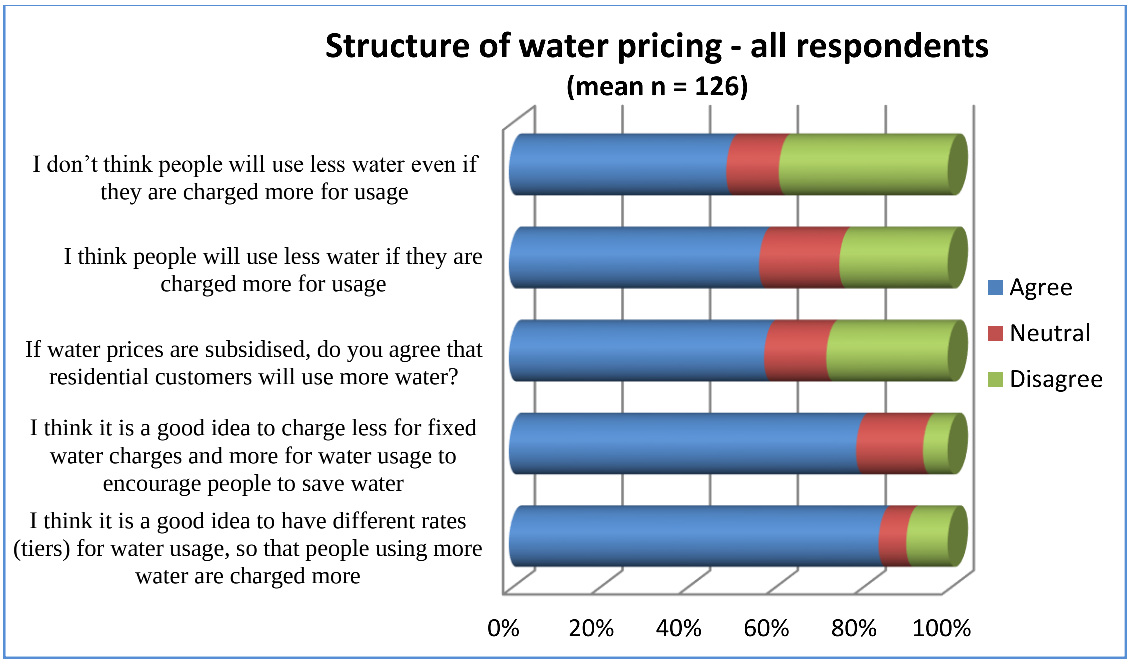


Figure 5.24: Respondents' attitudes towards water pricing & usage

Water pricing and costs – all respondents: Seven questions explored opinions about water charges and information about water costs (Figure 5.25). The first two questions had also been asked of existing PRW use respondents.

- *Price of PRW compared to mains drinking water:* Respondents were asked to respond to similar statements about the cost or PRW compared to mains water with the first having PRW 'slightly' cheaper and the second 'significantly' cheaper than mains water. Not surprisingly the highest approval was for significantly cheaper.

  'I think purified recycled non drinking water should be slightly cheaper than mains tap drinking water' - The majority at 68.3% agreed to some extent (42.9% A; 25.4% SA) although 23% still disagreed (10.3% DS; 12.7% D) with 8.7% neutral/unsure. (Mean 3.75 SA; SD 1.424).). Note that the existing PRW previously answered were: agree 56.5%, unsure 6.5% and disagree 37.1%. (Mean 3.35 N; SD 1.641).

  'I think purified recycled non drinking water should be significantly cheaper than mains tap drinking water' – A much greater majority at 82.7% agreed to some extent (65.4% A; 17.3% SA) with 8.7% again neutral and only 8.7% in disagreement (4.7% DS; 3.9% D) (Mean 4.35 SA; SD 1.08). The existing PRW answers previously were: agree 87.1%, unsure 8.1% and disagree 4.8%. (Mean 4.53 A; SD 1.004).

- *Water pricing & actual costs:* In response to the statement 'I think water charges should be based on actual water costs' a large majority (69.6%) agreed to some extent (42.4% A; 27.2% SA), although with a sizeable proportion unsure at 18.4% and 12% in disagreement (5.6% DS; 6.4% D) (Mean 3.94 SA; SD 1.19).

- *Water pricing & full costs:* In response to the statement 'I think water charges should reflect the full cost of supplying the water to encourage sustainable use of water' there was a lesser majority at 56% agreeing to some extent (30.4% A; 25.6% SA), with the largest single proportion unsure at 28.8% and 15.2% in disagreement (11.2% DS; 4% D) (Mean 3.67 SA; SD 1.141). The difference in response between these last two statements is somewhat surprising as full costs would be the actual cost, although probably this is not clearly understood by respondents.

  Water pricing & transport: This section (D) in its introduction did introduce the concept that water is heavy and therefore transportation costs can be high. Two statements explored reactions to the idea that this cost should be passed on to customers. The first statement - 'Water is expensive to transport, so the costs are not the same in all areas' received 60.8% agreement (36% A; 24.8% SA), but a sizeable number were unsure at 32.8% and only 6.4% in disagreement (3.2% DS; 3.2% D) (Mean 3.87 SA; SD 1.047). The second statement - 'I think everyone in South East QLD (including Brisbane, Gold Coast, & the Sunshine Coast) should pay the same amount per kl for their water' received slightly higher approval at 64% agreement (44.8% A; 19.2% SA), with fewer neutral/unsure (24%) and 12% in disagreement (9.6% DS; 2.4% D) (Mean 3.94 SA; SD 1.138). This indicates that although respondents agree transport costs may differ, they *may* prefer prices to be universal.

- *Water cost information:* In response to whether they felt they need more information -'I would like more information about water costs'- most (57.6%) agreed that they did 36% A; 21.6% SA), with a substantial number neutral (33.6%) and 8.8% in disagreement (Mean 3.78 SA; SD 1.154). This indicates that water costing & pricing is not fully understood.

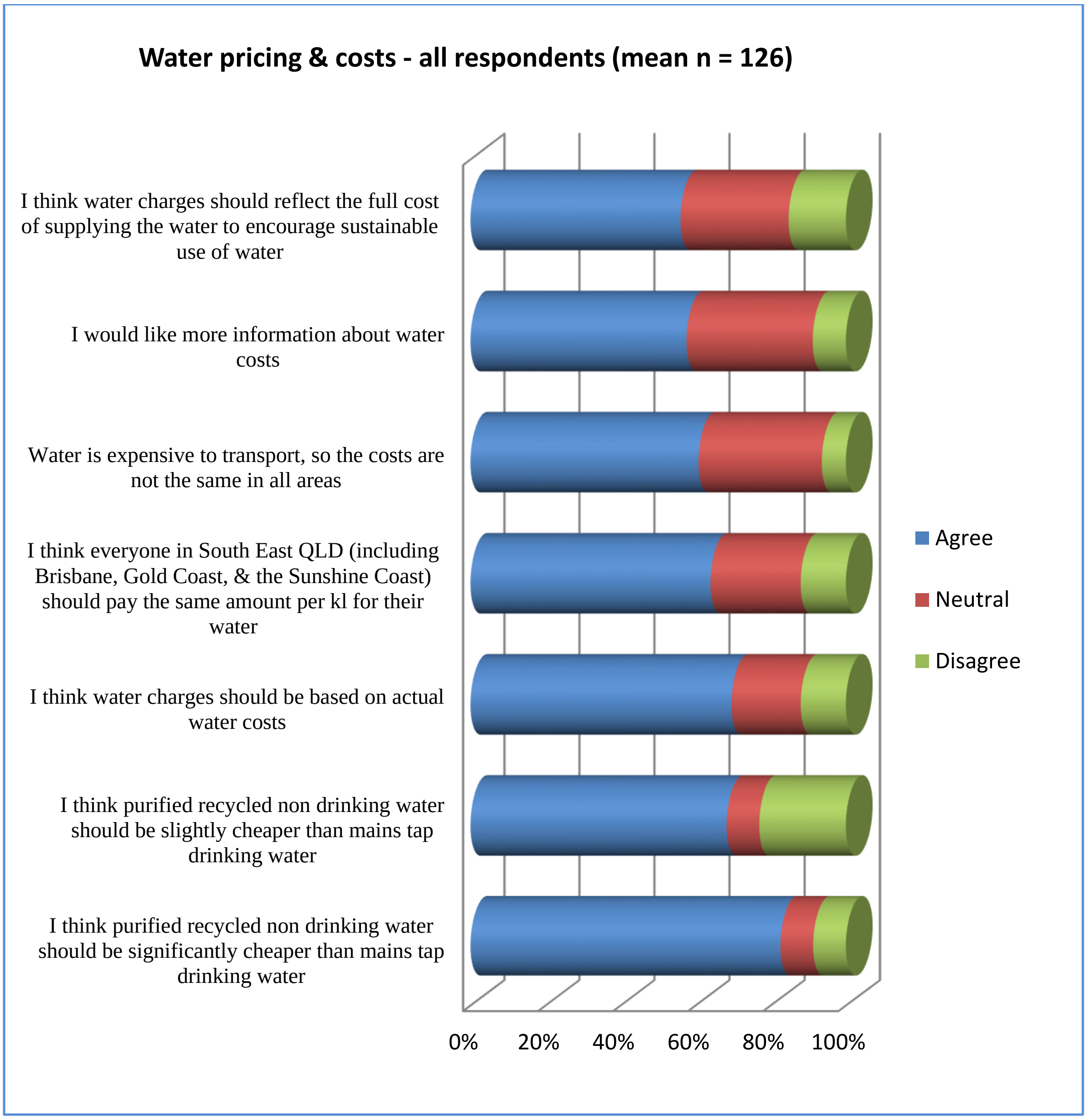


Figure 5.25: Respondents' attitudes towards water pricing & costs

5.2.6.2 <u>PRW Water pricing</u>

Recycled Water pricing & motivations: Six questions explored opinions more specifically about recycled water charges and possible motivations for accepting potable PRW. The first two questions pertained to non-potable PRW and the remaining to potable PRW. Price again proved the greatest motivator for using non-potable PRW over freedom from restrictions and even for potable PRW ahead of drought proofing drinking supply (Figure 5.26).

Access to cheap non potable PRW compared to mains drinking water: Respondents were asked to respond to the statement 'I would like to have access to purified recycled non drinking water if it was cheaper than mains tap drinking water to use as I choose' and a large majority at 75.4% agreed that they would use it in these circumstances (51.6% A; 23.8% SA), with 14.3% neutral and 10.3% in disagreeing (6.3% DS; 4% D) (Mean 4.13 SA; SD 1.124). Clearly the use of non- potable PRW is well supported if the price is right!

PRW and water restrictions: Price seems more important than lack of water restrictions and opinion was more divided. A smaller majority at 51.6% agreed to some extent (32.5% A; 19% SA) with the statement 'I would like to have access to purified recycled drinking water if using recycled water avoids water restrictions', 21.4% were neutral and a substantial 27% disagreed (11.9% DS; 15.1% D) (Mean 3.42 N; SD 1.433).

The remaining four questions pertained to drinking standard PRW and possible motivation for using it.

Potable PRW and cost: Two statements concerned the cost/price of the PRW. The price of potable PRW would also be a main consideration for many as 66.4% agreed to some extent (40.8% A; 25.6% SA) with the statement 'The cost of purified recycled drinking water would be a factor in my considering whether to use it or not', 19.2% were neutral and a further 14.4% disagreed (4.8% DS; 9.6% D) (Mean 3.832 SA; SD 1.281). When asked to comment on 'I would drink purified recycled drinking water if it reduced the cost of the drinking water supply' opinion was more divided although 51.2% agreed to some extent (34.4% A; 16.8% SA) 16.8% were neutral and a full 32% disagreed (14.4% DS; 17.6% D) (Mean 3.36 N; SD 1.51).

Potable PRW and drought proofing: Two questions considered this. In contrast to consideration of the price of potable PRW, only 45.6% agreed to some extent (29.6% A; 16% SA) with the statement 'I would drink purified recycled drinking water if it meant the water supply was less affected by droughts', 24.8% were neutral and a large proportion at 29.6% disagreed (12.8% DS; 16.8% D) (Mean 3.29 N; SD 1.441). For the second statement, although the largest proportion at 48.4% disagreed (15.1% DS; 33.3% D) that they would refuse to drink PRW in a bid to drought proof water supply -'I would not drink purified recycled drinking water even if it meant the water supply was more drought resistant'- 29.4% still agreed to some extent (19.8% A; 9.5% SA) and another 22.2% were neutral, so this statement divided opinion. (Mean 2.67 N; SD 1.512).

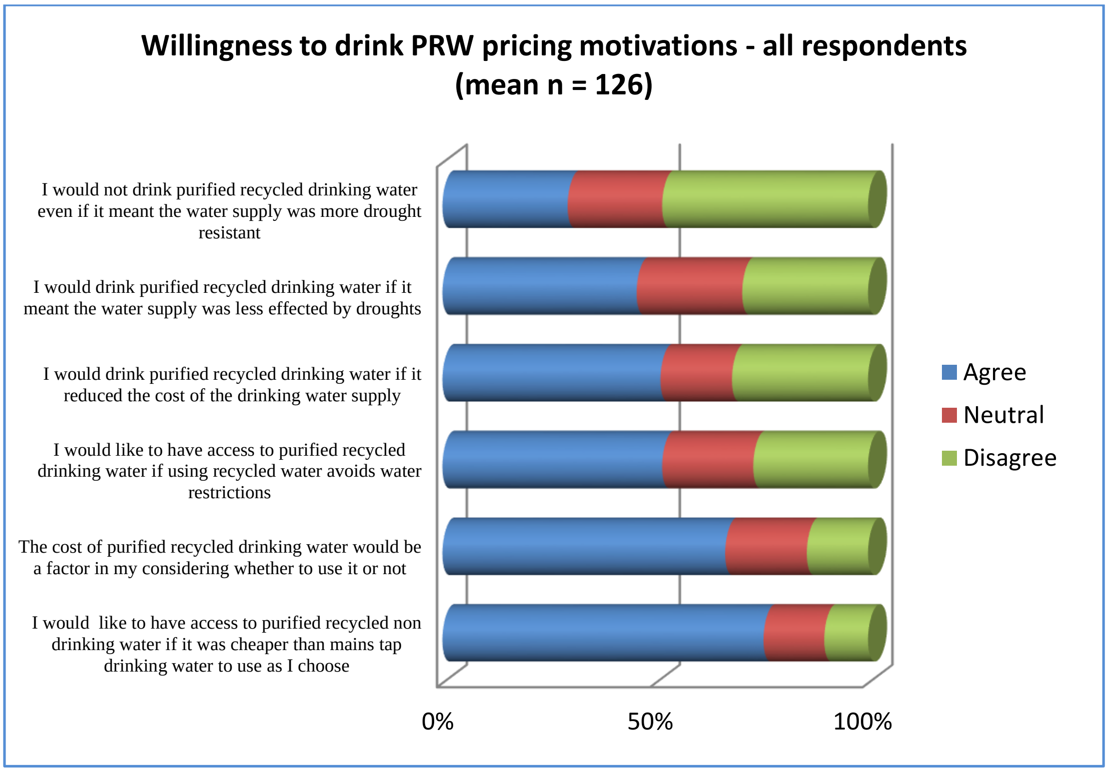


Figure 5.26: Respondents' attitudes towards drinking PRW and the effect of pricing

Table 5.44: Attitudes regarding the cost and use of Purified Recycled Water -All respondents (n=125-127: mean 126)

	Statements	A = 5		SA = 4		A Total	N = 3		DS =2		D = 1		D Total		
		n	%	n	%	%	N	%	n	%	n	%	%	M	SD
1	Historically, do you agree that water in Australia is a scarce resource?	57	44.9	40	31.5	76.4	12	9.4	15	11.8	3	2.4	14.2	4.05	1.112
2	If water prices are subsidised, do you agree that residential customers will use more water?	30	23.6	44	34.6	58.3	18	14.2	24	18.9	11	8.7	27.6	3.46	1.277
3	I would like to have access to purified recycled non drinking water if it was cheaper than mains tap drinking water to use as I choose	65	51.6	30	23.8	75.4	18	14.3	8	6.3	5	4.0	10.3	4.13	1.124
4	I think it is a good idea to have different rates (tiers) for water usage, so that people using more water are charged more	73	57.5	34	26.8	84.3	8	6.3	8	6.3	4	3.1	9.4	4.29	1.047
5	I think purified recycled non drinking water should be slightly cheaper than mains tap drinking water	54	42.9	32	25.4	68.3	11	8.7	13	10.3	16	12.7	23.0	3.75	1.424
6	I think purified recycled non drinking water should be significantly cheaper than mains tap drinking water	83	65.4	22	17.3	82.7	11	8.7	6	4.7	5	3.9	8.7	4.35	1.08
7	I don't think people will use less water even if they are charged more for usage	28	22.4	34	27.2	49.6	15	12.0	28	22.4	20	16.0	38.4	3.18	1.420
8	I think water charges should be based on actual water costs	53	42.4	34	27.2	69.6	23	18.4	7	5.6	8	6.4	12.0	3.94	1.19
9	I would like to have access to purified recycled drinking water if using recycled water avoids water restrictions	41	32.5	24	19.0	51.6	27	21.4	15	11.9	19	15.1	27.0	3.42	1.433
10	I would like more information about water costs	45	36.0	27	21.6	57.6	42	33.6	3	2.4	8	6.4	8.8	3.78	1.154
11	The cost of purified recycled drinking water would be a factor in my considering whether to use it or not	51	40.8	32	25.6	66.4	24	19.2	6	4.8	12	9.6	14.4	3.832	1.281
12	I think it is a good idea to charge less for fixed water charges and more for water usage to encourage people to save water	63	50.4	36	28.8	79.2	19	15.2	6	4.8	1	0.8	5.6	4.23	0.934
13	I would drink purified recycled drinking water if it meant the water supply was less effected by droughts	37	29.6	20	16.0	45.6	31	24.8	16	12.8	21	16.8	29.6	3.29	1.441
14	I would drink purified recycled drinking water if it reduced the cost of the drinking water supply	43	34.4	21	16.8	51.2	21	16.8	18	14.4	22	17.6	32.0	3.36	1.51
15	I think people will use less water if they are charged more for usage	37	29.4	35	27.8	57.1	23	18.3	24	19.0	7	5.6	24.6	3.56	1.249
16	I would not drink purified recycled drinking water even if it meant the water supply was more drought resistant	25	19.8	12	9.5	29.4	28	22.2	19	15.1	42	33.3	48.4	2.67	1.512
17	Water is expensive to transport, so the costs are not the same in all areas	45	36.0	31	24.8	60.8	41	32.8	4	3.2	4	3.2	6.4	3.87	1.047
18	I think everyone in South East QLD (including Brisbane, Gold Coast, & the Sunshine Coast) should pay the same amount per kl for their water	56	44.8	24	19.2	64.0	30	24.0	12	9.6	3	2.4	12.0	3.94	1.138
19	I think water charges should reflect the full cost of supplying the water to encourage sustainable use of water	38	30.4	32	25.6	56.0	36	28.8	14	11.2	5	4.0	15.2	3.67	1.141

Note: The answer with the highest percentage of responses has been highlighted (yellow), as has the second most common response (beige). Blue indicates that either the total 'agrees' or 'disagrees' have 50% or more responses.

5.2.6.2 Exploratory Factor Analysis (EFA)

Further analysis was undertaken for these questions asked of *all* respondents regarding cost and use of PRW. Factor analysis was applied to the nineteen Likert scale questions (Table 5.44 above).

The factor analysis identified five components of the survey results and explained 43% of the total variance (Table 5.46). These results were less easy to categorise as positive/negative towards PRW (Table 5.45). The results suggested positive attitudes to potable PRW use in certain circumstances e.g. to reduce drought/restrictions, but this was partly qualified by the desire for low costs (21% of the explained variance), although some respondents accepted the idea that PRW should cover its costs (a further 9%). Respondents indicating a desire for PRW to be low cost (but no other objection) were considered neutral (3%). Negative views were also influenced by cost but also by scepticism about water scarcity (6%) and a general opposition to potable PRW (4%).

Table 5.45: Component groupings of attitudes towards pricing PRW

Label	Positive	Neutral	Negative	% Var Expl
1. Drink PRW	accept potable PRW but cost conscious * to reduce drought * to reduce water costs * to avoid water restrictions			21
2. Actual Cost	*Price charged for PRW should reflect actual/full cost			9
3. OK2Use			* water not scarce * charging more for high use will not change usage * people will use what they want	6
4. Cost Same			* all SE customers should pay the same for water * no desire for PRW even if cheaper	4
5. Cheaper		* PRW should be significantly/slightly cheaper then tap water * need more information on water costs		3
Totals	**30%**	**3%**	**10%**	**43%**

The following sections outline the rationale and methodology of the factor analysis and the details of the results.

Factor analysis rationale and methodology

As this section on water pricing and customer attitudes contained nineteen questions, again for parsimony factor analysis was used to identify clusters of correlated variables, using direct oblimin oblique rotation method to allow for factor correlation (Field 2013; Pallant 2011). The 19 items were subjected to EFA using principal axis factoring (PAF). Using Kaiser's Criterion revealed the presence of seven eigenvalues greater than one. Catell's scree plot (Figure 5.27) was equivocal and showed flattening of the curve at several points, most obviously at Factors 5, 7, 9 and 12. Extracting 4, 5, 6 and 7 factors was considered (38.7-49.6% total variance explained) but with four factors a number of statements loaded on more than one factor, and with both 6 and 7 factors contained a factor with only one statement loading. It was therefore decided to use 5 factors.

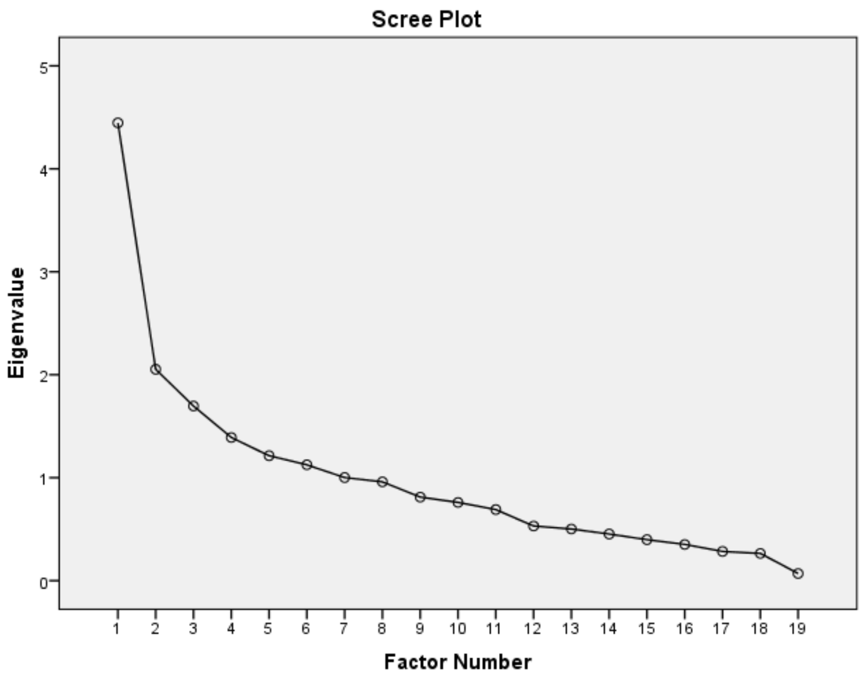


Figure 5.27: Catell's scree plot of PAF factors on respondent attitudes to water pricing

The mean sample size was hundred and twenty-six (126) purified recycled water respondents across the questions, however the Kaiser-Meyer-Olkin (KMO) measure verified the sampling adequacy for the analysis (KMO= 0.713), greater than the minimum acceptable of 0.5 suggested by Hutcheson & Sofroniou (1999). Bartlett's Test of Sphericity was also significant (p = .000).

Table 5.46: Principal Axis Factoring (PAF) – total variance explained

Total Variance Explained

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	4.446	23.402	23.402	4.019	21.152	21.152	3.473
2	2.053	10.804	34.206	1.636	8.612	29.764	2.223
3	1.696	8.925	43.131	1.083	5.702	35.466	1.951
4	1.391	7.319	50.450	.780	4.106	39.572	.781
5	1.214	6.387	56.837	.585	3.081	42.652	1.350
6	1.125	5.923	62.760				
7	1.001	5.271	68.031				
8	.959	5.050	73.080				
9	.811	4.271	77.351				
10	.759	3.997	81.349				
11	.691	3.634	84.983				
12	.531	2.794	87.777				
13	.502	2.641	90.418				
14	.453	2.384	92.802				
15	.398	2.095	94.897				
16	.352	1.851	96.748				
17	.284	1.494	98.243				
18	.265	1.393	99.635				
19	.069	.365	100.000				

Extraction Method: Principal Axis Factoring.

a. When factors are correlated, sums of squared loadings cannot be added to obtain a total variance.

<u>Outliers</u>

Once again, in order to detect potential outliers, the factor scores were also examined to identify any scores greater than +/- 3 standard deviations from the mean (as recommended in SPSS). No such score was identified.

PFA/PAF results

Under principal axis factoring the cumulative of the five factors explained 42.652% of the total variance, with component one explaining 21.152%, component two 8.612%, 5.787% and the remaining components each between 3-6% (Table 5.46). Analysis of the reproduced correlation residuals suggest that the model is acceptable as there are 25% non-redundant residuals with absolute values greater than 0.05, much less than the maximum of 50% suggested by Field (2013).

Identification and analysis of factors – water pricing - attitudes of all respondents

The five factors identified using PAF made theoretical sense and suggest that the survey instrument is robust. Only loadings above 0.3 were extracted, and where a statement/variable loaded on more than one component only the higher loading was used. All loadings greater than 0.3 are reported in Table 5.47.

Table 5.47: Principal Axis Factoring (PAF) pattern matrix and structure matrix

	5 FACTORS - PAF: Pattern matrix: 42.652%					5 FACTORS - PAF: Structure matrix				
	1	2	3	4	5	1	2	3	4	5
QU	DrinkPRW	ActualCost	OK2Use	CostSame	Cheaper	DrinkPRW	ActualCost	OK2Use	CostSame	Cheaper
1			-0.475			0.368	0.364	-0.562		
2			-0.399				0.311	-0.449		
3				-0.349		0.316	0.378	-0.306	-0.358	
4			-0.307				0.394	-0.389		
5					0.367					0.341
6					0.612		0.334			0.622
7			0.583					0.540		
8		0.781					0.758			
9	0.568					0.657				0.364
10					0.312					0.328
11	0.354				0.331	0.459	0.330			0.442
12	NO LOADING above 0.3					0.320	0.347			0.340
13	0.956					0.949				
14	0.909					0.907				
15			-0.633					-0.659		
16	-0.820					-0.762				
17	NO LOADING above 0.3					NO LOADING above 0.3				
18				0.583					0.577	
19		0.710					0.664	-0.338		
Qu	13,14, -16, 9,11	8,19	-15,7,-1,-2,-4	18,-3	6,5,10,11	13,14, -16, 9,11,1,3,	8,19,4,3,1,6,11,2	-15,-1,7,-2,-4,-19,-3	18,-3	6,11, 9,5,12,10

Note: Items highlighted in blue have the highest loading for that question, those in beige load on that factor for that question, but not at the highest value.

On analysis of the results of the *Pattern Matrix* the components were labelled as follows:

1. DrinkPRW

The statements that loaded on this factor reflected a positive attitude towards drinking recycled water under various circumstances – to reduce drought, reduce water costs, and to avoid water restrictions (statements 13, 14 and 9). The statement that they would *not* drink PRW even to make water supply more drought resistant appropriately loaded negatively on this factor. Interesting there was also a 0.354 loading for cost being a factor whether to drink it or not. So this suggests that even though in favour of the use of potable PRW, these respondents are cost conscious. This factor was coded

‘DrinkPRW’ as it reflected a positive attitude on the whole to potable PRW (Table 5.48).

Table 5.48: PCA – Statements loading on DrinkPRW component 1

13 - I would drink purified recycled drinking water if it meant the water supply was less effected by droughts (0.956)
14 - I would drink purified recycled drinking water if it reduced the cost of the drinking water supply (0.909)
-16 - I would not drink purified recycled drinking water even if it meant the water supply was more drought resistant (-0.820) (disagreed)
9 - I would like to have access to purified recycled drinking water if using recycled water avoids water restrictions (0.568)
11 - The cost of purified recycled drinking water would be a factor in my considering whether to use it or not (0.354)

2. ActualCost

Two statements loaded strongly positive on this factor, 8 and 19. Both regarded the costing of water/water charges and reflected a belief that actual costs and full costs should be included, hence the name ActualCost (Table 5.49).

Table 5.49: PCA – Statements loading on ActualCost component 2

8 - I think water charges should be based on actual water costs (0.781)
19 - I think water charges should reflect the full cost of supplying the water to encourage sustainable use of water (0.710)

3. OK2Use

Four statements loaded negative on this factor (-15,-1,-2,-4) & one positive (7) and all related to beliefs about water usage/availability. These reflected a belief that charging more for water usage i.e. increased variable cost for water would *not* influence consumers to use less (-15;7;-2) and therefore also associated with those disagreeing with having tiers or different rates for usage (-4). It was also associated with a belief that water in Australia is *not* a scarce resource and this has been labelled ‘OK2Use’ as it seems to reflect an attitude that people will use the water anyway and there is no problem with this i.e. it is OK to use it (Table 5.50).

Table 5.50: PCA – Statements loading on OK2Use component 3

-15 - I think people will use less water if they are charged more for usage (-0.633) (negative)
7 - I don't think people will use less water even if they are charged more for usage (0.583)
-1 - Historically, do you agree that water in Australia is a scarce resource? (-0.475) (negative)
-2 - If water prices are subsidised, do you agree that residential customers will use more water? (-0.399) (negative)
-4 - I think it is a good idea to have different rates (tiers) for water usage, so that people using more water are charged more (-0.307) (negative)

4. CostSame

One statement loaded positive (18) and one negative on this factor (-3) and reflected a belief that all SE QLD water customers should pay the same and a disagreement with the desire to have non-potable PRW even if it was cheaper than mains tap water. It is not entirely clear why this two should be associated unless it is just a general desire for traditional water use in QLD (subsidised and relatively cheap for all consumers) (Table 5.51).

Table 5.51: PCA – Statements loading on CostSame component 4

18 - I think everyone in South East QLD (including Brisbane, Gold Coast, & the Sunshine Coast) should pay the same amount per kl for their water (0.583)
-3 - I would like to have access to purified recycled non drinking water if it was cheaper than mains tap drinking water to use as I choose (-0.349) (negative)

5. Cheaper

One statement (6) loaded strongly positive on this component and two less strongly (5,10) and these reflect a view that non-potable PRW should be preferably significantly cheaper or at least slightly cheaper than mains tap drinking water (6;5) and also a desire for more information on water costs (10). This factor has been labelled 'cheaper'.

Cost would also be a factor in considering potable use as statement 11 also loaded on this question but has been included in factor 1 where its loading was slightly higher (Table 5.52).

Table 5.52: PCA – Statements loading on Cheaper component 5

6 – I think purified recycled non drinking water should be significantly cheaper than mains tap drinking water (0.612) 5 - I think purified recycled non drinking water should be slightly cheaper than mains tap drinking water (0.367) 10 - I would like more information about water costs (0.312) Statement 11- The cost of purified recycled drinking water would be a factor in my considering whether to use it or not - loaded positively on this factor (0.331) but loaded positively to a slightly greater extent on factor 1 (0.354) and has been included there.

5.2.6.4 Additional water use & pricing questions – ALL respondents

In addition to the exploratory 19 questions on a Likert scale, all respondents in Section D were asked a number of more specific/direct questions about water use and pricing and were also given the opportunity to make any other comments they wished Table 5.53).

Respondents found it difficult to suggest prices for non-potable and potable recycled water, but the clear message was that non-potable water should be priced substantially lower than mains tap water and potable PRW only marginally above that, with a number of respondents expressing a preference for rainwater tank use. The majority of respondents however were unsure what to recommend, as there was a complicated series of considerations.

Views on water prices – Potable PRW:

- What, in your opinion, should an average quantity user **pay** per kilolitre of potable recycled ***drinking*** water?

The survey instrument introduction for this section outlined the then water price structure or the region, both fixed charges and the three tier usage prices starting at $0.176 per kl for 0-7676 kl per day and daily fixed charge of $0.945.

Respondents found this question difficult to answer. Of the 129 householders, 8 did not attempt to answer and of the 121 responding 98 (81%) answered ‘unsure’. The remaining 23 gave a wide variety of answers, ranging from zero$ to $4, with the mean $0.7266, median $0.20 and mode $0.00, and standard deviation 1.01131 (Figure 5.28).

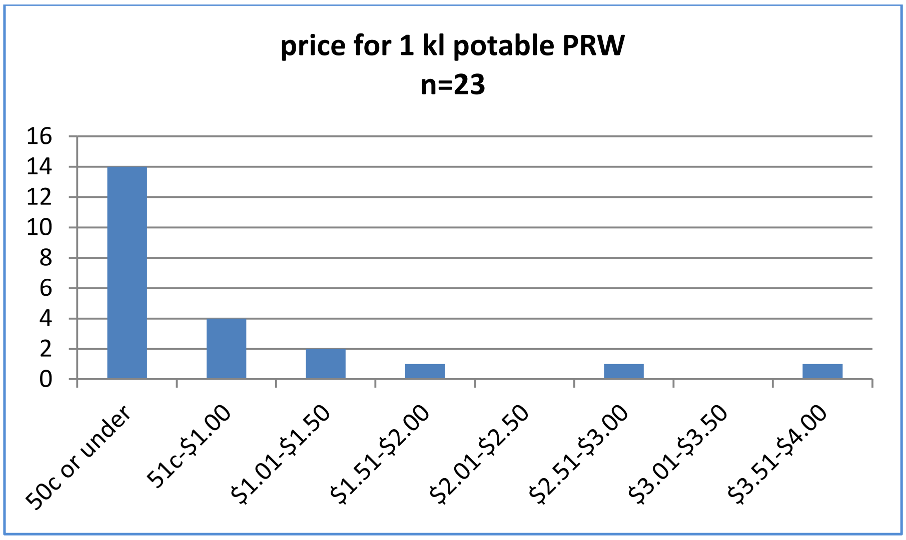


Figure 5.28: Respondent suggested prices for 1kl potable PRW

Respondents also had the opportunity to make a comment about potable PRW prices, and thirty-five did so.

In view of this, respondent perceptions were best captured by the comments that they made about PRW pricing. Most commonly respondents thought that PRW water should be close to free, or at least have an upper bound determined by the cost of mains tap water. The acceptance of recycled water price is therefore largely determined by other water source costs and the fact that traditionally in Australia water prices have been subsidised by local councils, and possibly by the historic use of rainwater tanks in Queensland. The comments are shown in Table 5.53.

Table 5.53: Comments on potable PRW pricing

No. of comments	Theme	Actual comments (35)
8	water should free/nearly free (1 preferred tank water)	"0-10 cents"; "As little as possible"; "I don't believe we should be paying for water - only a nominal fee if necessary"; "Nil - user has already paid for it once"; "Should be free"; "Should not have to buy water to drink"; "What are we paying rates for?"; "Why are we forced to pay for water even when tank water will do the job? Turn off the tap but still will be charged??? Water is free from the sky. Just like the air. Don't tell Unity about air."
8	Related to prices for other types of water supply – mains water as upper bound	"1/2 potable"; "A little less than the price for potable recycled drinking water"; "About 75% of the cost of recycled water"; "half price"; "I think it should be considerably cheaper than regular town water but slightly more than non-potable water"; "It should not be priced above the tier 1 rate"; "Less than what is current/charged"; "Not sure what I pay now. I think it should be 1/4 of the price of the mains water"
6	N/A as potable PRW should not be used (2 preferred tank water)	"I do not agree for using recycled water for drinking (direct)"; "I rarely drink tap water"; "I would not encourage people to drink recycled water no matter what you embark on. People should have a choice. If this was not the case we would not have introduced spring water for drinking"; "No-one wants to drink recycled water. I prefer tank water to drink"; "Wouldn't drink it"; "Encourage water tanks for drinking"
3	Suggested a basis for setting price e.g. actual cost or based on usage	"Based on actual cost with efficient distributor, retailer"; "on the basis of average usage"; "The price should be based on a % of cost and tiered for usage"
4	Too complicated/ confusing to calculate (1 trusting local authority to decide)	"I believe these charges would be subject to many standards and variable costs. I trust councils and Unitywater will make fair decisions"; "Many factors need to be taken into consideration e.g. location, house/unit/industrial, population of area"; "Many factors to be considered in the equation before deciding"; "The pricing system is not easy to follow"
6 different	* lack of trust in water management * same for all in QLD * depend on household size * increase * n/a as self-sufficient * stable price kept long-term	"I do not know whether CFOS etc are paid exorbitant salaries & or bonuses, superannuations etc"; "It should be the same charge wherever you live in Queensland No one should be disadvantaged by cost"; "It would depend how many people are in the house"; "More"; "We live on a farm so we are totally self-sufficient in water usage"; "No matter what we put who will listen? "But it should stay the same for a long period of time."; "No matter what we put who will listen?"

Views on water prices – Non-potable PRW:

- What, in your opinion, should an average quantity user **pay** per kilolitre of ***recycled*** non drinking water?

Respondents again found this type of question difficult to answer. Of the 129 householders, 8 did not attempt to answer and of the 121 responding 96 (79%) answered 'unsure'. The remaining 25 gave a wide variety of answers, ranging from zero$ to $4, with the mean $0.5422, median $0.30 and mode $0.00, and standard deviation 0.85143 (Figure 5.29).

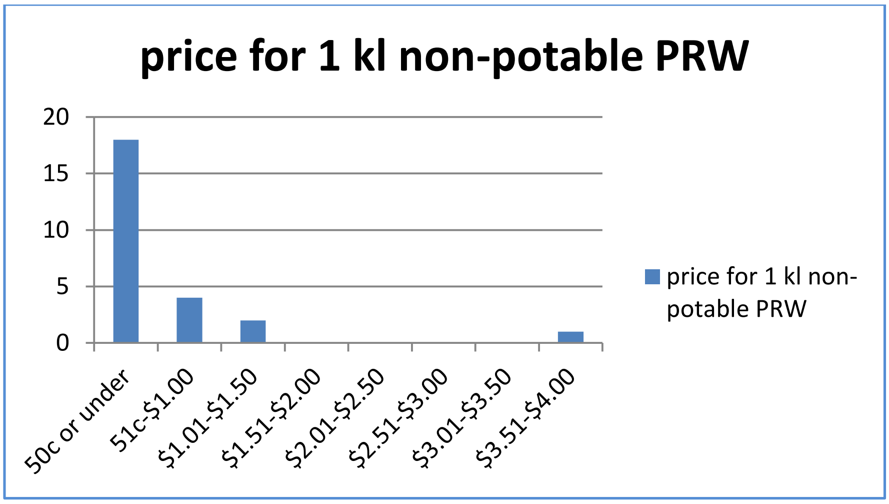


Figure 5.29: Respondent suggested prices for 1kl non-potable PRW

Comparing the preferred prices for potable and non-potable PRW, as might be expected, the mean price is lower for non-potable than potable PRW ($0.5422 compared to $0.7266) and a related-samples Wilcoxon Signed Rank Test was significant ($p = 0.009$). Although the sample sizes are small, it does appear that respondents expect to pay more for potable standard PRW.

Again respondents had the opportunity to make a comment about non-potable PRW prices, and thirty-three did so, many repeating comments similar to those for potable PRW. There was a general expectation for the price to be lower than for potable PRW. Only one respondent this time rejected its use for non-potable purposes, compared to 6 for potable PRW. The comments are shown in Table 5.54.

Table 5.54: Comments on non-potable PRW pricing

No. of comments	Theme	Actual comments (33)
11	water should free/nearly free/very low cost (1 preferred tank water)	“0 - 5 cents”; “10c - As it is not drinkable. Separate plumbing is also required”; “As little as possible”; “I don't believe we should be paying for water - only a nominal fee if necessary”; “It should be cheap”; “Less than we are currently being charged by Unitywater”; “Less than what is current/charged”; “Nil - user has already paid for it once”; “Rates are already over the top”; “Should be free”; “Use tank water first - then, if it runs low, use the above. That will solve all problems.”
11	Related to prices for other types of water supply – less than potable PRW	“1/2 potable recycled”; “1/3 cost potable water”; “1/8 of the price of the mains water”; “About 50% of the cost of non-recycled water.”; “Less”; “Less again than in previous answer”; “Less than potable recycled water, but again I appreciate many factors would be involved in the pricing schemes.” ; “More than 34c (recycled would cost more)”; “quarter of price”; “Should be less than drinking water”; “Recycled water should be same price as tap water”
1	PRW should not be used	“There should be fresh water and not pay for recycled”
3	Suggested a basis for setting price e.g. actual cost or set amount	“Based on actual cost with efficient distributor, retailer”; “$1.50 Including fixed charges”; “The price should be based on a % of cost and tiered for usage.”
2	Too complicated/ confusing to calculate	“Many factors to be considered in the equation before deciding”; The pricing system is not easy to follow”
2	lack of trust in water management	“I do not know whether CFOS etc are paid exorbitant salaries & or bonuses, superannuations etc” ; “Sure suppliers will just choose what they want anyway; privatising utilities has been a disaster.”
3 different	* stable price kept long-term * cheaper to opt out * emphasis on social responsibility * increase * n/a as self-sufficient	“No matter what we put who will listen? But it should stay the same for a long period of time.”; “At some price it becomes economic for those who can switch to tank systems which loads the infrastructure cost onto those who can't. Already it is cheaper to buy a few loads of water/year than to be connected to the water grid - cf the current solar panels mess!”; “Every individual should act responsibly to save out natural resources. Mining destroys so much of our waterways & forests.”

Water usage:

Survey respondents were also asked, based on their most recent actual water invoice, to disclose the household's average daily water usage in KL (this amount should be stipulated on the invoice) (Figure 5.30). Of the 129 households, four did not answer this question (blank) leaving 125 responses. Of these 33 (26.4%) were unsure, 19 declined to answer (15.2%) and 73 (58.4%) gave a figure for their usage. The daily amount of water used ranged from 0.94KL to 0.978KL with the mean 0.41523KL, median 0.36559, mode 0.340 and standard deviation of 0.2166.

Analysis made it apparent that households are poor at estimating their level of use, and generally inclined to underestimate their use. It would have been a useful addition to the survey to have asked respondents for a break-down of daily water use between recycled and mains water. Additional comments regarding recycled water were generally in favour of non-potable recycled water use and less favourable towards potable use, with again a number of comments in favour of rainwater tanks. However many respondents did seem to value drought-resistant supplies.

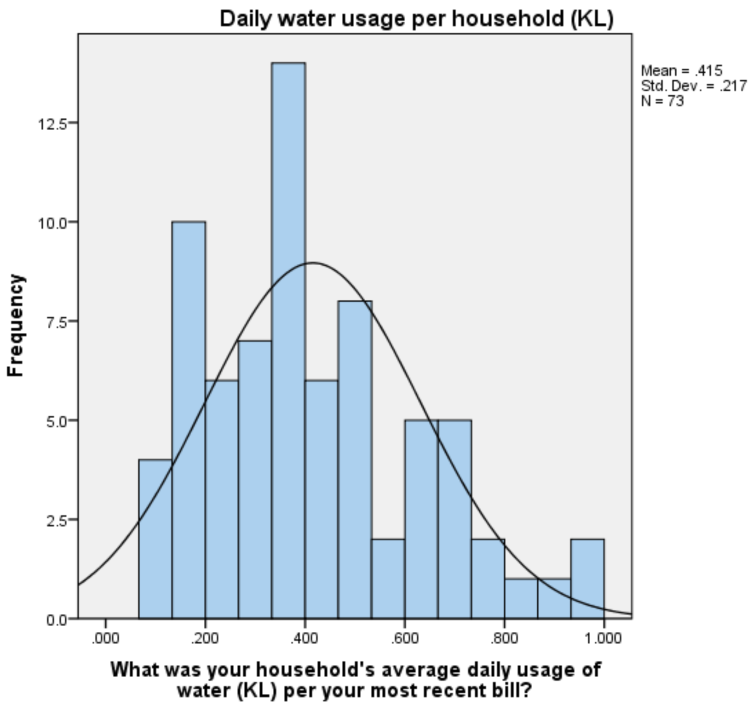


Figure 5.30: Average daily water use per household (kl)

In order to estimate a figure for daily water usage per person the results from this question were divided by the declared number of household members. The initial results revealed an outlier and the relevant original survey was reviewed. This respondent had identified as being a sole occupant, but in the comments regarding household water use the respondents mentioned that part of the house was sub-let (with combined water billing), so the household members were adjusted accordingly. This resulted in a sample size of seventy-one (71) households providing a daily usage figure and a total number of household members. The resulting per person daily water use revealed a mean of 0.1696KL (standard deviation 0.10218 KL) or mean 169.6 L per day (median 0.15KL; IQR 0.09325KL) (Figure 5.31). The local water authority/supplier for the region estimates a mean of 180 litres per person per day (over 12 months) for this time period. This is a relatively small respondent group, based on one bill reading selectively chosen by the respondent, rather than an average for the year. The respondent group would also contain a larger than usual number of PRW customers (as these customers were deliberately targeted by the survey), but it is broadly in line with the water authority estimate, if marginally lower than average consumption.

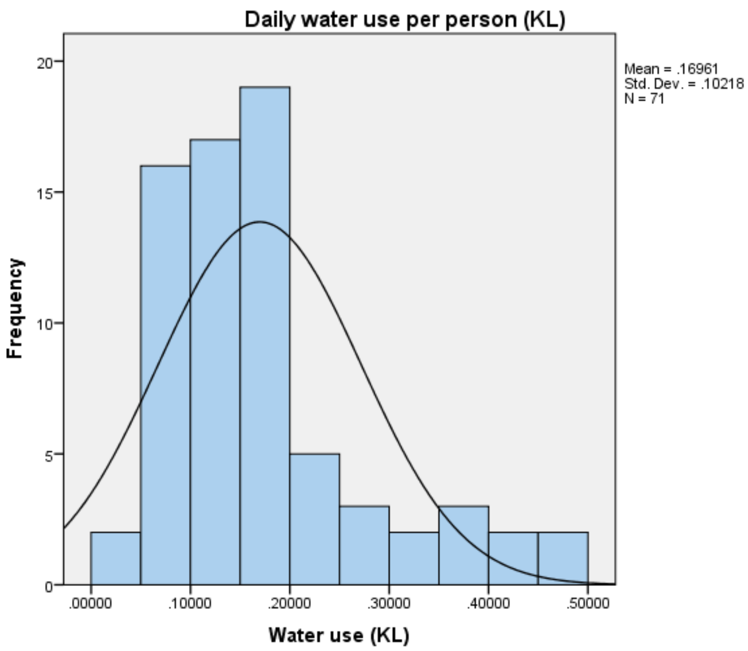


Figure 5.31: Average daily water use per person (kl)

Household perceptions regarding water use.

Of additional interest here are household perceptions regarding water use. Households self-identified their usage compared to other households in their area as either ‘low’; ‘medium’; ‘high’ or ‘unsure’ at the start of the survey. Does this correspond with their actual use?

Household daily use

Initial analysis was done by plotting responses to the continuous variable for each household’s recorded daily water usage in KL against the same household’s response regarding their use as either ‘low’; ‘medium’ or ‘high’ or ‘unsure’.

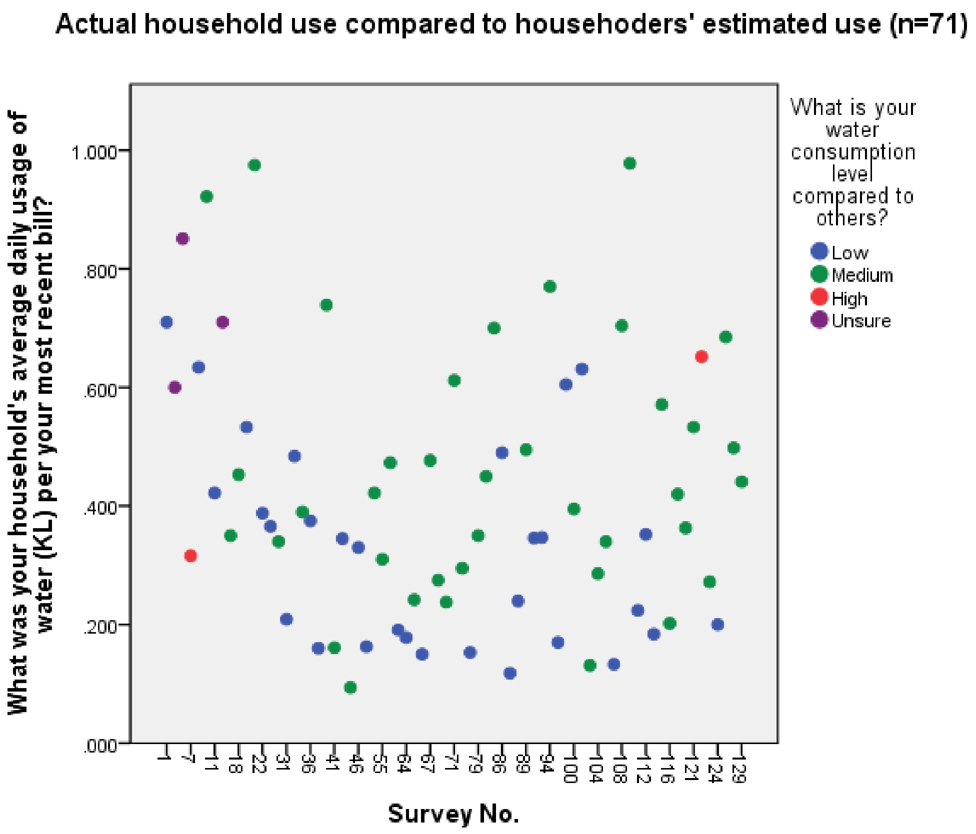


Figure 5.32: Actual average daily water use per household compared to estimated (kl)

The graph in Figure 5.32 indicates that householders self-assessing as low and medium use cover almost the range of responses given in reply to an actual reading from their water invoice. There were only two respondents who believed that their daily household water use was higher than others, and in fact one of these (0.316KL) was just below the mean (0.415KL) and the other well above it (0.652), but by no means the highest. All the other actual high use households assessed themselves as ‘medium’ use or were ‘unsure’. Generally it appears that households are poor at estimating their level of use, and generally inclined to underestimate their use.

A second approach was also taken to analyse the data. Although the data regarding actual water use is continuous, and the estimation of use by householders is ordinal, quartiles were used to approximately group data into low, medium or high use. Splitting the household which indicated a daily water use level into quartiles, and taking the lowest quartile to be ‘low’, the middle two quartiles to be ‘medium’ and the top quartile to be ‘high’ use, it is possible to compare with self-identified use levels of ‘low’, ‘medium’ or ‘high’. In the lowest quartile (n=19), 14 households (73.7%) identified as ‘low’ use with five (26.3%) indicating ‘medium’ use. In the two middle quartiles (n=36), 23 (63.9%) correctly identified as medium use, 1 (2.8%) incorrectly self- identified as high use, and 12 (33.3%) incorrectly self-identified as low use. In the highest quartiles (n=18), only 1 (5.5%) household correctly identified themselves as high use, 4 (22.2%) incorrectly identified as low use, 10 (55.6%) incorrectly self-identified as medium use, and 3 (16.7%) were unsure. The section most accurately identifying their use level was the lowest users (73.7% correct), then medium (63.9%) with the highest quartile by far the most inaccurate with only 1 correct identification (5.5%) and the remainder all understating their use levels or uncertain. As noted in relation to the graphical approach, only two households identified as high use.

Per person daily use

Were householders any more accurate in considering their level of water use if calculated on a per person basis? Initial analysis was again done by plotting responses to the continuous variable for each household’s recorded per person daily water usage in KL against their own assessment of the volume used.

The graph in Figure 5.33 indicates that householders self-assessing as high use were in fact not high use in terms of per person use in their household i.e. they use more water because there were more members in the household. Again self-assessed low and medium volume users cover almost the range of responses given in reply to an actual per person reading from their water invoice. The highest per person water use households self-assessed as low or medium use or uncertain.

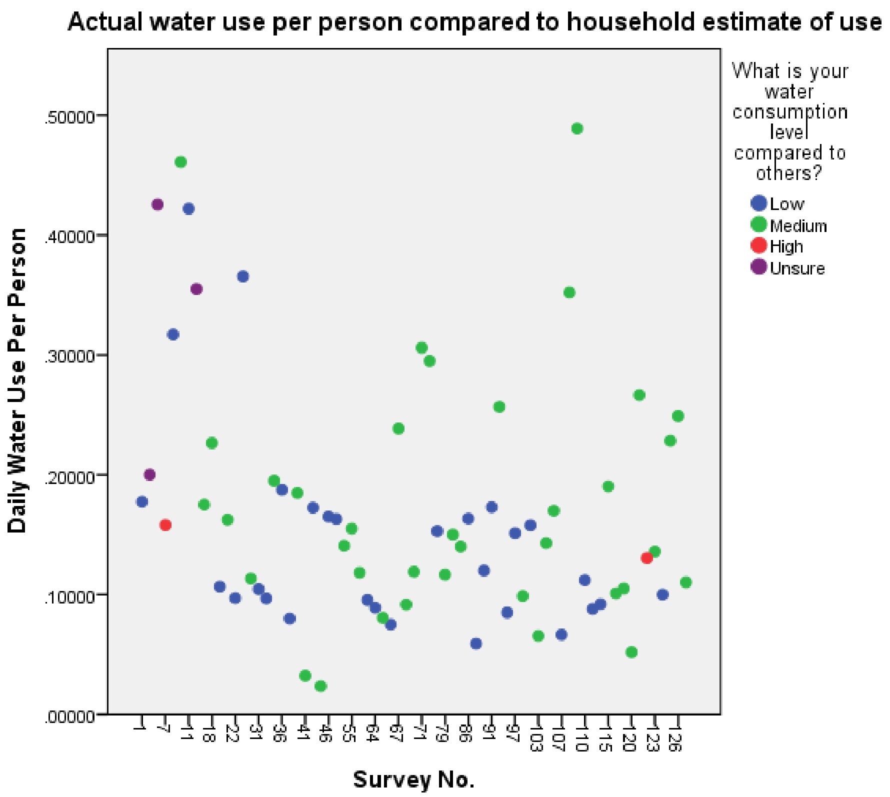


Figure 5.33: Actual average daily water use per person compared to estimated use (kl)

Again, for households which indicated a daily water use level and number of household members, the use was split into quartiles, taking the lowest quartile to be ‘low’, the middle two quartiles to be ‘medium’ and the top quartile to be ‘high’ use, a comparison was made with self-identified use levels of ‘low’, ‘medium’ or ‘high’. In the lowest quartile (n=18), 11 households (61.1%) correctly identified as ‘low’ use with 7 (38.8%) indicating ‘medium’ use. In the two middle quartiles (n=36), 19 (52.8%) correctly identified as medium use, 2 (5.6%) incorrectly self- identified as high use, and 15 (41.7%) incorrectly self-identified as low use. In the highest quartiles (n=17), no (0%) household correctly identified themselves as high use, the majority at 11 (64.7%) incorrectly self-identified as medium use, 3 (17.6%) incorrectly identified as low use, and 3 (17.6%) were unsure. The section most accurately identifying their use level was again the lowest users (61.1% correct), then medium (52.8%) and the highest use quartile was again by far the most inaccurate with no correct identification and the remainder all understating their use levels or uncertain.

This again indicates that households tend to underestimate their level of water use.

Household comments regarding water use.

Again respondents had the opportunity to make a comment about their water use, and twenty-eight did so. Eight respondents volunteered the break-down in (or a comment on) their daily water use between recycled and mains water (Table 5.55). In retrospect, this was a question that could have been included in the survey. The patterns of use from these few respondents suggest quite marked differences in proportions used of each type of water supply. Further research on the reasons for patterns of use would be insightful.

Table 5.55: Individual household comments regarding proportions of recycled and mains water used

	RW: Mains tap
1. 766L/day recycled & 86L/day mains	[88.9%; 10.1%]
2. 609 L RW + 313 L	[66.1%; 33.9%]
3. Recycled 309L Mains 112 L	[73.4%; 26.6%]
4. 55 recycle; 154 potable	[26.3%; 73.7%]
5. 77L per day recycled water and 407 l per day mains	[15.9%; 84.1%]
6. 193 recycled; 152 potable	[55.9%; 44.1%]
7. 33L Recycled water; 130 Drinking water	[20.2%; 79.8%]
8. This includes drinking water and recycled water both	

Note: calculations in brackets added by researcher

The remaining twenty comments on water use are shown in Table 5.56. Most were providing an explanation for why they didn't complete the section on actual use (4 because they were using rainwater tanks). Others provided further details about their water use e.g. 'We have been in minor drought & we use mains water to keep various plants alive. If I did not do this - even drought resistant shrubs deeply rooted could have perished in the last 3 month dry period'. Others provided general comments. Five comments were in support of PRW use, including one for potable use, and two referred to the influence of the media – one regarding its negativity and another suggesting a proactive media campaign to counter fears about PRW: "Adding recycled waste water to the dams is the way to go - no whinging from the public or very little - Just don't let the media turn it into a circus act." One respondent was opposed to potable PRW on health concern grounds.

Table 5.56: Other comments regarding water use

No. of comments	Theme	Actual comments (33)
8	explanation regarding why they had not filled in the water quantity used. (4 using rainwater tanks)	"We are a rental; usage varies with tenants" ; "Details not available at present time"; "N/A - live on a farm. Self-sufficient"; "No idea. I just pay my bill"; "We don't use any town water - just pay because it comes past the door"; "Don't have a water bill as we are on tank water."; "Less than .796 a day" (no actual amount specified); "Rainwater tanks only"
5	details on their use, each expressing an awareness of the scarcity value of water	"Garden use and toilet flushing use. Tanks for drinking. What happened to tank subsidy?"; "This is both recycled & fixed domestic water for 6 people per day."; "34KL for 93 days" "We have been in minor drought & we use mains water to keep various plants alive. If I did not do this - even drought resistant shrubs deeply rooted could have perished in the last 3 month dry period"; "I had a tenant on the wing of my house with 2 kids and a girlfriend. They abused my water supply."
5	In favour of PRW use (1 re. potable use) Includes 2 comments on the role of the media	"It is a worthwhile asset to our household."; "I think that recycled water should be used as much as possible, certainly for washing machines unless skin irritations might be an issue."; "Adding recycled waste water to the dams is the way to go - no whinging from the public or very little - Just don't let the media turn it into a circus act."; "Recycled water should be cheaper than mains to encourage people to use it instead of mains water."; "A private sector marketing/advertising expert should be engaged. Need a stunt such as using the Australian Swim Team to conduct a meeting in a pool filled with purple recycled water to show it causes no harm."
1	Against PRW use on health grounds	"I don't feel comfortable with PRW as there is no guarantee that all impurities including drugs are purified sufficiently for safe human consumption."
1	Supply difficulties	"The biggest problem is the means of supplying it to individual households - particularly apartments"

General comments regarding recycled water.

The final section of the questionnaire gave respondents an opportunity 'to make any other comments you wish to make regarding recycled water.' Some comments have been categorised in more than one area if they included multiple parts and some comments [in brackets] have been added by the researcher. [Note: PRW = purified recycled water; PPRW=Potable PRW]

Comments in favour of PRW

There were 22 comments in favour of PRW, although some were qualified, particularly regarding cost, and only half seem to support potable use - PPRW (three of these as a result of overseas experience of PPRW). e.g. "*Have drunk recycled water many times when traveling overseas so I'm no longer impacted by any 'yuck' factor*." Fear of health risk appears the most common qualification: *"Everything has its place, recycled water is good for yards and toilets but not for washing or drinking only because there will always be human error and no one wants to take responsibility for it."* One respondent made a comment about avoiding the deferred cost of dams if PRW was put to potable use: *"Why if water is 'recycled' & 'purified' should it be non-drinking? Once water is purified it is the same as the mains tap water (if various substances that were removed in the purification process and which is required for human consumption e.g. ions of Mg, Ca etc. are re-added). We should not build any more dams."* Some respondents were glad to use PRW for gardening as there were no restrictions: "*We moved from NSW to an area that has recycled water and I was pleased because I would not feel guilty using non-recycled water for usage on watering the gardens.*" A further comment has been included as in favour as it states that climate change is leading to decreased rainfalls in QLD, but it is only implied support (Table 5.57).

Table 5.57: Comments favourable towards use of PRW & some PPRW

- "Recycled water should be made available to all areas where possible." [PRW]
- "Should be mandatory on any new development in Australia. Should be significantly cheaper if not drinkable." [This has been included in the comments on price as well: [PRW & PPRW]
- "I fully support the concept of utilising recycled water. I believe all homes should be constructed with rainwater tanks plumbed into toilets and laundries. Also grey water systems should re-use laundry and bathroom water for gardening. I have no problem with the concept of drinking water which has been recycled to Australian Standards." [PRW & PPRW]
- "I like recycled non potable water at Caboulture. I would strongly resist drinking recycled water. Errors & accidents happen - too risky - my health is more important than money or water conservation." [PRW only: added to comments opposed as well]
- "We moved from NSW to an area that has recycled water and I was pleased because I would not feel guilty using non-recycled water for usage on watering the gardens." [PRW]
- "Have no qualms at all regarding the use of recycled water. If it's maintained at a high standard then it is suitable for drinking, if to a lower standard then for other purposes

& should therefore be sold at a lower price, I don't see any problems.” [PRW & PPRW]

- “It’s the only way to go forward for Australia as we don't have the water in the country to sustain the people in this country. We are one of the dry continents in the world.” [PRW & PPRW?]
- “Everything has its place, recycled water is good for yards and toilets but not for washing or drinking only because there will always be human error and no one wants to take responsibility for it.” [PRW only: added to comments opposed as well]
- “If strong measures are applied to PRW making it as pure as possible (naturally) without the adding of chemicals then every step should be taken to do so.” [PRW – qualified comment]
- “Keep it for what it was meant for in the first place -toilet, garden, car & house & window washing, to save the good drinking water & that's all. God always sends the rain.” [PRW only: added to comments opposed as well]
- “It's probably good, but it's too expensive. The fixed charges for the water is too much. Includes sewage.” [PRW – included in comments re. cost as well]
- “Recycled water is Ok with me but we don't have to drink it - it's raining again.” [PRW only: added to comments opposed as well]
- “Even though we have recycled non drinking water supplied, I still believe that we would be better off financially with our own rainwater tanks. The cost of recycled water is much too high!” [PRW – qualified comment: also included in complaints re. price and in comments re. alternative supplies]
- “I have no problem with recycled water usage.” [PRW & PPRW?]
- “Should be more of it especially in this dry country of ours.” [PRW & PPRW?]
- “I came from the UK where recycled water is commonplace. Main concerns: sloppy standards at filtration plants resulting in health issues. Australia is a lot hotter with some nastier bugs so perhaps more scope for mishap.” [PRW & PPRW? Qualified. Also include in opposed comments]
- “The cost of recycled water is not worth it! There will always be some selfish people. They don't care how much water they use or where it comes from, but a lot of people do care about our fresh water and are careful” [mixed response – possibly in favour of low cost PRW – also included in complaints re. cost]
- “Why if water is 'recycled' & 'purified' should it be non-drinking? Once water is purified it is the same as the mains tap water (if various substances that were removed in the purification process and which is required for human consumption e.g. ions of Mg, Ca etc. are re-added). We should not build any more dams.” [PRW & PPRW]
- “I support the use of recycled water for cleaning & certain household uses, garden & outside & commercial use, but I am concerned about health risks re drinking recycled water, cooking etc.” [PRW only: added to comments opposed as well]
- “Have drunk recycled water many times when traveling overseas so I'm no longer impacted by any 'yuck' factor.” [PRW & PPRW]
- “We already use recycled water on our property. I feel that rainwater tanks are one of the better ways to go. I have lived in London where the water is treated and put back into the Thames and then taken out again with no local negative perceptions whatsoever. Our sewage treatment systems can clean effluent to a high level that can then be filtered and chlorinated for human consumption very efficiently. Australia needs to keep up before they dry up!” [PRW & PPRW – also added to comments on alternative RW supplies]
- “I am from Singapore and perhaps you may already know that Singapore is at the forefront of using 'New Water' which is their version of PRW that is now already flowing through all household taps.” [PRW & PPRW]
- “Logic paths of survey could have been clearer in document. It is illusionary to think our annual rainfalls are not falling in QLD. Since 1997 rainfall has consistently been impacted by Climate shifts (Change).” (included in comments in favour of PRW as this seems to be implied – also included in negative comments re. survey instrument).

Comments not in favour of PRW

Ten comments were *not* in favour of PRW (Table 5.58), although all of these only related to its *potable* use on health/risk or human error grounds, (highlighted in table 5.58), whether from biological hazard or the presence heavy metals/other contaminants. One expressed a complete lack of trust in water authorities.

Table 5.58: Comments unfavourable towards use of PPRW

➢ "I like recycled non potable water at Caboulture. I would strongly resist drinking recycled water. Errors & accidents happen - too risky - my health is more important than money or water conservation." [PPRW only: added to comments in favour as well]
➢ "I wouldn't drink it as I have had ongoing stomach problems since contracting a bug from town water many years ago causing bloating and colic type symptoms."
➢ "Everything has its place, recycled water is good for yards and toilets but not for washing or drinking only because there will always be human error and no one wants to take responsibility for it." [PPRW only: added to comments in favour as well]
➢ "Keep it for what it was meant for in the first place -toilet, garden, car & house & window washing, to save the good drinking water & that's all. God always sends the rain." [PPRW only: added to comments in favour as well]
➢ "Recycled water is Ok with me but we don't have to drink it - it's raining again." [PPRW only: added to comments in favour as well]
➢ "I would not use recycled water for any sort of human consumption or clothes washing. I currently boil and filter any water used for human consumption (directly or indirectly) and will continue to do so. I do not trust government statements about safety of water treatment or additives, and I never will."
➢ "Evolusi virus & bacteria/toxins, poisons, chemicals, radiation, oils, nano tech particles etc could never be safe in drinking water"
➢ "I came from the UK where recycled water is commonplace. Main concerns: sloppy standards at filtration plants resulting in health issues. Australia is a lot hotter with some nastier bugs so perhaps more scope for mishap." [PPRW? Qualified. Also include in comments in favour]
➢ "I support the use of recycled water for cleaning & certain household uses, garden & outside & commercial use, but I am concerned about health risks re drinking recycled water, cooking etc." [PPRW only: added to comments in favour as well]
➢ "Will be full of medical waste and heavy metals"

Comments in favour of an alternative RW supply e.g. rainwater tanks.

There were nine suggestions as to alternative sources for recycled water (Table 5.59), six in favour of rainwater tanks, two suggesting schemes for piping water from other locations, and one in favour of conservation by more careful use of existing supplies and reducing waste. The carbon footprint of electricity used for rainwater tank pumps and pipelines from other regions does not seem to be known, or is not considered by respondents. This is an area requiring further consideration and a potential area where more information could be provided to households. Rainwater tanks may be not such a ‘green’ option depending on the source of the electricity supply. No comments on water pricing mentioned the cost of pumping – actual and environmental – either, or the cost of safe water storage and dosing (e.g. chlorine) during transport/piping.

Table 5.59: Comments in favour of an alternative RW supply e.g. rainwater tanks

- “I think if every household had 20,000L of rainwater tanks it would cut down mains consumption considerably & all new houses should have to have at least a 5000L rainwater tank installed. & commercial building should be capturing & using the rainwater from their roofs. We are squandering this replaceable resource every time it rains. Whole households relied solely on rain water, we all valued it as a natural resource & treated it as such.”
- “Everyone should have tank water for drinking water with filter.”
- “Even though we have recycled non drinking water supplied, I still believe that we would be better off financially with our own rainwater tanks. The cost of recycled water is much too high!” [also included in comments in favour and in comments re. cost]
- “We lived in a rural area prior to 2009 - the only water we had was what was in the tanks. According to the amount of water in the tanks our water usage varied - did not buy additional water for 13 years. Now we have 2 large tanks for house use (22500L). We monitor our own water use. We do a bit of caravanning, our van has toilet & shower - we use 40L/day in the van showering every day. Does not include laundry (done at laundry mart).”
- “Let's encourage people to be responsible for collecting their own water - rainwater tanks etc; use/recycle water from washing machine etc; bucket water after shower onto plants etc. Allow people to use a reasonable amount of water for very small fee - should be a government service to community.” [Also included in comments re. price]
- “I feel we waste a lot of water. Anything in moderation will help save our resources. During drought everyone in Samford valley works towards sustainable future.”
- “We already use recycled water on our property. I feel that rainwater tanks are one of the better ways to go. I have lived in London where the water is treated and put back into the Thames and then taken out again with no local negative perceptions whatsoever. Our sewage treatment systems can clean effluent to a high level that can then be filtered and chlorinated for human consumption very efficiently. Australia needs to keep up before they dry up!” [PRW & PPRW – also added to comments on alternative RW supplies]
- “Historically, it would seem to me that the federal government takes a heinously reactive approach to water supply and water conservation in this country. Less talk about climate change and more education about various oceanic and solar influences on weather patterns would be far more helpful not only to the public in general but also to policy makers. The northern parts of Australia have very reliable rainfall year in and year out much of which simply runs out into the northern oceans via vast river systems. I strongly believe the federal government needs to look at building sustainable infrastructure to pipe reliable supply from these wetter regions so that we are not constantly chasing silly, short term, expensive solutions to water supply problems across the more southern areas of the nation. Whilst the initial outlay would be very substantial, it is an insurance scheme against the vagaries of weather and population pressures that will only increase into the future.”
- “Pipe water from Tully river into Central QLD. Why let it run to sea? They did it in the Snowy Mountains.”

Complaints regarding the cost/value for money:

Eleven respondents complained about the cost of the PRW supply (Table 5.60), including high connection charges and fixed charges, and the infrastructure costs. One specifically stated that they preferred water under local council control. Other respondents commented that water supply a 'should be a government service to the community', and that full infrastructure costs should not be passed on, or should be subsidised by the federal government.

Table 5.60: Complaints regarding the cost/value for money

- "We had to pay a $1,000 connection fee for this utility, and it was made clear that this water was cheap to provide and to buy but this water now more expensive than town water and if I knew this was going to happen I would not have had it connected."
- "Mains water is expensive enough without having the same cost for recycled water. Councils plan the treatment plants for the state & Fed govt should pay to build. I was never asked if I wanted recycled water and the cost that we are being charged - I wouldn't want it at all."
- "For having recycled water in the estate (to be plumbed to house) I paid $20K more for the land $10K more for the house & highest bracket for rates (council) with double infrastructure fixed H2O access charges. Recycled water is good but you do pay for it every step and then some."
- "It's probably good, but it's too expensive. The fixed charge for the water is too much. Includes sewage." [PRW – included in comments re. cost as well]
- "Recycled water should be cheaper."
- "Even though we have recycled non drinking water supplied, I still believe that we would be better off financially with our own rainwater tanks. The cost of recycled water is much too high!" [also included as a comment in favour and in comments re. alternative supplies]
- "I think the cost of water is prohibitive. The government has sold off so much infrastructure to pay for unnecessary expenditure in the salaries and monies spent by government members, the waste is terrible and the average "Joe" has no real way of stopping the enormous waste of our money e.g. cost of a 'natural resource'"
- "Water supply should only be owned and operated by local councils on a not for profit basis. We are being slugged by greedy overpaid companies who are stripping profit from consumers. Return water ownership to councils."
- "The cost of recycled water is not worth it! There will always be some selfish people. They don't care how much water they use or where it comes from, but a lot of people do care about our fresh water and are careful" [mixed response – possibly in favour of low cost PRW]
- "We lived on water from a desalination plant during the 1990s & early 2000s. We were paying $5/KL at that time & it definitely controlled usage. Due to the arid environment rainwater wasn't a viable alternative & town ovals were watered on recycled effluent but there wasn't sufficient in summer to do it. I don't believe full cost of infrastructure can be passed on to the public. 2/3 of our account is for infrastructure."
- "Let's encourage people to be responsible for collecting their own water - rainwater tanks etc; use/recycle water from washing machine etc; bucket water after shower onto plants etc. Allow people to use a reasonable amount of water for very small fee - should be a government service to community." [Also included in comments re. alternative RW supplies]

Other complaints/comments:

There were two further complaints, one about the smell from the toilet using PRW non-potable water and the other about there being insufficient public information to make an informed decision about PRW.

Complaints regarding the survey instrument:

Technical comments/complaints:

One householder did not think respondents would understand the difference between the various methods for recycling water 'How many people know what RO and BAC are?!' It was noted that there was already interference in the natural water systems via dam use: 'We've interfered in the natural water cycle by building dams'. This is in part a criticism of the survey instrument. Although these terms were briefly explained in the instrument, it is hard to find a balance between providing information and overloading the respondents, thereby limiting response rates. It is also problematic in that any explanation is open to survey design/researcher bias.

Other complaints regarding the survey instrument:

There were four complaints from respondents regarding the survey itself (Table 5.61). Three were concerned about the difficulty of completing it due to number/ambiguity/repetition of questions. In hindsight, although a pilot test was done using the survey instrument, some questions do seem to have proved difficult to answer and it was a lengthy survey. However some similar questions were deliberately repeated to check for consistency in answers.

One respondent felt that the format of the questionnaire suggested a bias. To some extent this is a fair comment as explanations for terms were generally taken from the water authority website or publications. More fundamentally, sustainability research is 'intentional' (Peattie 2011 p.23), in as much as the motivation for such research lies in seeking solutions for a perceived current problem. An example is research accepting a current and predicted inadequacy and inequality of access to water supply, motivating investigations into alternative water sources. Research on sustainable water supplies necessarily accepts that water is a scarce and precious resource and is motivated by a desire to understand and manage water systems and interactions with society. However, in each section of the survey, respondent comments and opinions have been asked for and encouraged and fully reported.

Table 5.61: Complaints regarding the survey instrument

"Via your questions you seek a particular outcome - preconceived influence."
"Many of these questions are ambiguous and/or repetitive"
"Thank you for the opportunity to do this, but I feel it was too wordy and therefore difficult to answer. As we are on a septic system a lot of the questions did not relate to us."
"Logic paths of survey could have been clearer in document."

5.2.6.5 Research implications of Section D of the survey

Section D of the customer survey contained an explanation of the calculation of the then current water charges followed by questions exploring customer attitudes regarding the scarcity of water and water pricing, and questions exploring the possible motivations for agreeing to use PRW for non-drinking and drinking/potable use. This was primarily concerned with Research Questions 3 (risk – here the risk to the water provider regarding price recovery), 6 (customer perceived benefits and risks) and 7 (factors influencing acceptance of potable PRW). Key points on these research questions gained from Part D of the customer survey are summarised here:

RQ 3

- What are the risks of recycling and how can they be managed?

Risk for policy-makers/water authority is rejection of PRW schemes e.g. on grounds of perceived health concerns or excessive cost of supply (resistance to increased prices)

- The majority of respondents (77%) agree that water a is scarce resource and that subsidies increase usage (58%), but respondents are still price conscious; a large majority (83%) believed that PRW should be significantly cheaper than mains tap water, this majority reducing to 70% in agreement with paying 'actual' costs and a further reduction (56%) in those agreement with paying the 'full cost'
- Preference for increased variable/usage costs may be influenced by the fact that households appear to underestimate their water use in relation to other households

- Prefer that all prices in QLD the same
- Suggested prices from respondents usually stated in terms of reference to other prices – so capped by alternative sources. A problem if mains tap water supply is subsidised as it blocks introduction of PRW on costs basis.
- Sizeable minority completely opposed to potable PRW use on health grounds.

Risk for policy-makers/water authority re. public perceptions could perhaps be reduced by better information:

- 58% of respondents wanted further information
- Even though the majority of respondents agreed that water transport costs were high they seem uniformed about the high cost of transporting water – high electricity costs of pumping even from rainwater tanks and also storage costs and 32% were uncertain about transport costs. Still a substantial number with ideas that water is 'free' or low cost. Some see rainwater tanks as a low cost alternative but probably do not factor in actual and carbon footprint costs of electricity for the pump.

RQ 6

- What are the perceived benefits and risks (costs) of recycled water use for customers?

- The majority of respondents (77%) agree that water a scarce resource
- Non-potable PWR generally considered acceptable if costs less than potable PRW and mains tap water (75.4%) although rainwater tanks preferred by some.
- Cost: 66.4% agreed cost is a consideration. Price seems more important motivator for PRW than lack of water restrictions/drought proofing supplies for most, although 52% would use it to avoid restrictions in times of drought

RQ 7

- What factors influence customer acceptance of PRW for potable use?

- COST: 66.4% agreed cost is a consideration. Less than for non-potable PRW, but still a majority find potable PRW acceptable if costs less than mains tap water. Sizeable minority completely opposed to potable use on health grounds.
- majority support for paying 'actual' or 'full cost' (though may have assumed this is less than mains water cost)

- most respondents wanting more information on costs
- factor analysis identified 5 sets of respondents with similar attributes, again often direct opposites of each other:

  –Respondents with a positive attitude towards drinking recycled water under various circumstances – to reduce drought, reduce water costs, and to avoid water restrictions

  -Respondents who were in favour of actual costs & full costs

  -Respondents who think water is not a scarce resource and charging higher variable cost will not reduce use, and subsidised use does not increase it

  -Respondents not in favour of potable PRW use and in favour of all in QLD paying same price

  - Respondents in favour of all PRW cheaper than mains supply but also asking for more information on water costing– might use PRW if price right (‘Cheaper’)

5.3 Results conclusion

The research problem was to aim to build a model for costing an A+ recycled water facility:

(extract from **Figure 1.2**)

Information for the model was derived from a number of different sources (Figure 3.1) and the structure and key points are outlined below.

The economic aspect was addressed via site visits, interviews with staff, and literature review. It entailed the identification of costs objects (the treatment plants and the class A+ recycled water products). This required creation of process diagrams for each plant (Figures 4.7 and 4.10) and identification of product uses – both current (Figures 4.3 for non-potable uses) and potential (indirect potable use for residential customers – research indicating that it was possible for these products to be used for that purpose). It also required stakeholder analysis to identify key components of the system (section

4.3.6 and Figure 4.11) related to Research Question 1. The TBL aspects are overlapping so stakeholder analysis also provided information for environmental and social aspects (key personnel to interview about processes; access to information for customer perspectives).

RQ 1

- What are the characteristics of the recycled water supply chain in SE Queensland, including key stakeholders, and specifically the stakeholders in the 2 AWTPs studied

Test data was collected– operational cost data for 2 months at each facility and comparisons of economic data relevant to research question 5.

RQ 5

- Are the two methods of producing Class A+ recycled water as identified in the two case studies equivalent, or is there a preferred method?

The largest cost was electricity used. The MDAWTP RO operating process had higher energy costs but distribution energy costs were lower as it was located close to the industry client. The high energy fixed cost meant that the facility lacked economies of scale and was not running at capacity or as originally intended in terms of scale. The continuous running process also meant a greater amount of peak energy was used. Energy cost was lower for the SCWRP process (but not negligible) but there were higher distribution costs for a residential reticulation scheme. Both plants also had chemical costs. Problems encountered included a lack of data for lifecycle analysis capital cost; lack of disaggregation of energy costs; QCA regulatory environment; problems of separation of costs and benefits between recycled treatment plants and STP and sometimes separation of functions at SCWRP as it also treated wastewater for release to river. (Summary in section 4.4.1)

<u>The environmental aspect</u> was addressed via site visits, interviews with staff, literature review and customer survey. It required creation of material flow diagrams for each plant (Figures 4.12 and 4.13) and identification inflows and outflows and consideration of Scopes 1, 2 and 3 emissions. Identified concerns included: Carbon footprint of chemicals, and energy consumption; release of brine, possible fugitive emissions. The carbon footprint (and energy costs) could be greatly reduced by sourcing greener energy e.g. biogas recovery from the STP. Identified benefits included: reduced

nutrient release to river, avoidance of costs for alternative potable water supply – which may be expensive if the incremental water supply is sourced from a desalination facility or has to be pumped any distance; deferred capital costs of alternative supplies. Recycled water from wastewater has the advantage of being local to population centres where the demand for supply is and is less prone to the effects of drought.

The social aspect was addressed via site visits, interviews with staff, literature review and customer survey. Social benefits included drought proofing the water supply; the deferred cost for infrastructure (dams have a much larger social and environmental footprint); encouragement to local business if these are water intensive like Amcor (and consequent employment) as it reduces business risk and increased recreational use of river and sports facilities. There is evidence of non-use value as well (land premiums and some customer willingness to pay shown in the survey results). From a customer and social perspective there is a need to support innovation and new technology seeking acceptance. This may produce longer term benefits such as local skill development and market leadership (e.g. the biogas recovery in Melbourne). There is potentially a high political and social cost for policymakers of not managing stakeholders. The survey results suggested that respondents valued environmental aspects and were often concerned about issues such as climate change, but also demonstrated a lack willingness to pay and a dichotomy of stakeholder views regarding perceived health risk and trust in the system. There was also a perceived lack of information.

Chapter 6 looks at the overall model and links the results from Chapters 4 and 5 to the research objectives.

6. Conclusions and contributions

6.1 Introduction

In Chapter 1 a conceptual model for the research was provided in Figure 1.3, which set the research questions into a Triple Bottom Line framework. As the three TBL aspects overlap, the conceptual model is similar in form to a Venn diagram, with overlapping sections. In Chapter 3 the research questions embedded in the TBL aspects were linked to the methods used to acquire relevant data (Figure 3.1), in effect the research model. The aim of the diagrammatic representations of the model is to demonstrate how the aspects fit together with the Research Questions (RQs), as the structure of the research is multi-faceted and non-linear, with Research Questions being answered via multiple sources, hence appearing to be out of sequence. Chapters 4-5 presented the results and analysis of the quantitative and qualitative data. Each section of results chapters has a summary of the results as they relate to the Research Questions. The full detail of this will not be repeated in Chapter 6, but key results will be highlighted. The aim of Chapter Six is to align these results with the Research Questions and Problem posed in Section 1.3. The Chapter will then assess the contribution of this thesis and suggest implications for policy and for further research.

It is helpful to start with a reminder of the results of the literature research and consequent motivations that lead to the formulation of the research problem and questions outlined in Chapter 1.

The background to the importance of the issue of water recycling in Queensland is worldwide growth in demand for sustainability reporting in the light of the potential economic consequences of climate change highlighted by the Stern and Garnaut reviews. This is predicted to exacerbate the effects of existing Queensland weather patterns which fluctuate between El Niño (drought) and El Niña (flood) events and highlights the need for alternative water sources (Garnaut 2011a). This is coupled with predicted rapid population growth in Southeast Queensland (Taylor 2010). The prolonged 1997-2010 drought which affected the densely populated areas of Southeast Queensland, prompted the Queensland State Government investment in large scale infrastructure for new potable water sources, including Advanced Waste Water Treatment Plants (AWTPS) and the Western Corridor Recycled Water Project (WCRWP). The subsequent 2011 flood event, also affecting Southeast Queensland, eased pressure on water supplies, and combined with opposition to the idea of indirect use of potable Purified recycled Wastewater (PRW) led to a reversal of State Government policy on potable PRW, with consequent significant economic and political implications. Failures of attempts to introduce potable recycled water in Toowoomba in 2006 (Hurliman & Dolnicar 2010) and Brisbane via the WCRWP (Whiteoak, Jones & Pickering 2012) and media coverage of the so-called ‘yuk’ factor (Po, Kaercher & Nancarrow 2003; Menegaki et al. 2009), have highlighted the need for research into the social aspect of recycled water and customer perceptions.

Planning for the successful introduction of PRW therefore requires a wider view of the costs than a simple economic dimension. Inadequacy of water costing without including externalities – both benefits and costs – (Gray, Bebbington & Walters 1993) highlights the need for a systems approach (Meadows 2009), and a consideration of the problem along full cost or sustainability lines (WASB 2012; AWRCE 2010a), which fits well with a Triple Bottom Line (TBL) approach (Elkington 1994). This introduces additional environmental and social aspects or dimensions, which requires stakeholder/value chain analysis (Freeman & Liedtka 1997; Pagell & Wu 2009). Successful overseas introduction of potable PRW suggests a need to manage the social aspect and to provide adequate information for media coverage (Lim & Seah 2013). The social dimension has not been widely researched (Hermans et al. 2006). As the RW processing method may also be a factor influencing acceptance of PRW, a comparative case study approach looking at two Advanced Water Treatment Plants (AWTPs) seemed appropriate. Customer perceptions about different sources and uses for RW were also therefore an important part of the consideration of the social aspect. Lack of knowledge about sources of RW supply might be a factor in perceptions (Nancarrow et al. 2007; MJA 2014b). Historic water pricing policies and consequent attitudes towards higher water prices were also highlighted as an issue by prior research (Hunt, Staunton & Dunstan 2013; WBCSD 2012; Withey 2013), and it was of interest to see whether attitudes had changed following the prolonged drought in Southeast Queensland.

Prior research therefore suggested a multi-discipline methodology in order to build a TBL model for identifying costs and benefits of purified recycled water in Southeast Queensland, and a comparative case study approach was used to build a full cost picture of stakeholders and to inform a costing model. This lead to the development of the Research Problem and Research Questions outlined in Chapter 1 of the thesis (Figure 1.2).

6.2 Addressing the research questions

6.2.1 Conceptual model

As mentioned, in Chapter 1 a conceptual model for the research was provided (Figure 1.3) which set the research questions into a Triple Bottom Line framework.

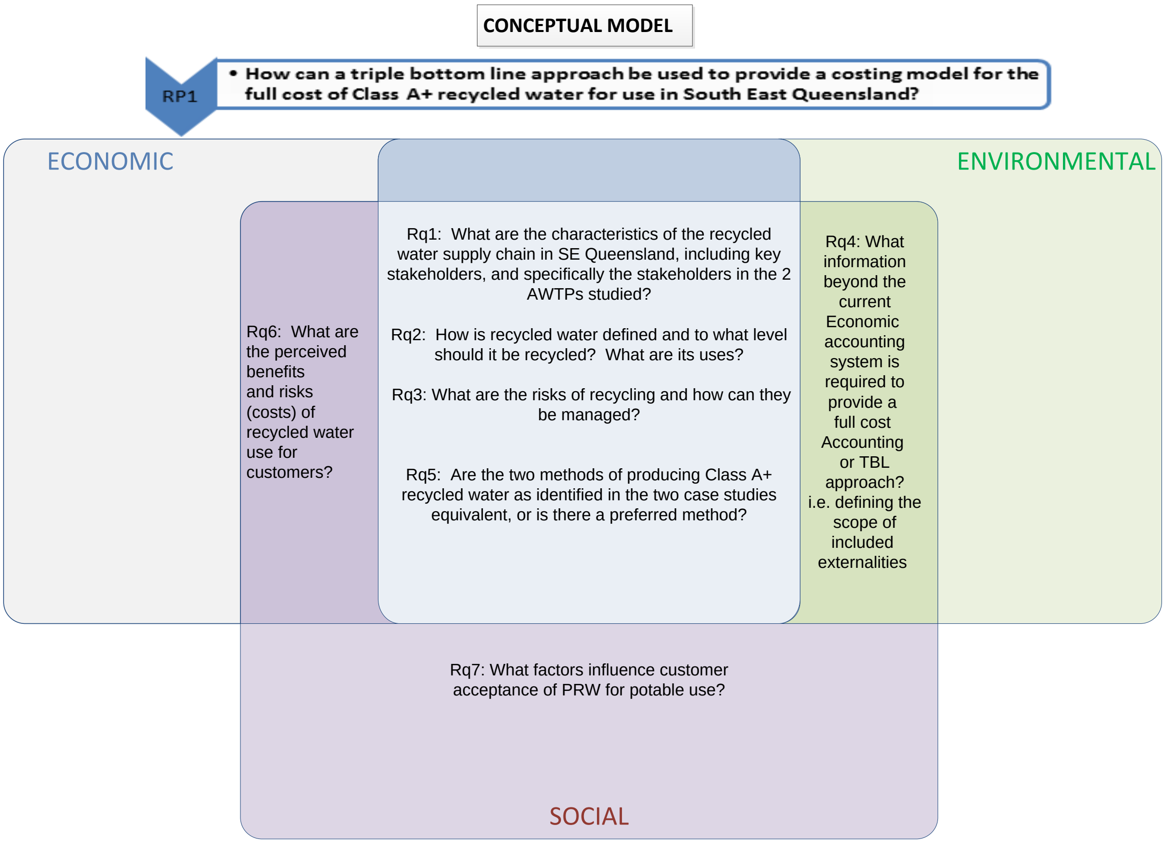


Figure 1.3: Application of the Research Problem and Questions to a Triple Bottom Line (TBL) model – repeated

As the three TBL aspects overlap, the conceptual model is similar in form to a Venn diagram. The methodology required to address the research problem meant analysis of data from a variety of sources and disciplines, and the three aspects (economic, environmental and social) overlap, so most research questions applied to more than one of the aspects.

An example of the use of multiple approaches/disciplines was the need to set the case studies in context and to look at social and natural systems, and the economic implications of these. This required an understanding of the operations of the plant (process diagrams Figures 4.7 and 4.10), and the application of management accounting techniques to the case studies such as materials flow diagrams (Figures 4.12 and 4.13) and a mapping of stakeholder interactions (Figure 4.11). Previous research has been undertaken into the case study AWTPs used in this thesis, but has concentrated on one perspective, such as (1) the quality of the recycled water output (Reungoat et al. 2010a) or (2) Life Cycle Assessment (Lane and Lant 2012) from an engineering perspective. This thesis synthesises results from previous research to inform a Triple Bottom Line approach from an accounting discipline perspective and applies the combined TBL approach to one setting. It is the first study to examine in depth the social aspect by direct questionnaire to the water customers (both PRW dual reticulation customers and other customers of the same water authority), and to look at customer perspectives in this setting. Nancarrow et al. 2007 carried out customer research in the South East Queensland area covered by Wivenhoe dam, but the customer perspective in this study looks at both existing recycled water users and potential users, and does so at a time when attitudes may well have changed as a result of the end of a record-breaking prolonged South East Queensland drought in 2010. The timing also provided a unique opportunity to carry out a study when both the recycled water plants in the area were still in operation. A major problem in introducing any sustainability policy, apart from issues with uptake on new technology and acceptance of new products, is the need for long-term top-down consistency of approach and this thesis illustrates how quickly policy changes and restructuring can take place, and the difficulties encountered as a result.

The conceptual model (Figure 1.3) demonstrated how each research question provides information for at least one TBL aspect, but usually for multiple aspects. Figure 6.1 maps a summary of the key results of the thesis to the research questions within the framework of the TBL model.

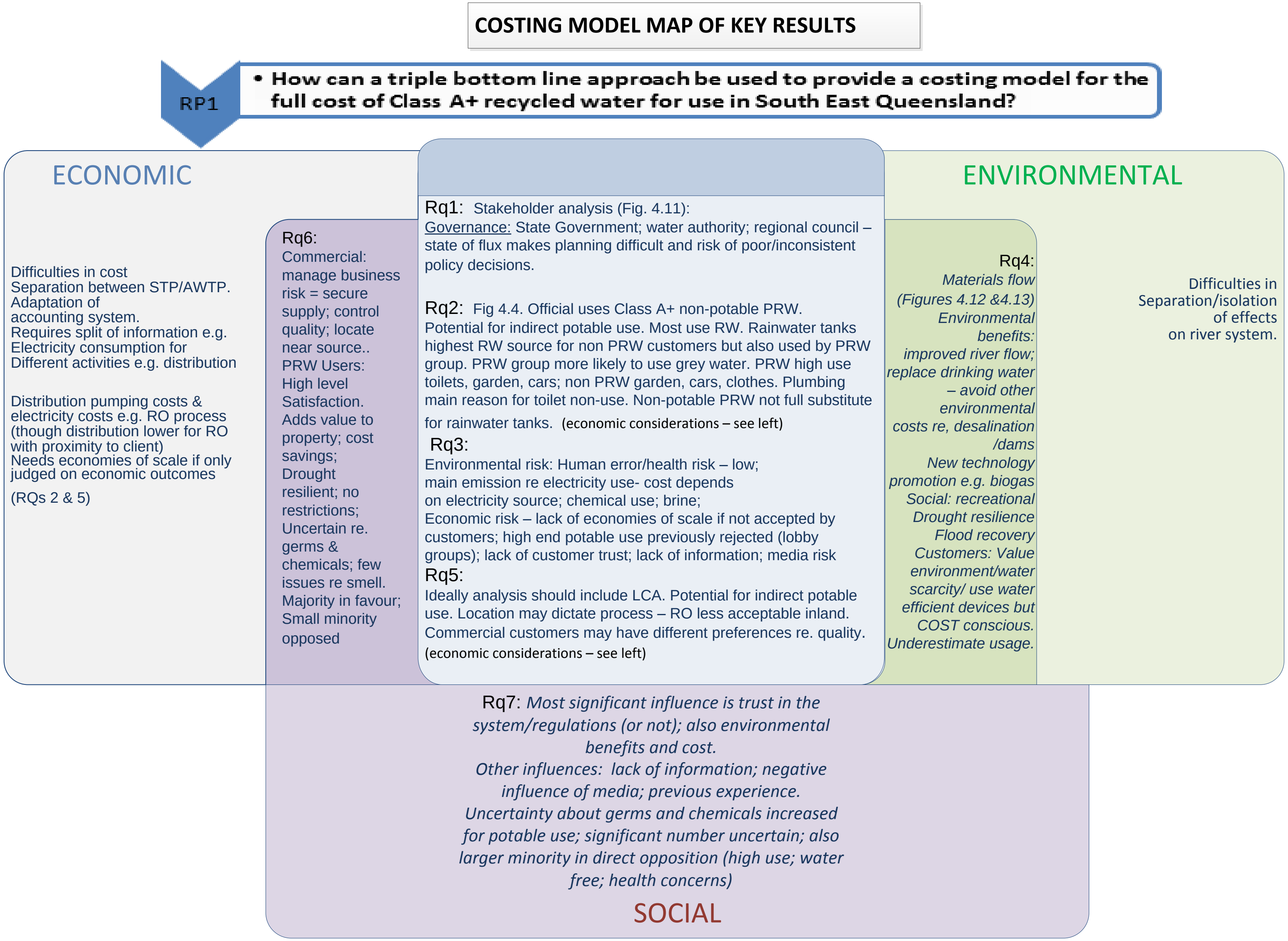


Figure 6.1: TBL full cost model with key results

6.2.2 Research Question 1

RQ 1

- What are the characteristics of the recycled water supply chain in SE Queensland, including key stakeholders, and specifically the stakeholders in the 2 AWTPs studied

The first research question concerned an examination of the supply chain for water in south east Queensland in order to set the case studies in context in their 'system' (Meadows 2009) (section 4.2), which in turn led to the identification of stakeholders of the two case study advanced water treatment plants (Figure 4.11) (Freeman & Liedtka 1997). A TBL approach requires systems thinking and the use of stakeholder analysis to broaden the reporting model. Figure 4.11 identifies relevant stakeholders under the headings 'influencers', 'users/beneficiaries', 'providers' and 'governance' (Office of Government Commerce (OGC) 2007), and immediately brings to attention the state of 'flux' in the governance perspective during this period. It also helped to identify externalities (RQ4) such as the local users of the two river settings and the environmentally sensitive location of a riparian landscape with improvement in water nutrient levels and estuarine health a key recent (and ongoing) concern of the local Moreton bay Regional Council and the pressures in the area on the ecosystem as a result of population growth and limited local water supply.

The stakeholder analysis was therefore used to identify cost areas in the Triple Bottom Line (TBL) approach, particularly environmental and social costs, which also pertained to Research Question 4 (externalities).

The governance structure is the same for both plants, as are many of the providers. The governance of recycled water in the area has undergone substantial changes over the period of the study, with uncertainty regarding the structure (control from councils to Unitywater and potentially back to councils). There has also been severe fluctuations in weather patterns (from record drought followed by unusually severe flooding) creating external pressure and influencing public and political policy, with consequent unfortunate inconsistency in approach to and support for recycled water as a public policy in Queensland. This had economic consequences in the case study at one AWTP, for example, concerning economies of scale.

This is exacerbated in a federal system where national and state policies may not be aligned (the National Water Initiative (NWI)), for example promoting full cost of water supply to avoid unwanted user behavioural outcomes, when increasing water costs are politically difficult to pass on to consumers at the local level. Implementation and acceptance of innovation requires consistency and careful management of stakeholders, as evidenced by the successful introduction of potable recycled water in Singapore (Lim and Seah 2013), and this has been very difficult to achieve in a state of change in Queensland. Acceptance of the product – PRW – is key to building a sizeable customer base and in developing plants with sufficient output to achieve economies of scale. It is also key to determining the level of substitution possible – PRW used for non-potable purposes or used as a source of water for indirect potable use. The economic analysis in this study and previous research (Lane and Lant 2012a) suggests that the best results come from substitution at the highest level (indirect potable use) to defer the need for alternative supplies (e.g. dams and desalination), achieve economies of scale, and reduce the high energy costs of distribution (if the AWTP is located near to the indirect source such as the dam/weir).

The management of stakeholders requires identification of users and influencers e.g. customers and those potentially impacted by the AWTPs. This information enabled examination of customer perceptions (RQ6) and identifies stakeholders within the surrounding system who could be affected by the AWTPs (RQ4) with social and environmental externality considerations. MDAWTP had one major commercial customer. SCWRP customers for recycled water were primarily dual reticulation non-potable use customers, but also commercial customer self-collecting water via tanker. Identification of users also directed research toward investigation of what constituted recycled water and how it was being used (RQ2).

An example of the presence of key influencers identified during this research, was the polarisation of views over potable PRW, and the possibility of this creating local lobby groups accompanied by intense media coverage surrounding ‘poo water’ campaigns and protests over increased prices. Water customers, as with the general population, may underestimate the effect media coverage has on their opinions (whilst overestimating the effect it has on others). Survey respondents tended to agree readily

(66.4%) with the statement that ‘People in SE QLD are influenced by the negative messages about Purified Recycled Water in the media’ whilst only 23.4% agreed that ‘I am influenced by the negative messages about Purified Recycled Water in the media’ *(section 5.2.5.5).*

Both AWTPS are located on river systems rather than a coastal environment, with the consequent implications for other users and public health. This was identified under research question 1, but expanded when considering Research Questions 3 (risk) and 4 (externalities). The stakeholder analysis and ‘in context’ systems approach therefore helps to identify potential risk areas and externalities to be considered. The interconnected nature of the Research Questions required to fit the model, and the stakeholder analysis, confirm the inadequacies of an approach based solely on the economic results of one facet of the system e.g. the running costs of a single AWTP.

6.2.3 Research Question 2

RQ 2

- How is recycled water defined and to what level should it be recycled? (substitute for industrial use/potable water added to consumer drinking supplies) What are its uses?

Research Question 2 concerned the definition of recycled water and an investigation into the level to which it should be appropriately recycled. This included technical considerations of water quality and permitted uses under water standards. These also have economic implications – higher quality water requires grater processing, and a choice between processing methods. The case study included two AWTPs using different water treatment suites to produce water categorised in Queensland as class A+ recycled water. Research Question 5 specifically addressed the question of whether there was a preferred method, so economic considerations are also discussed under that research question.

Lane, de Haas & Lant 2012 found that data was lacking regarding the interaction between the available water sources. Unanswered questions included:

- How far will consumers be happy to use recycled water for uses currently using mains water and how far would rainwater tank use be replaced?

- Does the use of recycled water increase the overall household water usage and only partially replace other water sources?
- What are the accepted uses from a customer perspective?

RQ2 also examined customer attitudes towards recycled water quality, sources and actual and preferred uses. Actual and preferred uses had implications for existing and likely levels of water substitution e.g. PRW replacing potable mains water or rainwater tanks. Matching customer perceptions regarding the uses of recycled water to provision of recycled water of an appropriate quality (fit for purpose) has policy implications and was explored via the customer survey (also relevant to RQ6).

Defining RW

A definition of class A+ recycled water was obtained from Unitywater (Figures 4.3 and 4.4) and the accepted uses for this class of water identified – i.e. all non-potable uses apart from close contact use such as drinking, clothes washing, filling of pools and, additionally since the survey, a prohibition on topping up rainwater tanks. This may have an effect on customer acceptance (post the survey) as one notable aspect was the widespread use of rainwater tanks, even by respondents with PRW supplied. Review of prior research and interviews at site visits also confirmed that both AWTPs were theoretically capable (with minor modification) of producing PRW to a standard acceptable for indirect potable use (section 4.3.2) (Reungoat et al. 2010a).

Substitution (commercial) and processing levels

MDAWTP had one major commercial customer and interviews confirmed that the motivation for this company was primarily water security in times of drought (RQ6 and RQ4 implications) and secondly the ability to determine the specifications of the water (such as lower salt content) provided by the reverse osmosis process. This industrial customer valued the quality/availability of the reverse osmosis processed water enough to invest in infrastructure to accommodate it. During the period of the research for this thesis (2009-2013) all capacity from MDAWTP (4ML per day) was used by the industrial client who stated that this reduced their consumption of potable town water at that site by 90% (Section 4.3.4). In other water authorities such as the WCRWS industrial use is made of the recycled water for power plant operations. It is possible that other industrial/commercial customers may be interested but a limiting factor was the cost comparison to mains water supply. Reverse osmosis is the treatment process for water supplied to these industrial customers, and for the respondents in this study, appeared to be appropriate to their needs, and transportation costs were minimised by deliberate location near to the customer's location. Smaller scale plants do have location advantage, but as this customer had not accessed any water from the BAC plant at SCWRP, then it is not certain whether the BAC process would be equally suitable. In terms of salt extraction, however, RO as a process may be preferred if that is a customer priority. Commercial customers of SCWRP were those using PRW form the BAC processing delivered/collected via tanker, and included, for example, local parks and sporting facilities for landscape watering. From interview it was clear that some of these customers may prefer the recycled water to still include trace elements suitable for garden/cultivation use. However these customers were not directly surveyed in this study and further research into commercial preferences regarding water attributes would be beneficial. It is clear that in many cases substitution of PRW for mains water supply for industrial purposes is both possible and currently practised where available.

Substitution (residential) and processing levels

Only SCWRP had residential customers. Currently in the area demand for potable water exceeds supply and water is imported from the SEQ water grid (Lane & Lant 2012a) (section 4.3.2). In a geographical area of high population growth PRW substitution for/augmentation of potable water supplies seems appropriate.

Residential respondents were asked (after a brief explanation regarding the processes) how they would prefer that PRW be processed and although the largest proportion (39.8%) (Table 6.1) did not think that the process mattered provided Australian standards were met, of those that expressed a preference a larger proportion (15.4%) preferred reverse osmosis (RO) as part of the process. Cost appears to be a lesser consideration and it should be noted that a sizeable proportion of respondents (26%) indicated that they would not drink any PRW in any case (Figure 5.18). Customer perceptions about risks and benefits are addressed more specifically in RQ6, and perceptions regarding PRW for potable use in RQ7.

Table 6.1 Survey responses regarding preferred processing of potable PRW

A multi barrier process including reverse osmosis (RO)	A multi barrier process including biologically activated carbon (BAC)	It does not matter provided the PRW meets the Australian standards	It should be decided on cost provided both meet Australian standards	I would not drink any PRW	I am unsure /don't know
15.4%	2.4%	39.8%	9.8%	26%	16.3%

Economic considerations and Substitution

The incremental cost to process the water beyond that achieved by sewage treatment plants (since upgrades) in the area may not be justified in terms of economics alone, particularly with regard to electricity costs (and this particularly so for reverse osmosis). Electricity use for the BAC process was also higher than anticipated (as per Lane and Lant 2012a), but to some extent this was still less costly than reverse osmosis due to the larger use of 'off peak' electricity (RQ5). At the time of the site visits the output from MDAWTP was exclusively used by the commercial customer, but going forward both plants' output is underutilised. Again, promoting greater use of recycled water increases its viability. The interconnections between the RQs underlines that from a policy perspective, the economics captured by conventional accounting is inadequate for an informed decision, hence consideration of environmental and social externalities (RQ4), and the need for a multi –dimension approach such as TBL.

A TBL approach adds dimensions such as customer perceptions, such as those expressed in Table 6.1, that otherwise may not be considered. Alternative water supplies, such as that from recycled treated wastewater, do help to make water supply in the region more drought resilient, but conversely mean that these facilities may be underutilised in years with higher rainfall. In flood situations this still provides emergency backup for traditional supplies that could be contaminated by floodwaters (as was the case with Tugun desalination plant in 2011), and this connection was acknowledged by respondents in the survey. Expected population increases in the region are predicted to exhaust current water supplies. Locally the Caboolture region already sources water from the wider (dam) system and the ability to substitute for this higher end supply is a major cost benefit for PRW if costs of marginal supply and externalities are considered. If the marginal substitution is the current water supply then, although the price charged to the region is relatively low, the potential ability to defer infrastructure investment such as building new dams is a large saving in terms of actual economic cost and also in terms of environmental and social impact. If the marginal water supply to be replaced is not the current situation (as predictions are that these supplies will be insufficient) then the marginal replacement water would need to be from another source. Currently Unitywater is purchasing water from the South East Queensland water grid for recycled customers while upgrade work is being undertaken, so water sources in the Caboolture area are already at capacity. The most likely alternative increased source is desalination using reverse osmosis. This is likely to be a higher cost alternative even compared to reverse osmosis for treated wastewater, as the higher salt content of the source water increases the electricity demand. It also would need to be transported to the area of need, and pumping and chlorination costs are a major contributor to total cost. In Australia the major population centres are coastal, but agricultural production and drought often occurs further inland as has been the case in Queensland in 2013-14 with coastal SE Queensland less affected than inland rural communities. Treated wastewater recycling is possible to use wherever the need may be (as its source is the population it would serve) and a BAC/ozone treatment suite might be preferable where disposal of brine is problematic (RQ4).

The marginal cost of electricity is also a consideration. Current sources for electricity in South East Queensland are coal fired power plants that consequently have high global warming potential (GWP) as they are carbon intensive (RQ4), and they are also water intensive, so there is a connection between saving electricity and saving water, and electricity production and the need for reliable water supply. Consequently savings in carbon emissions and water use can be most effectively made by promoting alternative sustainable energy sources, which would in turn reduce the cost of recycled water production in actual and environmental terms. The link between electricity and water may not be clearly understood by water customers as only 24.4% of all respondents surveyed agreed at all with the statement that ‘saving energy is more important than saving water’ although the majority (55.9%) agreed to some extent that ‘saving energy is a way of saving water.’ Another possibility is the exploitation of local energy sources, which for an AWTP could be biogas recovery from the adjacent STP, an in Melbourne Water (2015).

Ideally ‘fit for purpose’ use should be made of alternative water supplies. The higher the end use replacement, the higher the benefit, so class A+ could cost effectively be used to supplement potable supplies as well as non-potable uses. At MDAWTP fluctuations in the objectives of the facility meant that the plant was producing on a smaller scale than originally planned and not providing water for indirect potable use, and thus ‘high end’ substitution. Similarly SCWRP was originally intended for indirect potable PRW supply. However the critical factor is consumer demand and customer attitudes and acceptance of PRW for various uses (RQs 6 and 7). Managing stakeholder expectations is also a key aspect of social/political risk in planning for recycled water use relevant to RQ3.

<u>Residential customers RW use and substitution</u>

SCWRP customers for recycled water were primarily dual reticulation non-potable use customers. Indirect potable use was the original intended use for the recycled water from SCWRP and its original failed introduction highlights the effectiveness of key influencers (RQ1) in the form of local lobby groups and the intense media coverage surrounding ‘poo water’ campaigns. The stakeholder analysis, review of media coverage, and interviews revealed how critical the social aspect is for acceptance of recycled water, and potable recycled water in particular. Customer (and potential customer) perceptions and attitudes were explored more fully via direct survey of water users in the region and perceptions considered in more detail in RQs 6 and 7.

Respondents’ perceived level of water use (from any source) for various activities when compared to recent SE Queensland studies of actual use (Beal & Stewart 2011) suggests that households may underestimate their level of water use for taps and toilets and overestimate the percentage used in garden watering. This may have policy implications as saving tap water could be promoted more and assistance given for plumbing toilets to recycled water sources as lack of connection was the most cited reason for not using recycled water for this purpose.

Mains tap water is still overwhelmingly the primary source of drinking water (64%) suggesting that augmentation with PRW would provide savings in use of drinking water (although it remains to be seen whether this would increase bottled water or rainwater drinking use by respondents avoiding a perceived ‘contaminated’ supply).

Respondents generally underestimated their level of household water use (Figure 5.32).

For respondents not using PRW 55.7% had rainwater tanks, as did 20.4% of those respondents with access to PRW. Previous studies have had difficulty estimating the amount of cross-subsidisation of water supplies. In other words, if you provide PRW will it replace mains tap water or some other source, and to what extent? This survey provides evidence that PRW customers continue to use other sources of recycled water including tank water, storm water and grey water. There was some evidence that PRW respondents were using rainwater for closer contact purposes (clothes washing, drinking and cooking). Their supply of PRW was limited to permitted uses for PRW, however supply of potable PRW may lead to much greater levels of substitution, although customer attitudes to its introduction would be critical to this (see RQs 6 and 7). Further research is recommended in this area, particularly studies that measure actual RW use for different purposes for comparison with the perceived use by respondents provided in this study.

The survey examined what households were using recycled water for and the types of recycled water used (Section 5.2.4.3). Households were generally aware of the various sources for recycled water (Table 5.13), and there was limited evidence that respondents already using non potable PRW were also more inclined to use grey water (Table 5.18). The vast majority of all respondents are already using some form of recycled water (77.3% for PRW respondents and 55.4% of other respondents). Analysis of those *not* using RW suggests whilst most were willing to use PRW (71%), a sizeable minority (29%) indicated their non-use to be an active choice. This is of interest to policy-makers, and highlights the social cost of RW use in that perceptions would need to be managed.

Non PRW respondents estimated that they used RW most for garden watering, car washing, clothes washing and then toilet flushing. For PRW respondents the ranking changed to toilet flushing, closely followed by garden watering and car washing (section 5.2.4.4; Figure 5.12). Those not using PRW for toilet flushing (non PRW respondents with rainwater tank or other RW) cited lack of plumbing connection as the reason for not doing so.

Class A+ permitted uses for non-potable use are reportedly - well established and accepted, with most PRW respondents having used the system for more than two years. The level of overall respondent satisfaction (75.8% 'very good' or 'good') (Figure 5.15) was significantly above average on a scale of 1-10 (M = 7.57, SD 2.519 $p < 0.05$) with comments favourable towards its use for toilet flushing, garden watering and to a lesser extent car washing (section 5.2.4.5). A small number (12.5%) of comments regarding pools expressed an interest in using it for this purpose, although 6.3% expressed an aversion to this use. The vast majority of users supported the dual pipe system, with lack of water restrictions, cost savings and concerns over climate change the most cited motives.

Responses from existing users of non-potable PRW regarding the attributes of PRW – *safety as regards germs and chemicals* - elicited a doubtful response from householders (Figure 5.15). Only 17.7% (germs) and 18% (chemicals) of respondents rated the safety as either 'very good' or 'good', a much lower rating than for the mains water where the majority were happy with these attributes. It is - interesting that these are rated similarly, whereas in the scientific community the concern is greater about chemicals. This might reflect the negative media coverage which has tended to concentrate on biological concerns and label recycled water from treated wastewater 'poo water', the so-called 'yuk factor' (Price et al. 2010). Most householders expressed uncertainty as their answer to these attributes. Some comments from survey respondents linked such views to media influence, for example:

> "Adding recycled waste water to the dams is the way to go - no whinging from the public or very little - Just don't let the media turn it into a circus act."

And suggested better management of the media was necessary:

> "A private sector marketing/advertising expert should be engaged. Need a stunt such as using the Australian Swim Team to conduct a meeting in a pool filled with purple recycled water to show it causes no harm."

Certainly the example of Singapore suggests that a more consistent and pro-active approach to managing key influencers makes successful introduction of potable PRW more likely (Lim & Seah 2013).

Split between mains: recycled water usage

Some householders volunteered information about the split of their actual water use between mains and recycled water. This was not directly asked in the survey, and in hindsight perhaps should have been, as the results from these few responses are interesting. They suggest quite marked differences in proportions used of each type of water supply between respondents, ranging from a 90%: 10% recycled water to mains water split to 16%: 84% (Table 5.56). The reasons for this would be worth more detailed investigation.

6.2.4 Research Question 3

RQ 3

- What are the risks of recycling and how can they be managed?

Risks can be economic (running a recycled water facility if there is a lack of demand, the demand being linked to social acceptance) or environmental (the risk of spills or contamination which should be low in a modern electronically monitored plant; monitoring brine released to the river from reverse osmosis) or social/political as a result of lack of public acceptance. These latter costs can be high witnessed in the volte face over the intended use of the Western Corridor Recycled Water Project. Social risk is connected to perceived risk and was specifically addressed in the social aspect of this TBL this thesis via the customer survey. Perceived risk (mostly health concerns) is explored more fully in response to Research Questions 6 and 7.

It was not possible to do a full risk assessment of the two case study AWTPs. However site visits and background research suggested that the risk levels were low (Sections 4.3.1 and 4.3.4). The operation of both plants was observed as efficient, with monitoring and checks in place and at SCWRP separate clearly labelled pipework for residential supply. Both plants were run using a programmable logic controller (PLC), using supervisory control and data acquisition (SCADA). There were multiple test points for water quality throughout the system, and regular flow meters, and the site was clean and well maintained. Human/management error is the most documented cause of risk (to human health and environment), particularly at times of change. Both AWTPs were established operations, although MAWATP at the time of the visits was about to change operator from the original contracted plant operator to the local water authority. However no in-depth human risk assessment was done as part of this thesis, and it is acknowledged that further research in this area would be beneficial (Cloete et al. 2012).

Potential problems in the Queensland bulk water distribution, following amalgamations, were identified with non-integrated SCADA systems in previous research (Cloete, Horberry & Head 2011 & 2012). This was found to be much less likely to occur at a recently commissioned AWTP with highly automated stand-alone SCADA system (Cloete, Horberry & Head 2012). However human risk assessment and management remains essential, as demonstrated by the *E. coli* contamination in Walkerton, Ontario in 2000 from farm runoff which was largely the result of human error and subsequent cover-up (Wu et al.2009). Human error was also a contributing factor in excess fluoride entering the North Pine Dam in Queensland in 2009 when a water treatment plant was shut for maintenance (Fraser 2009; Cloete, Horberry & Head 2012), and also in the spillage of treated sewage and industrial effluent as a result of faulty valves at Bundamba AWTP in 2008 (Roberts 2009). The Bundamba incident was not disclosed until 2009, fuelling public fears about lack of trust. Public perceptions regarding trust in water authorities, and fear of human health risk are examined in the social aspect of this thesis (RQ6 & 7).

There does not appear to be any evidence that an AWTP would be any more likely to have management errors than existing STPs, quite the reverse once established as they are likely to be a more modern construction with advanced automated monitoring system as observed at both AWTPs in this study. Even for potable PRW, presuming the use to be indirect via augmentation of dams/weirs, then the PRW would pass through the same system as normal water supplies and therefore the risk of human error should be the same as that for any potable water supply.

As already noted, demand for potable water in the area exceeds supply and water is imported from the SEQ water grid. The main motivation for the commercial customer at MDAWTP was to manage commercial risk by securing water supply, particularly in times of drought (Collins 2010). Demand risk is also a function of political risk – the political will to introduce and support PRW in light of a perceived problem (potential water shortages) and the reaction of consumers (voters in a democracy). Stability of policy is usually a prerequisite for any successful innovation. Political risk can be high, as demonstrated with the WCRWP. This makes the social aspect of this thesis most pertinent. Customer perceptions and acceptance of PRW are again critical (RQs 6 and 7).

Analysis of respondent perceptions about PRW and potable PRW use revealed majority support but a polarisation of opinions. Principal Component Analysis (PCA) of PRW respondents, for example, (section 5.2.4.7) revealed a minority but potentially significant component Group (Group 6 dubbed 'NEGUseEnvC') (Table 5.26) with negative views on RW use, the environment and prices and lacking trust over regulations/health issues. Assuming a desire to promote PRW use and ultimately potable PRW use, from a policy perspective, there is a need to manage this potential social/political risk (and to promote trust) to avoid the potential of negative minority acting as a lobby group.

Media as an influencer – all respondents (section 5.2.5.5)

Respondents tend to believe that others are influenced by negative media coverage regarding PRW, but that they personally are not. See RQ7.

Political risk is complicated by a perceived negative media influence, and by the number of neutral/undecided/'don't know' responses to survey questions about concerns such as potential health risks of PRW. Just over half of the respondents (52%) believe that they have enough information to make a decision about PRW, which - means that almost half did not have sufficient information regarding PRW (Table 5.35).

Potential further environmental risks are considered in response to RQ4.

6.2.5 Research Question 4

RQ 4

- What information beyond the current economic accounting system is required to provide a full cost accounting or TBL approach? i.e. defining the scope of included externalities

Stakeholder analysis (RQ1 and Figure 4.11) was used to identify areas beyond economic consideration to inform the Triple Bottom Line (TBL) approach, particularly environmental and social costs, or externalities. It helped to identify externalities such as the local users of the two river settings and the environmentally sensitive location of a riparian landscape with improvement in water nutrient levels and estuarine health a key recent (and ongoing) concern of the local Moreton Bay Regional Council and the pressures in the area on the ecosystem as a result of population growth and limited local water supply (Unitywater 2011; Borskjaer 2012).

In terms of environmental considerations the value of replacing or easing pressure on high-end potable water supplies has wider potential benefits within the system, such as the deferment of the need to source alternative supplies. Given that demand for potable water exceeds supply in the local area of the AWTPs, and demand in times of drought in the past had led to severe water restrictions in South East Queensland, an area of high population growth, it is likely that additional water supply sources will be required in the near future. Easing the demand could at least defer the need for such new sources, and the environmental and social costs of alternative additional sources could be very high if they require the building of dams or desalination plants. PRW does present a drought resilient water supply which had the potential to increase water security and aid planning for population increase.

In terms of the case studies in this thesis, the MDAWTP industrial customer cited secure supply source for a water intensive industrial process as a key motivation for using PRW, although a limiting factor was the cost comparison to mains water supply. The local council was also motivated by the benefit to the community of retaining local industry to promote local employment. At MDAWTP the use of 4ML per day of PRW saved the equivalent and reduced pressure on alternative sources. The ability to find a local solution also reduces distribution costs. Imported water incurs increased transportation costs (pumping: electricity & emissions costs; storage & chlorination). This was relevant at the SCWRP plant with demand in local area exceeding supply and the weir at capacity, so additional water needing to be sourced from SEQWater. Ultimately this puts pressure on the system and increasing supply at a ‘bottleneck’ is beneficial in times of drought.

Water security provides benefits to society not included in traditional economic accounting, but which should be considered in the social aspect for TBL. Benefits from business include regional job and food security and the ability to continue using water at times of drought permits continued social use of recreational and institutional spaces and possible associated health benefits for the community. At SCWP non-residential customers include sporting/recreational facilities.

Reduction in demand on mains water supply due to the existence of alternative supply sources could allow dams to be kept at a lower level at times of risk of high rainfall, to permit greater use of these for flood mitigation. Emergency release of water from dams filled to capacity has been a recent source of controversy in Queensland and management of dams is currently under investigation by the Queensland Government (Bailey 2015). In the event of flooding an alternative water supply may also be useful to supplement shortfalls due to inundation and damage to water infrastructure, as was the case in 2011.

It is also possible that there will be benefits from investing in technological innovation often associated with seeking alternative solutions. The BAC processes for treatment of wastewater, for example, are innovative and still being developed (Gerrity et al. 2015; 2014) and have potential application overseas, for example in areas of California also severely drought affected. Climate change predictions suggest that finding such solutions will become an increasing imperative.

In terms of environmental considerations, the motivation for the regional council in supporting the development of both AWTPs was that of reducing outflow nutrient levels into the two riparian catchment areas and thisis borne out by a reduction in waterway nutrient build up (eutrophication) (Daniels et al 2012b; Lane, de Haas & Lant 2012). Subsequent improvements at the adjacent STPs have since reduced that imperative. At SCWRP underutilised purified water is released to the river, which should improve quality and increase healthy flow providing downstream benefits (increasing water flow below the weir), which is a consideration in Moreton Bay Regional Council planning. This has use value to (recreational) river users and non-use value to society.

Materials Flow analysis (Figures 4.12 and 4.13) identified environmental considerations at the two case study plants. Both AWTPS discharged to the river systems. In the case of the RO process this included brine, although proportions of discharge were regulated and timed to match discharge from the STP to avoid salt contamination, and this mix was monitored. Monitored amounts of water treated with chlorine were also discharged from SCWRP. As the quality of the water is higher than from most STPs this is not likely to be a problem. Overall river water quality in Caboolture Catchment and particularly the estuary remain a cause for concern (figures 4.5 and 4.6), as to a lesser extent does Pine River estuary (Figure 4.8) with nutrient and algae concentrations above desired levels. It is hard to isolate causes for changes in river and estuarine water quality given the number of users, and increased residential and commercial development, and further research is required to determine this (Sections 4.3.2 and 4.3.4).

The largest environmental impact was from emissions from electricity use and chemical use (carbon footprint). The RO process has higher electricity use for processing (although it was perceived as a higher quality product and is more possible to tailor to customer needs e.g. commercial). At the time of this study when supplying one local commercial customer the energy needs for distribution were lower (direct to one local customer) than would be required for residential indirect potable use. In the BAC processing at SCWRP the highest processing electricity use was for pumps, although variable speed pumps were fitted. The highest pumping use is distribution to residential customers (commercial tankers collect at site). The environmental impact from electricity depends on source. Current electricity supply in QLD is primarily coal-powered, which is emissions intensive and has high water use (although currently supplemented by PRW). There is therefore an incentive to seek alternative energy sources. Biogas retrieval from STPs for use in process is currently being researched and trialled in Melbourne. Again, innovation in technology in alternative power sources can provide social benefits. The benefit of having decentralised water sources (to reduce transportation) and the available supply for wastewater recycling makes PRW in inland areas more prone to drought an attractive option. Given the current unprecedented high levels of inland drought declared regions in Queensland, in key agricultural producing areas, investment in potential localised water solutions is a planning imperative. RO is possibly less attractive as an inland option due to the production of brine residue.

To a lesser extent fugitive emissions were also a concern, (Methane (CH_4) and Carbon Dioxide (CO_2) and Nitrous Oxide (N_2O)), although at a much lower level than the neighbouring STPs, which offer the best opportunity to reduce the entity's footprint (section 4.5.2) (Lane, de Haas & Lant 2011; Lane & Lant 2012b). As mentioned, there is the possibility of capturing fugitive emissions, such as the use of lagoon covers at Melbourne Water's Western Treatment Plant, where these have halved their greenhouse gas emissions and enabled methane gas capture to provide biogas energy (Melbourne Water 2015). Fugitive emissions should not be ignored given the severe Global Warming Potential (GWP) in terms of ozone depletion of N_2O. Fugitive emissions are also a possible issue with dams (potentially avoided by increased PRW substitution and deferred dam construction) but research into emissions is generally lacking. SCWRP had invested in an ozone destructor to eliminate ozone emissions (Figure 4.7).

In terms of emissions, seeking alternative power generation provides the greatest potential reduction at both AWTPs. Combining water infrastructure with investment in alternative energy is one solution. Saudi Arabia, for example, announced a plan in

2012 to build three solar powered desalination plants (Lack 2012). Sydney's desalination plant sources energy from a purpose-built wind farm at Bungendore (Sydney Water 2014). Western Australia also sources energy for a Perth desalination plant from Emu Downs Wind Farm (Water Technology 2014).

<u>Respondent perspective on externalities – environmental concerns</u>

General views about water scarcity and a willingness to conserve water suggested that externalities *do* have value in the eyes of the customers. A large majority of respondents were concerned about water shortages (81%) and open to the idea of alternative water sources (83.2%) (Figure 5.5) and agreed (76.4%) that historically water in Australia is a scarce resource (Figure 5.23) The vast majority had already taken steps to conserve water in the home with the use of water efficient domestic devices (Figure 5.4).

PRW user responses to Likert questions about their perceptions (Table 5.23) on various issues showed that 89% of respondents agreed to some extent (74% strongly) that they enjoyed 'living in a community that actively contributes to environmental sustainability' and 68% agreed that they were concerned about climate change, although they were less inclined to pay for this with 42% agreeing that the 'environmental benefits of dual water supply are more important than financial benefits' (although only 24% disagree; 34% unsure). 42% also agreed that the PRW system added value to their property (47% unsure; 11 disagreed).

6.2.6 Research Question 5

RQ 5

- Are the two methods of producing Class A+ recycled water as identified in the two case studies equivalent, or is there a preferred method?

In terms of public perception, as mentioned, reverse osmosis (RO) appears to be the preferred treatment process according to residential customer respondents, for those expressing a preference, although the largest proportion (39.8%) (Table 6.1) did not think that the process mattered provided Australian standards were met. RO is doubtless better known as a process due to extensive media coverage in Queensland of the WCRWP, and because it is the process associated with desalination plants producing RW from sea water, and this is a more accepted source for replenishment of potable water, without the perceived ‘yuk’ factor of potable PRW. In terms of public perception, source appears to be more of an issue then process.

In terms of industrial customer perception, the ability to tailor the PRW product (e.g. for lower salt content) make some customers prefer RO. In interview it was also stated that some SCWRP commercial customers prefer higher nutrient (nitrate) levels and do not wish to improve processing e.g. for irrigation (Unitywater staff 2010, pers. comm., 27 September) – although environmentally there is a risk of increased agricultural nutrient high run-off. Commercial motivations for PRW adoption is an area requiring more detailed research.

In terms of substitution for indirect potable water use, RO is the method used in desalination plants and the WCRWP capable of producing indirect potable use standard water, and there is evidence that the BAC method stream could potentially be used in terms of ability to meet water standards (Reungoat et al. 2010a; Gerrity et al. 2014), although this is more likely to be readily achieved by the RO process. The highest cost in economic and environmental footprint terms is the energy use, and for RO processing this is significantly higher, although energy was a high cost for both. Sourcing alternative energy would therefore be advantageous, as would avoiding long-distance distribution. To this end PRW provision close to the intended user (a localised solution) might be preferable e.g. close to an industrial user; or for residential supply it is lower cost to pipe to a dam/weir for indirect potable use than to residential customers for non-potable use via a second supply. In terms of replacing potable water any PRW use (potable or non-potable) can be beneficial to relieve a bottleneck or secure drought resilient water supplies. This is useful in more rural areas where distance makes transportation costly. BAC processing would be preferable to RO in a rural setting if disposal of brine residue is a concern. For residential consumers further research is needed to confirm actual use for various activities. It is possible that availability of PRW could encourage increased use e.g. for garden purposes, although this has a potential social benefit in terms of recreation and ‘liveability’ of cities.

6.2.7 Research Question 6

.

RQ 6

- What are the perceived benefits and risks (costs) of recycled water use for customers?

The social aspect of this thesis was the area where relevant information from previous research was most lacking. The customer survey in this thesis obtained information on respondent use of RW (RQ2) and respondent perspectives on perceived benefits and risks of RW (RQ6), and attitudes towards indirect potable PRW use (RQ7).

Summary:

Perceived benefits of PRW include: Lack of water restrictions; cost savings; environmental benefits and to a lesser extent added value to their property.

Perceived risks/costs of PRW include: Perceived health risks regarding chemicals and germs in PRW. Lesser complaints regarding smell and about residue left after car washing. Trust issues demonstrated to some extent with water authority and more so with water regulations.

Influences on these: Price/cost to respondent a consideration (even for those interested in drought proofing); Negative media; lack of information on RPW.

Benefits – Commercial customer

As mentioned, the commercial customer at MDAWTP saw the benefit of a secure water supply for a water-intensive process (i.e. managing business risk) and consulted with customers but did not find customer objections to be a factor (Collins 2010). The ability of the MDAWTP to 'tailor' the water quality/attributes to suit the client, particularly in regards to low salt content, was an attraction (Unitywater staff 2010, pers. comm., 27 September). Further the commercial customer advertised on their website and in published reports that this reduced the Mill's consumption of potable town water by 90% (Collins 2010), and therefore saw a CSR and reputational value in PRW use.

Residential – survey results

Benefits: *Overall satisfaction with current uses of PRW*
Significantly above average levels of overall satisfaction (79%) with PRW supply were expressed by PRW respondents (Figure 5.15), regardless of gender.

Benefits: *environmental issues and water shortages – all respondents (section 5.2.3.2)*

In general households are not environmentally active in terms of participation in any environmental group (13.2% only) but overwhelmingly they express some level of concern regarding water supply shortages (81%) and have considered alternative sources of water (83.2%) (Figure 5.5). This concern does not appear to be related to either age or gender (Tables 5.7 and 5.8), but appeared to be influenced by education level (Table 5.10) and the majority of respondents in the survey also indicated that they would like more information about the costs of recycled water.

A significant majority (76.4%) of respondents agreed that historically water in Australia is a scarce resource (Figure 5.23). This attitude was evidenced by widespread use of water efficient devices, particularly dual flush toilets (92.7%) and water efficient shower heads (82.3%) (Figure 5.4).

Benefits and risks (PRW respondents): *Acceptance of RW for non-potable uses – but concern about risks of germs/chemicals*

A large majority of all respondents are already using some form of recycled water (77.3% for PRW respondents and 55.4% of other respondents) (section 5.2.4.3). Analysis of those *not* using RW suggests whilst most were willing to use PRW (71%), a sizeable minority (29%) indicated their non-use to be an active choice. This is of interest to policy-makers, and highlights the social cost of RW use in that perceptions would need to be managed.

Responses from existing users of non-potable PRW regarding the attributes of PRW showed a clear majority of PRW respondents (75.8%) rated the *overall* quality of their

PRW supply as either ‘very good’ (25.8%) or ‘good (50%)’ (Figure 5.14). The majority of householders were also satisfied as regards colour and smell but the vast majority answered ‘don’t know’ about the less demonstrable aspects of safety as regards germs (73%) and chemicals (74%), a much lower rating than for the mains water where the majority were happy with these attributes. This indicates a lack of trust in the system in this regard, even though overwhelmingly respondents were using the PRW for recommended non-potable uses, and explains the reluctance to use PRW for closer contact uses. Unlike previous studies, the data indicated that experience in the use of PRW for non-potable purposes did not make respondents more (or less) inclined to accept indirect potable use of PRW.

The majority of PRW respondents’ comments about using the PRW for non-potable purposes were positive (Table 5.22), mostly regarding toilet flushing, garden watering and car washing (also lack of restrictions and better than wasting drinking water supplies). Most negative comments regarded concerns over chemicals or germs, smell and staining of toilet bowl or residue left after cash washing, and there were mixed comments regarding price.

PRW respondents were asked a to indicate whether they agreed or disagreed on a 5 point Likert scale with eighteen (18) questions designed to indicate their attitudes towards recycled water, their motivations for using it, and to explore their attitudes (Table 5.23). Initial analysis showed that the majority of users had a ‘positive’ attitude towards the use of recycled water and the results are internally consistent.

Benefits: environmental issues– PRW respondents (Table 5.23)

As already mentioned with regard to RQ4, PRW responses showed that 89% agreed to some extent (74% strongly) that they enjoyed ‘living in a community that actively contributes to environmental sustainability’ and 68% agreed that they were concerned about climate change. and 42% thought it added value to their property (47% unsure; 11 disagreed).

Benefits: environmental issues– All respondents (Figure 5.20; Table 5.35)

Generally respondents agree that floods cause water supply problems, that droughts were likely to recur and that climate change is of concern to them (Figure 5.20).

Benefits: economic– PRW respondents (Table 5.23)

- 69% agreed to some extent that 'I save money by using recycled water'
- 42% of PRW respondents thought availability of PRW added value to their property (47% unsure; 11 disagreed).

Benefits: secure supply

A large majority (73%) of PRW respondents (Table 5.23) agreed that the PRW should not be subject to water restrictions and 64% of all respondents agreed (Table 5.35).

Potential risks (PRW respondents): Trust in the system and concerns (Table 5.23)

A number of questions were aimed at exploring the trust (or lack of it) in the *safety* of the PRW supply and the *trust* in the authorities providing it.

Overwhelmingly PRW respondents were happy with the operation of the PRW system (84%) and 66% indicated that they 'trust the water authority to ensure recycled water quality' (19% disagreed), support dropping again slightly to 63% with the statement that there is 'adequate regulation to ensure safe use of recycled water' (13% disagreed).

Again respondent concerns centred on potential health risks with 45% agreeing that they were confident 'there are no health risks associated with the dual water supply system', 29% unsure and 26% disagreeing. The data indicated that is the risk issue that polarises opinion, and where there is a much higher level of uncertainty (undecided respondents) regarding health impacts.

Exploratory principal components analysis (PCA) (section 5.2.4.7) was used to reduce the 19 question data set of PRW responses to a manageable size and to attempt to identify clusters of variables that may be driven by the same underlying variable. The analysis suggested six PRW respondent groupings or components, where respondents held a similar set of views, and these groupings explained 70% of the variance, indicating relatively robust results (Table 5.26):

GROUP: Demonstrated attributes

1. POStrust: Positive with regard to the PRW system, trust in the authorities and water regulation, less concerned over health risks, believe in the environmental benefits of the scheme (30% explanatory factor).
2. TRAD: 'Traditionalist' historic view of the water system with recycled water significantly cheaper than non-recycled water and not subject to water restrictions. This group is concerned about cost and availability and has no other concerns i.e. not opposed to PRW except on cost (11% explanatory factor).
3. QUAL: Value quality in PRW and are willing to pay for this (8.5%).
4. NEGEnvC: Negative about environmental benefits, not concerned regarding climate change, unwilling to pay for recycled water (7.5%).
5. POSInvest: Positive towards the system due to cost savings and adding value to their property (7%).
6. NEGUseEnvC: Prefer *not* to have dual water supply and avoid using it, disagree that it saved money, believe it may have a negative environmental impact (also some fears regarding health risks) (6%).

Despite majority support for PRW use for non-potable use amongst existing PRW use respondents, there does exist some polarisation of opinion, with the largest explanatory component exhibiting trust (POSTrust - 30% explanatory) but a significant minority component (NEGUseEnvC – 6%) at the other end of the spectrum and entirely negative. These perceived risks were explored further with questions aimed at all respondents (Table 5.35).

Potential risks (All respondents): Trust in the system and concerns (section 5.2.5.3)

Again results for all respondents exhibit some polarisation of opinion. That is to say acceptance of PRW use does not decline evenly from a position of acceptance, through a non-committed stance, towards a gradual decline in acceptance. A large majority of users support the non-potable PRW scheme but the minority who do not are at the other extreme and oppose it strongly on a number of grounds. This indicates that influencers such as lobby groups have potential support (RQ1). This split became more pronounced when respondents were asked about potable PRW use.

The vast majority agree that the present water quality system in Queensland is good (73.8%) but the level of agreement fell regarding trust in scientific evidence (57.5%) and the likelihood of an incident leading to a health risk from PRW (57.5%) and slightly again when a specific reference to Australia was added i.e. 'I do not think it likely in Australia that there would be an incident using Purified Recycled Water that would lead to a serious health risk' (44.1%). If respondents think that the risk of an incident is higher in Australia than overseas then this would rationalise a reluctance to use potable PRW in Australia despite successful use overseas. They were most uncertain about 'human interference in the natural water cycle' (Table 5.35). General comments on this subject included 'I don't feel comfortable with PRW as there is no guarantee that all impurities including drugs are purified sufficiently for safe human consumption' and 'I support the use of recycled water for cleaning & certain household uses, garden & outside & commercial use, but I am concerned about health risks re drinking recycled water, cooking etc.'

Views about the benefits and risks of PRW (All respondents)

Exploratory principal axis factoring of the 24 questions asked of all respondents (Table 5.35) grouped responses into 5 factors, although the explanatory power was not - strong at 43% of the total variance explained (Table 5.37). The 5 factors/groups (Table 5.36) and their attributes were:

1. TustHealthNeed: trust the scientific evidence, think people are influenced by negative media, think the health risk is small, expect future droughts and agree that PRW is needed to ensure a constant water supply (23% explanatory).
2. HighUse: high volume users who doubted droughts would recur (a justification for high use) (8%).
3. MediaInfo: those who felt that they had been influenced themselves by negative media and needed more information (4.4%)
4. EnergyRWCC: awareness of the link between electricity and water use in SE QLD, concern about climate change, a desire to conserve water (and a belief that droughts will recur) (3.6%).

5. ProAdv: positive attitude towards the advantages of PRW, an acceptance that PRW needs to cover its costs, agreement that floods damage water infrastructure and approval of the current QLD water quality system (3.4%).

This sheds light on the attitudes of the key stakeholders (RQ1) and confirms that among all respondents many agree that PRW provides increased drought security and are concerned about this in the light of environmental issues such as climate change, some trust the QLD water authority system. It also shows (as with climate change!) that groups also believe that using PRW is unnecessary because droughts are not likely to recur. There is also a section of respondents who are undecided on the issue and feel that they lack sufficient information.

Views about the perceived costs of PRW (All respondents)

The vast majority of respondents were in favour of different pricing tiers, and a greater weighting on variable charges rather than fixed charges, so that larger volume water users pay more. Oddly respondents had less belief in the link between price and customer behaviour, or that charging more for water would reduce use and subsidisation encourage use (Figure 5.24). This may be partially explained by the fact that households appear to underestimate their own water use (63% agree that that their household used less than the average amount per day in their area) and a comparison with self –assessed usage and actual usage reported by respondents from their water bill demonstrated that households were poor at estimating their water usage and tended to underestimate it (Figure 5.33). This belief would mean that they could expect to benefit from pricing system that had a lower proportion of fixed costs and penalised higher users.

When asked to suggest a fair price per kl for mains and PRW (non-potable) most struggled to do so or declined to, however all appeared to agree that PRW should be less (and generally significantly less) than mains water, and most would use non-potable PRW if it was cheaper than mains. Cost also appeared more of a factor in deciding to drink potable PRW than drought resistance (Figure 5.26).

6.2.8 Research Question 7

RQ 7 • What factors influence customer acceptance of PRW for potable use?

Source more important than process

Residential respondents were asked (after a brief explanation regarding the processes) how they would prefer that PRW be processed and although the largest proportion (39.8%) (Table 6.1) did not think that the process mattered provided Australian standards were met, of those that expressed a preference a larger proportion (15.4%) preferred reverse osmosis (RO) as part of the process. Cost appears to be a lesser consideration and it should be noted that a sizeable proportion of respondents (26%) indicated that they would not drink *any* PRW in any case (Figure 5.18).

This is in accord with previous research findings that acceptance of the use of recycled water decreases as the use becomes more personal, and is influenced most by the source of the recycled water, with a preference for storm water or grey water harvesting over recycled waste water (Hurlimann 2007; Marks, Martin & Zadoroznyj 2006; 2008).

PRW respondents' attributes relevant to accepting/ rejecting potable PRW use (Trust)

In the analysis of RQ6 above it was mentioned that PRW respondents responded to Likert scale questions (Table 5.23) about their perceptions of PRW use and that the results were analysed using principal component analysis (PCA) to identify groups of respondents with similar attributes (i.e. responding in a similar fashion to each other on a group of questions), and six component Groups were identified (Table 5.24).

Research Question 7 had the objective if identifying factors that may influence customer acceptance of PRW for potable use. Further analysis was therefore undertaken using independent-samples t-tests to see if any of the 6 'component' Groups identified were associated with a willingness to accept/reject using PRW for indirect *potable* use (section 5.2.4.7). The aim was to identify attributes related to the willingness to accept (or reject) the idea of using PRW for indirect potable (drinking) use e.g. How important is a customer's trust in the system for determining if he/she will accept PRW for potable use? Are PRW respondents from Component Group 1 'POSTust' more or less likely to accept the use of PRW for potable water? (Figure 5.17). (Group 1 'POSTust'attributes: trust the scientific evidence, think people are influenced by negative media, think the health risk is small, expect future droughts and agree that constant supply is an advantage of potable PRW).

The analysis found evidence to support the view that PRW respondents with the 'POSTust' attribute are more likely to accept PRW for indirect potable use (Figure 5.17), but there were no other significant associations with acceptance and other attribute/components. As would be expected, the respondents with the most negative component attribute Group 6 'NEGUseEnvC' who were opposed to PRW use for non-potable purposes, who distrusted the regulatory system, doubted the environmental benefits and expressed concern regarding cost and health risks, were significantly more likely to reject PRW for indirect potable use as well.

Potable PRW support – majority of all respondents

In the last section of the survey, aimed at all respondents (both PRW respondent s and other respondents in the same area) respondents were asked if, during water restrictions, they would support the use of PRW for indirect drinking water use and again a majority at 59.1% said yes that they would support it, with 15% undecided but 26% saying no that they would not support it (Figure 5.18).

Contrary to previous research at Mawson Lakes which suggested that support for using (and drinking) recycled water increases with positive experience of using recycled water for non-drinking purposes (Hurlimann & McKay 2006), no difference was found in in this thesis' survey between existing non-potable PRW respondents and other respondents in their response to - supporting/rejecting potable PRW use.

This suggests that although indirect PRW may have majority support, there remain significant proportions of the population both undecided and opposed to the scheme. As noted, when asked about their preferred method of processing for potable PRW, 26% indicated that it was not relevant as they would not drink *any* recycled water. Respondents were encouraged to make any other comments they wished about recycled water, and 22 comments supported the use of non-potable PRW but only half also supported its potable use, three of these as a result of overseas experience of its use.

Prior research indicated that the social aspect of recycling schemes for drinking water is likely to be most prominent, including a ‘yuk factor’ or strong reaction to the suggestion of recycled effluent (Po, Kaercher & Nancarrow 2003; Marks, Martin & Zadoroznyj 2008). This reaction to recycled water is influenced by culture (social conditioning) where origin of the water and the name given to the water source (‘recycled water’ not ‘treated wastewater’ (Menegaki et al. 2009)) strongly determine reactions, and by the psychology of ‘disgust’ provoking irrational responses (Prevos 2013; Russell & Lux 2009). This research confirms that there is a social acceptance hurdle for treated wastewater, based on perceptions rather than science, and social norms, that needs to be addressed before acceptance is likely. However the survey results in this thesis also show that this is now clearly a minority view, and taking into account the number of ‘don’t know’ or undecided responses, and the significant expression of a desire for more information on potable PRW from respondents, it indicates that views may be changing and that better information could be provided to counter perceived negative media influences.

Perceived risks of indirect potable PRW use – all respondents

Reluctance to use PRW for indirect potable use may be associated with perceived risks of this choice. The identification of risks and attitudes to risk is also relevant for Research Question 6.

All survey respondents were asked directly about their perceived risk of various uses on drinking water standard (potable) PRW on a scale from 1 (no risk) – to 10 (extreme risk) (Table 5.34). The only uses where the mean score was above 5 (medium risk) were dinking indirectly (5.23) and directly (5.9). No use received a mean rating higher than a medium risk, but again opinions were polarised. In common with previous studies (Hurlimann 2007; Marks, Martin & Zadoroznyj 2006; 2008), acceptance of the use of recycled water decreased as the use became more personal.

This would not explain the *strength* of past opposition to the introduction of indirect potable use of PRW in Caboolture, although this could be due to changing attitudes over time. The dispersion of perceived risk scores (standard deviation) dramatically increases as close contact increases, starting with vegetable growing where the responses in the two largest categories are (0) no risk (37.4%) and (10) extreme risk (11.4%). A similar polarisation of results is seen with washing hands and showering. For the dinking uses (indirect and direct) the largest categories were (10) extreme risk (25% & 32.8%) and low risk (1) (16.9% & 12.8%). The spread of opinions is greatest for these four close contact categories as well – shower standard deviation 3.929, drink directly SD 3.835, drink indirectly SD 3.824 and wash hands SD 3.724. Perceptions of risk are therefore both more diverse and more polarised on these categories. There was no significant difference in perceptions of risk for potable PRW between respondents using non-potable PRW and other respondents.

Once again it is this polarisation, and the strength of negative opinion held by the minority opposition, that are key.

Media influence – all respondents

As suggested by previous research on the 'third-person effect' (Davison 1983; McLeod, Eveland & Nathanson 1997) respondents tend to believe that others are influenced by the media, but that they personally are not. A clear majority of respondents (66%) did agree that negative media coverage regarding PRW influenced the public (9% disagreed; 24% uncertain), but most respondents did *not* agree that negative media coverage regarding PRW influenced them personally (only 23% agreed). This has relevance to RQ1 (media as an influencer) and RQ3 (social/political risk).

Lack of information about PRW – all respondents

Given the large number of neutral/undecided/'don't know' responses to survey questions about concerns such as potential health risks of PRW, a lack of information on the subject was indicated. When asked, just over half of all respondents (52%) believed that they had enough information to make a decision about PRW, which means that almost half did not (Table 5.35).

The influence of customer cost/price for potable PRW– all respondents

Cost also appeared more of a factor in deciding to drink potable PRW than drought resistance (Figure 5.26).

6.3 The research problem

The research problem asked *how* a TBL costing model could be developed for full costing of Class A+ purified recycled water. In answering this the methods used to gather information for the TBL aspects form as much part of the answer to the research problem as the model itself. To this end the 'research journey' was also fully described over two results chapters in order to explain the multi-disciplinary approach and how each provided method acquired information pertinent to answering the research questions and building the model. Chapter 4 concentrated on site visits, interviews and stakeholder analysis, research and environmental management techniques applied. Each section included a summary of the relevant information obtained from these methods to address the research questions. Chapter 4 results were primarily concerned with economic and environmental aspects and preliminary social results. The social perspective was more fully explored via the customer survey, and these results were presented in Chapter 5. Together they explained the 'how' TBL information was obtained in these case studies. Addressing the research questions was the next step in refining the information to build a costing model and address the research problem costing model. Chapters Four and Five therefore outlined the results under the aspects relevant to a Triple Bottom Line approach – economic, environmental and social. This provided the information for the summary model in Figure 6.1, which was the stated aim of the Research problem.

RP1

- **How can a triple bottom line approach be used to provide a costing model for the full cost of Class A+ recycled water for use in South East Queensland?**

<u>Economic aspect summary (section 4.4)</u>

For the economic aspect it was suggested that in addition to traditional operational accounting information an Activity Based Costing (ABC) approach be attempted and process diagrams used to identify activities (Figures 4.7 and 4.10). Difficulties found in costing the advanced water treatment plants were highlighted, such as separation of costs and activities between the treatment plant and the adjacent waste water/sewage treatment facility (STP) and adequate metering for separation of electricity costs. High fixed costs require sufficient scale of output and customer base to cover these, which can be difficult for an early technological innovator. The interaction between TBL aspects becomes clear – as the development of a customer base for an innovation requires a long-term perspective and management of key stakeholders (RQ1).

Environmental aspect summary (section 4.5)

For the environmental aspect the approach suggested was to use the process diagrams to prepare materials flow analysis for inputs and outputs to the processes. This can be used to assess external impacts (RQ4) (e.g. discharge to a river) and identify emissions and carbon footprints of inputs and outputs (Figures 4.12 and 4.13). Stakeholder analysis aids in assessing the likely impacts of the plant's activities and influences on them (such as the regulatory and governance regimes) (RQ1). Site visits, interviews and review of prior research also helped to identify risks (RQ3). This process also highlighted the type of information and interaction with other areas of the organisation (e.g. process engineers) necessary to obtain sufficient information for an environmental assessment. Comparison of the processes allows for consideration of a preferred process for PRW, but the choice of process can be be location and customer specific (RQ 5).

Prior research has established that scope 1 fugitive emissions, although much lower for the AWTPS than the adjacent STPs, should be considered, but information for doing so is lacking (Lane, de Haas & Lant 2011; Lane & Lant 2012b). Scope 2 emissions are dominated by power use of the facility, and hence also dependent on the marginal power source (in QLD mostly coal-powered power generation) (Lane, de Haas & Lant 2012). Chemical usage is not insignificant and scope 3 emissions stem generally from the production of the chemicals (Lane, de Haas & Lant 2012). For MDAWTP there is also brine release to the Pine River. Upgrades to both treatment facilities and construction of each AWTP were motivated by a desire to improve the quality and reduce the quantity of effluent released to the two catchments, and water quality in the catchment areas has been prioritised, possibly with the result of transferring some of the environmental impact to land rather than water catchments e.g. by the use of PRW for irrigation.

If externalities are considered (RQ4) then it can be argued that any negative environmental impact is offset by avoidance of other large-scale capital water projects such as additional dams or the marginal cost of the assumed water substitution (particularly if this water is from a desalination facility)(Lane, de Haas & Lant 2012). Estimating how far PRW displaces other water sources, and which they are is difficult without further research. The results of the social aspect of this thesis suggest that households with PRW continue to use other recycled water sources such as rainwater tanks. Other externalities to consider include:

- long-term security of water supply, particularly in times of drought and also flood damage to other facilities.
- Health risks in terms of malfunction or cross-contamination of water supply.
- Reduced transportation involved in a local solution.
- Recreational use of dams and their availability for flood mitigation.
- Recreational use of other green spaces which can continue to be watered

Social aspect summary

The social aspect of the TBL approach was the one least addressed by prior research and a major motivation in undertaking this thesis to add this aspect to the model. This is addressed in this thesis via interviews, literature review and by stakeholder analysis (Chapter 4) and directly by survey of customers (both using PRW and not) (Chapter 5). The socio-political cost in the history of water supply development in Queensland has been very high. The survey instrument was designed to explore all of the research questions and results for this were reported separately in detail in Chapters 4 and 5 (with a results summary at the end of Chapter 5). Summary findings are discussed in section 6.2 above, and are summarised in the model in Figure 6.1.

6.4 Contribution and implications for theory

The aim of this thesis is to suggest a model for a TBL approach to full costing of Class A+ recycled water as applicable to South East Queensland. To his end two case study Advanced Water Treatment Plants (AWTPs) in South East Queensland (SEQ), which both recycle water to Class A+ (potential indirect potable use quality), were used to build and inform the model. A TBL approach has not been previously been applied to an Advanced Water Treatment Plant, much less a comparative case study of two plants, although individual aspects have been investigated (environmental and economic). The synthesis of information from a variety of disciplines to form the combined model is therefore innovative, and makes a contribution towards sustainability accounting and the theories that underpin it, such as stakeholder analysis and management accounting techniques such a materials flow cost analysis. The need for a cross-disciplinary approach is a difficult aspect of sustainability research studies, and is one reason why such research is comparatively rare (Chalmers, Godfrey & Potter 2012). Single aspects of TBL e.g. an economic study or an environmental impact study (generally taking an engineering approach) are recent developments, but more frequent, for example process engineering studies of recycled water quality (Reungoat et al. 2012a) or an engineering approach to Life cycle analysis (Lane, de Haas and Lant 2012; Lane & Lant 2012a & 2012b). The summary TBL model is presented in Figure 6.1. As far as the author is aware, such a study has not been undertaken on a recycled water system in Australia, where it has simultaneously been tied in to a Triple Bottom Line model for recycled water supply. The entire field of water measurement is innovative in Australia and little has been done from a management accounting (rather than a purely engineering) viewpoint.

The thesis contributes to the current literature in this area by adding several perspectives and by adding depth because it is applied to two comparative case studies, and is unique in that both are located in the same water management system/authority and similar catchment areas, in the same time frame and the social aspect of the study looks at customers in the same geographical area, again in a matching time frame. Research Question 1 addressed stakeholder analysis and the system setting of recycled water in SE Queensland. A review of the structural changes to water management in

SE Queensland was undertaken as part of the background research and literature review and the political and economic cost, and implications for consistent recycled water policy were highlighted. Key stakeholders were identified by research, interviews, and site visits and mapped in Figure 4.11 in order to identify the three TBL aspects and identify the customer perspectives that need to be examined.

The social aspect was the area identified as least researched in prior literature. A major contribution to customer perceptions in the area of recycled water was therefore made via interviews and in particular a survey of water customers in the same water authority area, with two groups, one having PRW available and the other a sample of non PRW customers. This social aspect is crucial to stakeholder management and to an understanding of the reasons for reluctance to adopt potable recycled water, particularly from a recycled wastewater source. It also touches on the willingness to pay for water services in general, and for recycled water in particular.

Lane, de Has & Lant 2012 also noted a lack of data on the interaction between water sources (mains water and different sources of recycled water) from a customer perspective. How far does the use of recycled water replace mains water use and would Purified Recycled Wastewater (PRW) be a substitute for rainwater tanks? What are accepted uses from a customer perspective? The social aspect of this thesis throws some light on the first of these questions, and specifically addresses the second. Research Question 2 addressed how recycled water was defined by the water authority (Fig 4.4) and in terms of customer perceptions by examining respondent awareness of recycled water (RW) sources (generally high), and their use of various RW sources (mostly PRW and rainwater tanks), and by examining respondent uses for their recycled water, and the difference in these between PRW respondents (high uses toilets, garden, cars) and respondents who had no PRW available (high use garden, cars, clothes) was mostly lack of toilet use for non PRW respondents due to plumbing issues. It was noted that a significant number of PRW respondents also had rainwater tanks and rainwater was being used for higher-end (more personal) RW uses such as clothes washing and drinking. The research specifically examined customer perceptions about acceptable uses, for both non-potable and potable PRW, a noted gap in the literature (Lane, de Has & Lant 2012). Research Question 6 addressed customer perceptions about the risks and benefits of RW/PRW, and RQ7 examined the factors influencing acceptance on potable PRW. The survey gauged support for both PRW and non-PRW and identified that while the non-potable PRW was well supported, provided the price was acceptable (less than potable and mains water), potable PRW despite theoretical majority support also left many respondents undecided about potential health risks, and wanting further information, and potable PRW suffered from perceived negative media information. Trust in the water regulations and science played a key role, as did environmental considerations and drought proofing to a lesser extent. The polarisation of respondent views in the responses was also noted.

The survey on customer perceptions also provides insight into the historical resistance to the idea of 'user pays' and the perception that water is a cost-free or at least a low-cost commodity. Certainly some respondent comments still exhibited this view, and the factor analysis identified it as a minority view characterising a 'traditional' view of readily available, low cost supply. This was a minority view, however, although all respondents were cost-conscious, even those with greater interest in environmental concerns. As most respondents when asked 'pegged' their water pricing to slightly less than the next 'higher' alternative (PRW less than potable PRW, less than mains water) then subsidisation of prices for mains water will have an undesirable knock-on effect. This results of this study indicate that the greatest opportunity to reduce the economic and environmental costs of PRW is to reduce electricity costs. These could be achieved by the use of clean technology and location of the facility near to the distribution base, due to the high transportation cost. This makes substitution for potable water use the best outcome e.g. by feeding into a nearby dam (localised solution) to minimise distribution costs. These have policy implications such as the pricing of mains water and its interaction with customer acceptance of PRW and decisions regarding the scale, location and method of processing PRW.

6.5 Implications for policy and practice

The inclusion of the third TBL aspect – the social aspect – is a key contribution as it also addresses a research gap and comprehension of the social dimension of recycled water use has implications for policy and planning in Queensland. The Queensland setting provides evidence of previous mismatches between planning/intended outcomes and results. A striking example is the Western Corridor Recycled Water Project in Southeast Queensland. As originally designed, it envisaged a closed loop supply chain, with greatest benefit in terms of maximisation of the water supply. However public resistance to, and concerns about, the idea of recycled potable water prevented its full implementation, resulting in considerable political and economic costs. There is clearly a perception issue surrounding the use of recycled water, and a negative media influence to counter with greater provision of information.

The social aspect research of the thesis also suggested that whilst both non-potable and potable PRW had majority support, there existed both a significant number of undecided respondents (particularly regarding potable use and health concerns) and a desire for more information. Trust in the system plays an important role. There also exists a polarisation of opinion, especially for potable PRW use, with a significant minority strongly opposed. Analysis of respondent perceptions about PRW and potable PRW use revealed majority support but a polarisation of opinions. Principal Component Analysis (PCA) of PRW respondents, for example, (section 5.2.4.7) revealed a minority but potentially significant component Group (Group 6 dubbed 'NEGUseEnvC') (Tables 5.24 & 5.32) with negative views on RW use, the environment and prices and lacking trust over regulations/health issues. Assuming a desire to promote PRW use and ultimately potable PRW use in order to find less rainfall dependant water supply sources (Garnaut 2008, 2011; Wong 2008), from a policy perspective there is a need to manage this potential social/political risk (and to promote trust) to avoid the potential of a negative minority acting as a lobby group.

There was some suggestion that attitudes can be changed even in the short time, and that experience of potable water use (e.g. overseas) increased trust and the example of the information management surrounding the introduction of potable PRW in Singapore suggests that stakeholder management is possible.

The model also provides a starting point for moving towards full cost pricing or user pays for water customers, but suggests ceilings in prices based on other water sources available, which has implications for water pricing policies that subsidise mains water supply prices. The model helps to provide a broader perspective on the true costs and benefits of RW supply, and hence inform decision making e.g. about economies of scale, location of PRW sources, and investment in technologies to reduce the electricity costs (such as use of biogas). This is highlighted by the comparison between the two AWTPs (RQ5), with each PRW source possibly being attractive to different customers, or preferred for differing locations (due to proximity to sea/river for brine release; proximity to customer for reduction in distribution costs; ability to tailor supply to suit customer needs).

6.6 Limitations

Economic

The major limitation was one of boundary. As the economic aspect of costing is the most heavily researched aspect, this thesis concentrated on specific problems relating to the case studies and recycled water, such as separation of costs between the WTP and the adjacent AWTP, and noted difficulties such as segregation of electricity cost information between processing and distribution of wastewater/PRW. A small time period was covered, and a longitudinal study would be preferable. Neither AWTP was operating at capacity, and this would also make results lack economies of scale and comparability with other facilities. This was evident, for example, in the analysis of electricity costs, where high levels of fixed costs distort the results for a small scale plant in comparison to a larger PRW scheme.

Environmental

The thesis examined the flows from the processes within the advanced treatment plants, using materials flow analysis, but did not set this within the context of the water system beyond considering the replacement of other water sources with the recycled water and the effect on the immediate catchment area. Potential externalities are identified and discussed, but not quantified. Difficulties were also found in isolating environmental effects specific to the relevant AWTP e.g. the effect on riparian water quality, due to the large number of local users.

Social Aspect

The primary concern with the social aspect was the low response rate from the survey instrument. Ideally a second mail out should have been sent and a greater incentive for responding provided. Lack of resources for a PhD study was the main reason for this. Questionnaire design could have been improved to shorten the survey, however this did mean that the responses returned provided information on a large number of areas/facets. Again, a longitudinal study would have been preferable.

6.7 Implications for future research

Economic

A longitudinal study, with the researchers working with the client to improve separation of information, and an AWTP working at normal capacity would improve the robustness of future research results in this area.

Commercial motivations for PRW adoption is an area requiring more detailed research, and this may shed further light on whether there is any preference in term of process used for PRW treatment.

Environmental

More long-term research on catchment area water quality specific to the AWTP is needed. Greater research on the emissions from AWTPs would inform the environmental aspect, or research on the benefits of alternative power sources e.g. biogas capture.

Social Aspect

Follow up research with a longitudinal study to examine changes in attitude over time regarding climate change and the implications for water supply, and to investigate whether water saving habits (such as water efficient devices and tank water use) continue in periods when there had been no recent drought (the current drought in Queensland is affecting more rural areas). Although this study asked respondents to provide actual water use information for total water use, this would be more illuminating if it was over several time periods, and if actual water use for various activities was measured. Studies that measure actual RW use for different purposes would provide comparison for the perceived use by respondents provided in this study.

Respondents' perceived level of water use (from any source) for various activities when compared to recent SE Queensland studies of actual use (Beal & Stewart 2011) suggests that households may underestimate their level of water use for taps and toilets and overestimate the percentage used in garden watering. This may have policy implications as saving tap water could be promoted more and assistance given for plumbing toilets to recycled water sources as lack of connection was the most cited reason for not using recycled water for this purpose.

The split in actual respondent water usage between mains: recycled water appears to vary widely between respondents, based on additional information volunteered in comments and was not asked for by the customer survey (Table 5.55). The reasons for this would be worth more detailed investigation.

6.8 Final conclusion

This thesis outlines the rationale and methods used to obtain information beyond a traditional economic accounting, sufficient to demonstrate how a TBL (full) costing model could be researched and provides an outline of the model obtained, using two exemplar case studies in novel setting (RP1). It demonstrates the difficulties of such a cross-disciplinary research method, and suggests practical approaches to overcome some of these. This is an area where very little of such research has been done. The thesis further contributes by adding research on the social (and political) cost of introducing purified recycled water, which can be used to inform policy approaches in this field.

7. List of References

AAP 2009, 'Water usage falls under new restrictions', *Brisbane Times*, December 6, viewed 15 April 2011 http://www.brisbanetimes.com.au/queensland/water-usage-falls-under-new-restrictions-20091205-kbr1.html

AAP 2010, 'Queensland desalination plant to be mothballed', 5th December 2010, viewed 14 March 2011, http://www.news.com.au/breaking-news/queensland-desalination-plant-to-be-mothballed/story-e6frfku0-1225965887460

ABC 7.30 report 2015, 'Worst drought 'on record' getting very different State government responses', Reporter David Mark, 5 June 2015, viewed 5 June 2015, http://www.abc.net.au/7.30/content/2015/s4250055.htm

ABC TV News 2008, 'Bligh rejects recycled water pipeline a waste of money,' 1 December 2008, viewed 14 March 2011, http://www.abc.net.au/news/stories/2008/12/01/2433775.htm

ABC News 2009, 'Garrett rejects Traveston Dam,' 11 November 2009, viewed 25 March 2011, http://www.abc.net.au/news/stories/2009/11/11/2739725.htm

ABC Gold Coast 2011 'Tugun desalination plant on stand-by, operators say', 7pm ABC Television News QLD, April 5, viewed 21 October 2012, http://www.abc.net.au/news/video/2011/04/05/3183216.htm?site=goldcoast

ABS – see Australian Bureau of Statistics

Agyemann, J 2011, 'Foreword: Joined-up Research', in A Franklin & P Blyton (eds), *Researching Sustainability: A guide to social science methods, practice and engagement'*, Earthscan, Abingdon, Oxon.

Andersen, B 2011, 'Wivenhoe put to the ultimate test', *ABC News*, 11 January, viewed 14 April 2011, http://www.abc.net.au/news/stories/2011/01/11/3110758.htm

Anderson, J 2013, 'Water for life: diversification and water reuse as ingredients in Sydney's integrated water plan' and 'Australia's urban and residential water reuse schemes', in Lazarova, V, Asano, T, Bahri, A & Anderson, J (eds), *Milestones in Water Reuse – The best success stories*, IWA Publishing, London

Anderson, S 2014, 'At-a-glance: Agencies to be abolished in the Budget ', *SBS News*, 12 May, viewed 12 May 2012, http://www.sbs.com.au/news/article/2014/05/12/glance-agencies-be-abolished-budget

AQUA Projects 2007, *What is different about delivering projects in a water crisis?* AQUA Projects, Brisbane, 3 August, viewed 18 May 2014, http://www.aquaprojects.com.au/documents/WhatisdifferentaboutdeliveringprojectsinawatercrisisVer4a.pdf

Arthur, C & Moore, B. 2014, ''Drastic' water restrictions in sight for Longreach', *ABC Western Queensland*, 12 February 2014, viewed 8 May 2014, http://www.abc.net.au/local/stories/2014/02/12/3942913.htm

Asian Development Bank (ADB) 2013, *Measuring Water Security in Asia and the Pacific*, Asian Water Development Outlook 2013, Mandaluyong City, Philippines, March 2013, viewed 11 April 2013 http://www.adb.org/sites/default/files/pub/2013/asian-water-development-outlook-2013.pdf

Australian Bureau of Agricultural and Resource Economics 2010, *Energy in Australia* 2010, ABARE, Australian Government Department of Resources Energy and Tourism, viewed 1 April 2011, http://www.abare.gov.au/publications_html/energy/energy_10/energyAUS2010.pdf

Australian Bureau of Statistics 2010, *1370.0 - Measures of Australia's Progress 2010: International Comparisons*, ABS 15th September 2010, viewed 15 April 2014, http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/1370.0~2010~Chapter~International%20comparisons%20(6.3.8)

Australian Bureau of Statistics 2013, *2011 Census QuickStats, All people - usual residents- Moreton Bay*, ABS 28 March 2013, viewed 10 November 2015, http://www.censusdata.abs.gov.au/census_services/getproduct/census/2011/quickstat/LGA35010?opendocument&navpos=220

Australian Bureau of Statistics 2014a, *Population Clock*, ABS 22 April 2014, viewed 22 April 2014, http://www.abs.gov.au/ausstats/abs%40.nsf/94713ad445ff1425ca25682000192af2/1647509ef7e25faaca2568a900154b63?OpenDocument

Australian Bureau of Statistics 2014b*, 3101.0 - Australian Demographic Statistics*, ABS, March 2014, viewed 22 April 2014, http://www.abs.gov.au/ausstats/abs@.nsf/mf/3101.0

Australian Water Recycling Centre of Excellence 2010a, *Discussion Paper Theme 3: Social Institutions and Economic Challenges*, AWRCE, Brisbane, 23 October, viewed 12 April 2011, http://www.australianwaterrecycling.com.au/coe/images/stories/publications/Microsoft_Word_-_Theme_3_-_Social_Institutional_and_Economic_Challenges_PDF.pdf

Australian Water Recycling Centre of Excellence 2010b, *Discussion Paper Theme 4: Sustainability - Life Cycle Assessment and Integrated Resource Management Strategies*, AWRCE, Brisbane, 23 March 2010, viewed 12 April 2011, http://www.australianwaterrecycling.com.au/coe/images/stories/publications/Microsoft_Word_-_Theme_4_-_Sustainability_PDF.pdf

Australian Water Recycling Centre of Excellence (AWRCE) 2010c, 'Strategic Research Plan', AWRCE, Brisbane , 5 August 2010, viewed 12 April 2011 http://www.australianwaterrecycling.com.au/coe/images/stories/AWRCE_SRP_2010.pdf

Avant, DD, Finnemore, M & Sell, SK (eds) 2010, *Who Governs the Globe?*, Cambridge University Press, Cambridge

AWRCE –see Australian Water Recycling Centre of Excellence

Bailey, M (Main Roads, Road Safety and Ports and Minister for Energy and Water Supply) 2015, '*Independent review into dam operators' warning systems'*, Queensland Government, Media statement, 20 May 2015, viewed 7 June 2015, http://statements.qld.gov.au/Statement/2015/5/20/independent-review-into-dam-operators-warning-systems

Barrett, R 2011, 'Bligh's $300m U-turn on water', *The Australian*, 8 April, viewed 8 April 2011, http://www.theaustralian.com.au/national-affairs/blighs-300m-u-turn-on-water/story-fn59niix-1226035631618

Barrett, R & Schliebs, M. 2010, 'Desal plant to be mothballed after rainfall', *The Australian*, 6th December 2010, viewed 14 March 2011, http://www.theaustralian.com.au/national-affairs/desal-plant-to-be-mothballed-after-rainfall/story-fn59niix-1225966036882

Baue, B 2006, 'Sustainability Reporting Improving, But Not Necessarily Contributing to True Sustainability', *Social Funds*, viewed 13 November 2006, http://www.socialfunds.com/news/article.cgi/2159.html

Baumfield, VS 2012, 'The Allconnex Water Debacle', *Bond Law Review*, vol. 24 no. 2, viewed 9 May 2014, http://epublications.bond.edu.au/cgi/viewcontent.cgi?article=1432&context=blr

Baxter, T, Bebbington, J & Cutteridge, D 2004, 'Sustainability Assessment Model: Modelling Economic. Resource, Environmental and Social Flows of a Project', in A Henriques & J Richardson (eds.), *The Triple Bottom Line: Does it All Add Up?*, Earthscan, London

Baynes, TM, Reedman LJ & Turner, GM 2007, 'The impact of large Scale Deployment of Distributed Electricity Generation on Water Resources in Australia', *CSIRO*, viewed 1 April 2011, http://www.mssanz.org.au/MODSIM07/papers/30_s38/TheImpactofLarge_s38_Baynes_.pdf

Baynes, TM, West, J, Vitovsky, J & Murray, H 2009, *A Framework for Modelling the Energy and Greenhouse Implications of Water Demand and Supply Scenarios*, August, Urban Water Security Research Alliance Technical Report No. 15, Brisbane, viewed 21 May 2014, http://www.urbanwateralliance.org.au/publications/UWSRA-tr15.pdf

BCC – see Brisbane City Council

Beal, C & Stewart, R 2011, 'South East Queensland Residential End Use Study: Final Report', *Urban Water Security Research Alliance*, Technical Report No. 47, November, viewed 16 June 2014, http://www.urbanwateralliance.org.au/publications/UWSRA-tr47.pdf

Beal, C, Stewart, R & Huang, T 2010, 'South East Queensland Residential End Use Study: Baseline Results -Winter 2010', *Urban Water Security Research Alliance*, Technical Report No. 31, November, viewed 15 April 2011, http://www.urbanwateralliance.org.au/publications/UWSRA-tr31.pdf

Beck, U. 1995, 'Ecological Enlightenment: Essays on the Politics of Risk Society, trans. M. Ritter, Atlantic Highlands, NJ: *Humanities Press* quoted in Marks, J. S., Martin, B., and Zadoroznyj, M. 2008 'How Australians order acceptance of recycled water: National baseline data', *Journal of Sociology*, 44 (1), pp.83-99.

Bennett, A 2004, 'Powering ahead with alternative water sources', Filtration and Separation, vol. 41, no. 10, pp. 18-20

Benyon, R 2015, 'Tony Abbott's responses to climate change are not conservative', 22 July, viewed 26 June 2016, The Sydney Morning Herald, comment, http://www.smh.com.au/comment/tony-abbotts-responses-to-climate-change-are-not-conservative-20150722-gihpxi.html

Birnberg, JG, Luft, J & Shields, MD 2007, 'Psychology Theory in Management Accounting Research', in Chapman, CS, Hopwood, AG & Shields, MD (eds), *Handbook of Management Accounting Research*, vol. 1, pp. 113-136, Elsevier Ltd, Oxford.

BITRE - see Bureau of infrastructure, transport & regional economics

Borskjaer, K 2012, *Case Study: Murrumba Downs waste water Treatment Plant Upgrade*, PSG Electrical Solutions factsheet 31 July 2012, viewed 8 October 2013, http://www.psgelectric.com.au/projects/Case%20Studies/00033%20Murrumba%20Downs%20WWTP%20Upgrade%20FINAL.pdf

BOM – see Bureau of Meteorology

Bourke, L 2014, 'G20 summit: Barack Obama puts climate change at fore in speech at University of Queensland', *Sydney Morning Herald*, November 15 2014, viewed 31 May 2015, http://www.smh.com.au/federal-politics/political-news/g20-summit-barack-obama-puts-climate-change-at-fore-in-speech-at-university-of-queensland-20141115-11ndmg.html

Branco, J 2014, 'Unitywater not going anywhere despite feisty water forum', *Sunshine Coast Daily*, 13 March, viewed 9 May 2014, http://www.sunshinecoastdaily.com.au/news/water-issues-heat-up/2197551/

Brisbane City Council 2011, *Resident Flood Information*, BCC, viewed 14 April 2011, http://web.brisbane.qld.gov.au/community-support/emergency-management/flooding/Resident-flood-information/033524

Brisbane City Council 2015, *Stormwater Harvesting and Reuse Project*, updated 30 March 2015, viewed 1 June 2015, http://www.brisbane.qld.gov.au/environment-waste/natural-environment/brisbanes-creeks-rivers/protect-our-waterways/norman-creek-2012-2031-project/norman-creek-2012-2031-master-plan/stormwater-harvesting-reuse-project

Brisbane Times 2011, 'Brisbane to stick with QUU for water', 3 June, viewed 9 May 2014, http://www.brisbanetimes.com.au/queensland/brisbane-to-stick-with-quu-for-water-20110603-1fjv9.html

Brown, C & Cornwell, R 2006, 'The day that changed the climate', *The Independent*, 31 October, viewed 17 May 2009, http://www.independent.co.uk/environment/climate-change/the-day-that-changed-the-climate-422282.html

Browne, AL, Leviston, Z, Green, MJ & Nancarrow, BE 2008, *Technical and Community Perspectives of Risks Associated with Purified Recycled Water in South East Queensland: A Q-Study*, April, Urban water Security Research Alliance, Brisbane, Technical Report No. 4, viewed 21 May 2014, http://www.urbanwateralliance.org.au/publications/UWSRA-tr4.pdf

Bureau of Infrastructure, Transport & Regional Economics 2013, *Population growth, jobs growth and commuting flows in South East Queensland – report 134,* Australian Government Department of Infrastructure and Transport, BITRE 2013, viewed 23 April 2014, http://www.bitre.gov.au/publications/2013/files/report_134.pdf

Bureau of Meteorology (BOM) 2009, *Water Accounting: Frequently Asked Questions*, Australian Government Bureau of Meteorology , 23 June 2009, viewed 30 April 2014, http://www.bom.gov.au/water/standards/wasb/documents/FAQs.pdf

Bureau of Meteorology (BOM) 2012, *Accounting for Australia's water*, Australian Government Bureau of Meteorology InfoSheet 8, 10 December 2012,viewed 31 July 2013 http://www.bom.gov.au/water/about/publications/document/InfoSheet_8.pdf

Bureau of Meteorology (BOM) 2014a, *Water Accounting Standards Board*, Australian Government Bureau of Meteorology viewed 30 April 2014 http://www.bom.gov.au/water/standards/wasb/

Bureau of Meteorology (BOM) 2014b, *Australian rainfall patterns during El Niño and La Niña events*, Australian Government Bureau of Meteorology , viewed 9 May 2014 http://www.bom.gov.au/climate/ahead/soicomp.shtml

Brundtland Report – See UNWCED

Caica, P, (SA Minister for water and the River Murray) 2012, *Reduce recycled water price in 2013*, Government of South Australia, Adelaide, 14 December, viewed 16 May 2012, http://www.sawater.com.au/nr/rdonlyres/01245a54-6bab-432a-adfa-5f904de96c1a/0/medrelrecycledwaterpricered.pdf

Caboolture News 2013, 'Recycled water piping going to waste after facility shutdown, 3rd Dec 2013', viewed 5 June 2015 http://www.cabooltureneews.com.au/news/going-down-the-gurgler/2103291/

Capati, B 2013, *Demerging the water corporation – The Story of Allconnex Water*, 10 September, Manager Service Sustainability, Gold Coast City Council, viewed 9 May 2014, http://www.lgnsw.org.au/files/imce-uploads/48/2.Bill_Capati.pdf

Carbone, D & Hanson, J 2012, 'Floods: 10 of the deadliest in Australian history', *Australian Geographic*, 8 March, viewed 9 May 2014, http://www.australiangeographic.com.au/topics/history-culture/2012/03/floods-10-of-the-deadliest-in-australian-history/

CDM – see United Nations Climate Change Clean Development Mechanism

CERES – see Coalition for Environmentally Responsible Economies

Chalmers ,K, Godfrey, J & Potter, B 2012, 'Discipline-Informed Approaches to Water Accounting', *Australian Accounting Review*, no. 62, vol. 22, issue 3, pp. 275-285

City of Gold Coast 2014, *Recycled water*, City of Gold Coast Council, viewed 16 May 2014, http://www.goldcoast.qld.gov.au/environment/recycled-water-7870.html

Climate Action Network Australia 2006, *The Social Impacts of Climate change: Global – Increases in Refugees*, CANA viewed 31 March 2011, http://www.cana.net.au/socialimpacts/global/refugees.html

Cloete, S, Horberry, T & Head, B 2011, *Human Factors in Urban Water System Safety: Stage 1 - Initial Findings* , June, Urban water Security Research Alliance, Brisbane, Technical Report No. 46, viewed 29 May 2014, http://www.urbanwateralliance.org.au/publications/UWSRA-tr46.pdf

Cloete, S, Horberry, T & Head, B 2012, *Human Factors in Urban Water System Safety: Humans and Technology* , September, Urban water Security Research Alliance, Brisbane, Technical Report No. 80, viewed 29 May 2014, http://www.urbanwateralliance.org.au/publications/UWSRA-tr80.pdf

COAG – see Council of Australian Governments

Coalition for Environmentally Responsible Economies 1989, *The Ceres Principles* CERES, , viewed 1 May 2014 http://www.ceres.org/about-us/our-history/ceres-principles

Coalition for Environmentally Responsible Economies 2008, CERES, Boston MA, viewed 30 June 2008 http://www.ceres.org/NETCOMMUNITY/Page.aspx?pid=415&srcid=556

Coffee J 2014, 'Climate change a growing concern for companies expanding their footprint', *The Guardian*, 29 April 2014, viewed 30 April 2014, http://www.theguardian.com/sustainable-business/hubs-water-climate-change-siting-drought-flood-business

Collins, KM 2012, (pp. Mark McArdle, Minister for Energy and Water Supply), *Tugun Desalination Plant Study- Desal Plant Study to examine Tugun Desal Plant operating options*, QLD Government Media release, 5 June 2012, viewed 21 October 2012, http://statements.qld.gov.au/Statement/Id/79447

Collins, R 2010, 'Continuity in a crisis: Worried that business could dry up due to stringent water restrictions, Amcor found a new business partner to whet its processes', *WME Magazine*, 2 February, viewed 27 May 2014, http://www.wme.com.au/categories/water/feb2_10.php

Commonwealth Scientific and Industrial Research Organisation 2007, *Stronger evidence for human-induced climate change*, CSIRO 2 February 2007, viewed 1 May 2008, http://www.csiro.au/Organisation-Structure/Divisions/Marine--Atmospheric-Research/Stronger-evidence-for-human-induced-climate-change.aspx

Council of Australian Governments 2004, *Intergovernmental Agreement on a National Water Initiative 2004*, Department of the Prime Minister and Cabinet *&* COAG, 30 June, viewed 23 April 2014, http://nwc.gov.au/__data/assets/pdf_file/0008/24749/Intergovernmental-Agreement-on-a-national-water-initiative.pdf

Council of Australian Governments 2008 *Meeting Communiqué*, COAG, Adelaide, 26 March 2008, Viewed 14 March 2011, http://www.coag.gov.au/coag_meeting_outcomes/2008-03-26/index.cfm

Courier Mail 2008 'Gone to water', Brisbane, 26 November, p.1

Creswell, JW 2009, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, 3rd edn, Sage publications, Thousand Oaks

CSIRO –see Commonwealth Scientific and Industrial Research Organisation

Daniels P, & Porter, M 2012, *A Preliminary Framework for Externality Assessment and Economic Valuation for Total Water Cycle Management: An Application to the Moreton Bay Regional Council Planning Process*, November, Urban Water Security Research Alliance, Brisbane, Technical Report No. 92, viewed 21 May 2014, http://www.urbanwateralliance.org.au/publications/UWSRA-tr92.pdf

Daniels P, & Porter, M & Bodsworth, P 2012, *Externalities in Sustainable Regional Water Strategies: Application of a Simple Methodology* ,October, Urban Water Security Research Alliance, Brisbane, Technical Report No. 81, viewed 21 May 2014, http://www.urbanwateralliance.org.au/publications/UWSRA-tr81.pdf

Daniels P, & Porter, M, Bodsworth, P & Coleman, S 2012, *Externalities in Sustainable Regional Water Strategies: A Compendium of Externality Impacts and Valuations* , February, Urban Water Security Research Alliance, Brisbane, Technical Report No. 42, viewed 21 May 2014, http://www.urbanwateralliance.org.au/publications/UWSRA-tr42.pdf

Davies, A 2014, ' Qld to decide what to do with botched $4b water 'assets'', *The Queensland Times*, 3 April, viewed 7 May 2014, http://www.qt.com.au/news/qld-decide-what-do-botched-4b-water-assets/2218887/

Davison WP 1983, 'The third-person effect in communication', *Public Opinion Quarterly*, vol. 47, no. 1, pp.1-15, viewed 24 June 2014, EbscoHost Business Source Complete, doi:10.1086/268763

DBM Consultants 2007, *Economic Valuation of Water Reliability in South-East Queensland Using Choice Modelling*, Final report prepared for QLD Water Infrastructure Pty Ltd, Victoria, April 2007

De Blas, A 2003, *Water: What's a fair price to pay?,* Earthbeat – ABC Radio National, Broadcast 23 August 2003. (Participants: Professor Mike Young, CSIRO; Dr Poh-Ling Tan QUT; John Langford, Water Services Association of Australia), listened to 13 March 2011, http://www.abc.net.au/rn/science/earth/stories/s927332.htm

Deegan, CM 2003, *Environmental management accounting project: case study subject*: G H Mitchell and Sons, EPA Victoria, Sydney, NSW

Department of Energy and Water Supply 2010, *South East Queensland Water Strategy*, Queensland Government DEWS, 15 July, viewed 26 May 2014, http://www.dews.qld.gov.au/__data/assets/pdf_file/0019/32734/seqws.pdf

Department of Energy and Water Supply 2013, *Coal seam gas recycled water*, Queensland Government DEWS, updated 23 February 2013, viewed 15 May 2014, http://www.dews.qld.gov.au/water-supply-regulations/recycled-water/coal-seam-gas-recycled-water

Department of Energy and Water Supply 2014a, *Bulk water prices,* Queensland Government DEWS, updated 6 February, viewed 29 April 2014, http://www.dews.qld.gov.au/policies-initiatives/water-sector-reform/water-pricing/bulk-water-prices

Department of Energy and Water Supply 2014b, *Queensland Water Commission*, Queensland Government DEWS, updated 15 May, viewed 18 May 2014, http://www.dews.qld.gov.au/policies-initiatives/water-sector-reform/queensland-water-commission

Department of Energy and Water Supply 2014c, *WATERQ: a 30-year strategy for Queensland's water sector,* Queensland Government DEWS, July 2014, viewed 31 May 2015, https://www.dews.qld.gov.au/__data/assets/pdf_file/0007/176344/waterq-strategy.pdf

Department of Energy and Water Supply 2015a, *Water supply security*, Queensland Government DEWS, updated 24 February 2015, viewed 31 May 2015, https://www.dews.qld.gov.au/water-supply-regulations/security

Department of Energy and Water Supply 2015b, *South East Queensland water strategy*, Queensland Government DEWS, updated 24 February 2015, viewed 31 May 2015, https://www.dews.qld.gov.au/water-supply-regulations/security/water-supply-security-assessments/south-east-queensland

Department of Environment 2014a, *The Intergovernmental Panel on Climate Change – Special Report on Extreme Events*, Australian Government DOE, viewed 15 April 2014, http://www.climatechange.gov.au/climate-change/climate-science/intergovernmental-panel-climate-change

Department of Environment 2014b, *Measuring Sustainability program,* Australian Government DOE, viewed 5 May 2014, http://www.environment.gov.au/topics/sustainable-communities/measuring-sustainability

Department of Environment 2014c, *Water*, Australian Government DOE, viewed 5 May 2014, http://www.environment.gov.au/topics/water

Department of Environment and Heritage 2005, *The State of Sustainability Reporting in Australia 2005*, Australian Government DEH, viewed 15 April 2008, http://www.environment.gov.au/settlements/industry/finance/publications/indicators/index.html

Department of the Environment 2015, *Review of the national Water Commission*, Australian Government DOE website, viewed 9 October 2015, https://www.environment.gov.au/topics/water/australian-government-water-leadership/council-australian-governments-water-reform-1

Department of the Environment and Water Resources 2007, *Corporate Sustainability Reporting*, DEWR website, updated 24.3.2007, viewed 11 April 2007, http://www.environment.gov.au/settlements/industry/corporate/reporting/

Department of the Environment, Water, Heritage and the Arts 2009, *Refusal of Approval: Traveston Crossing Dam, Mary River, Queensland, (EPBC: 2006/3150), (NWI 2010)*, DEWHA, Peter Garrett, Minister for the Environment, Heritage and the Arts, 2 December 20009, viewed 10 June 2014, http://www.environment.gov.au/epbc/notices/assessments/2006/3150/refusal-approval.pdf

Department of the Environment, Water, Heritage and the Arts 2010, *National Water Initiative pricing principles (NWI 2010)*, Steering Group on Water Charges, Council of Australian Governments (COAG), 27 April 2010, viewed 23 April 2014, http://www.environment.gov.au/system/files/resources/34dbb722-2bfa-48ac-be7e-4e7633c151ed/files/nwi-pricing-principles.pdf

Department of Foreign Affairs and Trade 2008, *Australia's environment at a glance*, DFAT last updated May 2008, viewed 15 April 2014, http://www.dfat.gov.au/facts/env_glance.html

Department of Local Government, Planning, Sport and Recreation 2005, *Mandatory sustainable housing measures – 2006*, Queensland Government Building Codes Queensland, 12 August 2005, viewed 29 December 2015, http://www.hpw.qld.gov.au/SiteCollectionDocuments/193.pdf

Department of Natural Resources and Mines 2005, *South East Queensland Water Strategy*, Queensland Government, Spatial Information and Mapping Group, Indooroopilly Sciences Centre, 2005, viewed 5 June 2015, https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0017/106082/moreton-planning-map.pdf

Department of Sustainability, Environment, Water, Population and Communities 2010, Australian Government, viewed 4 October 2010, http://www.environment.gov.au/

Department of the Prime Minister and Cabinet 2004, *Intergovernmental Agreement on a National Water Initiative 2004*, Council of Australian Governments (COAG), DPMC 30 June 2004,viewed 23 April 2014, http://nwc.gov.au/__data/assets/pdf_file/0008/24749/Intergovernmental-Agreement-on-a-national-water-initiative.pdf

Department of the Prime Minister and Cabinet 2007, *Australia's Climate Change Policy – our economy, our environment*, Australian Government DPMC 17th July 2007, viewed 11 April 2009,
http://www.pmc.gov.au/publications/climate_policy/index.cfm

DEWR– see Department of Environment and Water Resources

DEWS – see Department of Energy and Water Supply

Dimitriadis, S, 2005, 'Issues encountered in advancing Australia's water recycling schemes ' *Science, Technology, Environment and Resources Section, Australian Parliament Library*, Research Brief no. 2 2005–06, 16 August, viewed 20 June 2012 http://www.aph.gov.au/library/pubs/RB/2005-06/06rb02.htm

DOE - see -Department of (the) Environment

Durham, B & Turner, N 2004, 'Recycled water stakeholders: best practice ideas based on international experience', *proceeding of International Water Association Marrakech AQUAREC workshop* ' Social and economic dimensions of water reuse projects' (cited in Bennett 2004)

Edmistone, L, Wardill, S, McDonald, R & Johnstone, C 2008, '$2.2 billion wasted as Anna Bligh backflips on water', *Brisbane Courier Mail*, 25 November, viewed 6 May 2014, http://www.couriermail.com.au/news/special-features/bligh-defiant-after-backflips/story-e6freoyo-1111118140276

Edwards J 2015, *Victorian desalination plant could be used for first time to cope with hot summer*, ABC News, posted 7 October 2015, viewed 7 October 2015, http://www.abc.net.au/news/2015-10-07/victorian-desalination-plant-may-be-switched-on-over-summer/6835042

Edwards, P, Roberts I, Clarke, M, DiGuiseppi, C, Pratap, S, Wentz, R & Kwan, I 2002, 'Increasing response rates to postal questionnaires: systematic review', *BMJ*, pp. 324-51, viewed 27 May 2014, http://www.bmj.com/content/324/7347/1183

Eisenhardt, KM 1989, 'Building theories from case study research', *Academy of Management Review*, vol. 14, no.4, pp.532-550

Elkington, J 1994 'Towards the sustainable corporation: Win-win-win business strategies for sustainable development,' *California Management Review*, vol. 36, issue 2, Winter 1994, pp. 90-100

Elkington, J 1998, 'Partnerships from Cannibals with Forks: The Triple Bottom Line of 21st-Century Business', *Environmental Quality Management*, vol. 8, no.1, pp. 37-51, viewed 12 March 2011, EBSCOhost MegaFILE Complete, Business Source Complete . Item AN1211364

Elkington, J 2004, 'Enter the Triple Bottom Line', in A Henriques & J Richardson (eds.), *The Triple Bottom Line: Does it All Add Up?*, Earthscan, London

Emerton, L, Bos, E 2004,‘Value. Counting Ecosystems as an Economic Part of Water
Infrastructure’, *IUCN*, Gland, Switzerland and Cambridge, UK. 88 pp. viewed 20 May 2014, http://cmsdata.iucn.org/downloads/10_value.pdf

Environment Australia, 2003, *Triple Bottom Line Reporting in Australia: A guide to reporting against environmental indicators*, Department of the Environment and Heritage, June 2003, viewed 15 April 2014 http://www.environment.gov.au/archive/settlements/industry/finance/publications/indicators/pubs/indicators.pdf

Environment & Heritage 2014, *What is sustainability?,* NSW Government E&H website, viewed 5 May 2014, http://www.environment.nsw.gov.au/sustainability/

Environmental Xprt 2014, *Wastewater Treatment Plant Monitors Greenhouse Gas Emissions*, courtesy of Gasmet Technologies Oy, Helsinki, 16 April, viewed 26 May 2014, http://www.environmental-expert.com/articles/wastewater-treatment-plant-monitors-greenhousegasemissions423085?utm_source=Articles_Water_01052014&utm_medium=email&utm_campaign=newsletter&utm_content=feattextlink

European Union 2007, *Addressing the challenge of water scarcity and droughts in the European Union*, Communication from the Commission to the European Parliament and the Council, COM 2007 0414 final ,18 July, EU, Brussels, , viewed 1 September 2010, http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52007DC0414:EN:NOT

European Commission 2009, *The State of Sustainability Reporting in Europe*, Commission Statement March 2009, viewed 25 May 2009 http://www.sustainabilityreporting.eu/general/ec08.html

Field, A 2013, *Discovering Statistics Using IBM SPSS Statistics*, 4th edn, Sage Publications Ltd, London & Thousand Oaks.

Finnemore, M and Sikkink, K 1998, ‘International Norm Dynamics and Political Change’, *International Organization*, vol. 52, pp. 887-917

Foley, P 2011, ‘You broke it, you fix it: Council’, *The Queensland Times (QT)*, 8 April, viewed 8 November 2011, http://www.qt.com.au/story/2011/04/08/you-broke-it-you-fix-it-council-water-ipswich/

Franklin, A & Blyton, P 2011, *Researching Sustainability: a guide to social science methods, practice and engagement*, Earthscan, London

Fraser, A 2009, ‘Premier Anna Bligh embarrassed by overdose of fluoride in water supply’, *The Australian*, 15 May, viewed 6 May 2014, http://www.theaustralian.com.au/archive/news/fluoride-overdose-trips-alarm/story-e6frg6no-1225712538643

Fraser, A 2011, 'Wivenhoe Dam saving Queensland's capital - for now', *The Australian*, 11 January, viewed 14 April 2011 http://www.theaustralian.com.au/news/nation/wivenhoe-dam-saving-queenslands-capital-for-now/story-e6frg6nf-1225985231803

Freeman, RE 1984 *Strategic Management: A Stakeholder Approach*, Pitman, Boston

Freeman, E & Liedtka, J 1997, 'Stakeholder Capitalism and the Value Chain', *European Management Journal*, vol. 15, no. 3, pp.286-296

Frontier Economics 2011, *Externality pricing in the Australian water sector,* Waterlines Report series No. 43, April, National Water Commission, Canberra, viewed 26 May 2014, http://archive.nwc.gov.au/__data/assets/pdf_file/0019/10936/43_Externalities.pdf

Garnaut, R 2008, *The Garnaut Climate Change Review Final Report*, Commonwealth of Australia, *Cambridge University Press*, viewed 29 April 2009, http://www.garnautreview.org.au/index.htm

Garnaut, R 2011a, *The Garnaut Review 2011: Australia in the Global response to Climate Chan*ge, Commonwealth of Australia, Cambridge University Press, viewed 24 January 2012, http://www.garnautreview.org.au/update-2011/garnaut-review-2011/garnaut-review-2011.pdf

Garnaut, R 2011b, *The Garnaut Climate Change Review Update 2011, Update Paper 1, Weighing the costs and benefits of climate change action*, Commonwealth of Australia ,Cambridge University Press, viewed 13 March 2011, http://www.garnautreview.org.au/update-2011/update-papers/up1-key-points.html

Garnaut, R 2011c, *The Garnaut Climate Change Review Update 2011*, *Update Paper 5*, *The Science of climate change*, Commonwealth of Australia, Cambridge University Press, viewed 13 March 2011, http://www.garnautreview.org.au/update-2011/update-papers/up5-key-points.html

Gerrity, D, Owens-Bennett, E, Venezia, T, Stanford, BD, Plumlee, MH, Debroux, J & Trussell, RS 2014, 'Applicability of ozone and biological activated carbon for potable reuse', *Ozone: Science & Engineering*, vol. 36, issue 3, pp.123-137, viewed 7 June 2015, EBSCOhost, Academic Search Complete, DOI:10.1080/01919512.2013.866886

Gerrity, D, Pisarenko, AN, Marti, E, Trenholm, RA, Gerringer, F, Reungoat, J & Dickenson, E 2015, 'Nitrosamines in pilot-scale and full-scale wastewater treatment plants with ozonation', *Water Research*, vol. 72, 1 April 2015, pp.251-261, viewed 7 June 2015, Science Direct, DOI:10.1016/j.watres.2014.06.025

Gibson, K 1996, 'The problem with reporting pollution allowances: Reporting is not the problem', *Critical Perspectives on Accounting*, vol.7, no. 6, December, pp.655-665

Global Reporting Initiative 2006 *About reporting framework* (G3), GRI issued October 2006, viewed 31 March 2010: http://www.globalreporting.org/ReportingFramework/AboutReportingFramework/

Global Reporting Initiative 2013, *G4 Sustainability Reporting Guidelines*, GRI 14 May 2013, viewed 15 April 2014, https://www.globalreporting.org/resourcelibrary/GRIG4-Part1-Reporting-Principles-and-Standard-Disclosures.pdf

Gold Coast Water 2007, *GC Waterfuture - Recycled water in Pimpama Coomera*, Gold Coast City Council factsheet 5, Pimpama Coomera Alliance, 2 May, viewed 16 May 2014, http://greensquarewater.com.au/media/uploads/resourcecontent/PC_FS5_recycledwater.pdf

Gould, J 2014, 'At last! A dam plan that will restrict flood effect', *The Queensland Times*, 3 April, viewed 7 May 2014, http://www.qt.com.au/news/at-last-a-dam-plan-that-will-restrict-flood-effect/2218627/

Gray, R & Bebbington, J 2001, *Accounting for the Environment*, 2nd edn, Sage Publications, London

Gray, R, Bebbington J & Walters, D 1993, *Accounting and the Environment (Greening of Accountancy II)*, Paul Chapman Publishing, London

Greenfield, P., Quiggin, J., Griffiths, A. & Nixon, P. 2011, 'Post floods, cyclones & inland tsunamis – Managing our Water Infrastructure in Challenging Times', *UQ Alumni Debate*, Customs House, Brisbane 13 April 2011

GRI –see Global Reporting Initiative

Hall, M, West, J, Lane, J, de Haas, D & Sherman, B 2009, *Energy and Greenhouse Gas Emissions for the SEQ Water Strategy*, September, Urban water Security Research Alliance, Brisbane, Technical Report No. 14, viewed 21 May 2014, http://www.urbanwateralliance.org.au/publications/UWSRA-tr14.pdf

Halliday, S 2006, *Ozone In The Water Reclamation Process At South Caboolture, Queensland, Australia*, 2 June, Watertec Engineering, Brisbane, viewed 19 may 2014, http://www.watertecengineering.com/Caboolture%20report%20-%20Watertec.pdf

Hanemann, WH 2006, 'The economic conception of water', in Rogers, PP, Llamas, MR &, Martinez-Cortina, L (eds), *Water Crisis myth or reality?*, Taylor & Francis plc., London, viewed 2 May 2014, http://are.berkeley.edu/~gh082644/The%20economic%20concpetion%20of%20water.pdf

Hanna, C & Waters, G 2011, 'Flooded households asked to conserve water', *Brisbane Times*, January 11, viewed 14 April 2011, http://www.brisbanetimes.com.au/environment/weather/flooded-households-asked-to-conserve-water-20110111-19mgt.html

Hannam, P 2014, 'Tony Abbott downplays role of climate change in current drought', *The Sydney Morning Herald*, 17 February 2014, viewed 10 April 2014, http://www.smh.com.au/federal-politics/political-news/tony-abbott-downplays-role-of-climate-change-in-current-drought-20140217-32vub.html

Hasham, N 2012, ‘Yuck factor of recycled sewage may not be such a big obstacle’, *Sydney Morning Herald*, May 8, viewed 15 May 2014, http://m.smh.com.au/environment/water-issues/yuck-factor-of-recycled-sewage-may-not-be-such-a-big-obstacle-20120507-1y95a.html

Hatton MacDonald D, Proctor W 2008, ‘The Economic Dilemmas of Water Management and Reuse’, in Jimenez, B & Asano, T (eds), *Water Reuse: An International Survey of current practice, issues and needs*, International Water Association, London

Hatzakis, M 2011, ‘Massive low a very big event, flood inquiry hears’, *ABC News*, 14 April, viewed 14 April 2011, http://www.abc.net.au/news/stories/2011/04/14/3191051.htm

Hatzakis, M & staff 2011, ‘Dam release wouldn't have stopped flood, inquiry told’, *ABC News*, 14 April 2011, viewed 14 April 2011, http://www.abc.net.au/news/stories/2011/04/13/3190429.htm

Hayward, G 2014, ‘Lake Kurwongbah Water Ski Club to lose its lake before motorboat ban and major maintenance program’, *Courier Mail*, 11 April, viewed 6 June 2014, http://www.couriermail.com.au/questnews/moreton/lake-kurwongbah-water-ski-club-to-lose-its-lake-before-motorboat-ban-and-major-maintenance-program/story-fni9r1i7-1226881251290

Head, B & Cammerman, N 2010, *The Water-Energy Nexus: A Challenge for Knowledge and Policy,* December, Urban Water Security Research Alliance, Brisbane, Technical Report No. 39, viewed 21 May 2014, http://www.urbanwateralliance.org.au/publications/UWSRA-tr39.pdf

Health-e-Waterways 2009 *Moreton Bay Report Cards*, Health-e- Waterways, Brisbane, viewed 30 May 2014, http://www.health-e-waterways.org/reportcard/2006/subregion/Moreton%20Bay

Healthy Waterways 2013a, *Caboolture River Catchment and Estuary, Ecosystem health monitoring Program*, Healthy Waterways, Brisbane, viewed 5 June 2015, http://www.ehmp.org/EcosystemHealthMonitoringProgram/2010ReportCardResults/CatchmentResults/MoretonBayCatchments/CabooltureRiverCatchmentandEstuary.aspx

Healthy Waterways 2013b, *Caboolture Catchment*, Healthy Waterways, Brisbane, viewed 8 January 2013, http://www.health-e-waterways.org/reportcard/2012/catchment/Caboolture%20Catchment

Healthy Waterways 2013c, *Pine Rivers Catchment and Estuary*, Healthy Waterways, Brisbane, viewed 5 June 2015, http://www.ehmp.org/EcosystemHealthMonitoringProgram/2010ReportCardResults/CatchmentResults/MoretonBayCatchments/PineRiversCatchmentandEstuary.aspx

Henderson, S, Peirson, G & Herbohn, K 2008, *Issues in Financial Accounting*, 13th edn, Pearson Education Australia, pp.990-1019

Hepworth, A 2010, 'Regional water utilities hung out to dry', *The Australian*, 15 December 2010, viewed 11 January 2011, http://www.theaustralian.com.au/national-affairs/regional-water-utilities-hung-out-to-dry/story-fn59niix-1225971191343

Herbohn, K 2005, 'A full cost environmental accounting experiment', *Accounting Organizations and Society*, vol. 30, pp.519-536

Hermans, L, Renault, D, Emerton, L, Perrot-Maître, D, Nguyen-Khoe, S & Smith, L 2006, 'Stakeholder-oriented valuation to support resources management processes; Confronting concepts with local practice', *Food and Agriculture Organization of the United Nations & Imperial College (London)*, FAO Water Reports 30, Rome

Higgins, J, Warken, J, Sherman, PP &Teasdale, PR 2002, 'Survey of users and providers of recycled water: quality concerns and directions for applied research', *Water Research*, vol. 36, pp.5045-5056

Holznagel, C 2011, 'Government Scraps Water Utilities', *The Noosa Journal*, 8 April, viewed 8 November 2011, http://noosa-journal.whereilive.com.au/news/story/government-scraps-water-utilities/

Hopwood, AG 2009, 'Accounting and the environment', *Accounting Organizations and Society*, vol. 34, pp.433-439

Hough, C & Rogers, E 2014, 'Queensland's largest drought-declared ever' , *ABC Rural*, 11 March, viewed 14 May 2014, http://www.abc.net.au/news/2014-03-07/qld-drought--most-widespread-ever-recorded/5306044

Houghton, J 2015, 'Minister says desalination plant a $15m per year insurance policy against drought', *Gold Coast Bulletin*, 3 March, viewed 28 September 2015, http://www.goldcoastbulletin.com.au/news/gold-coast/minister-says-desalination-plant-a-15m-per-year-insurance-policy-against-drought/story-fnj94idh-1227245196639

Hunt, C & Dunstan, K 2007, *Why do Queensland Urban Water Entities Resist the Adoption of User Pays Pricing?*, Accounting & Finance Association of Australia and New Zealand (AAFANZ) Conference paper 218, 1-3rd July 2007, viewed 10 December 2007, http://www.afaanz.org/openconf/afaanz/paper.php?p=218.doc

Hunt, C, Staunton, J, & Dunstan, K 2013, 'Equity tension and new public management policy development and implementation in the water industry', *Accounting, Auditing & Accountability Journal*, vol. 26, no. 8, pp. 1342-1377, viewed 5 May 2014, Emerald Insight

Hurlimann, A 2007, 'Time for a water re-'vision'', *Australasian Journal of Environmental Management*, vol. 14, pp. 14-21

Hurlimann, A & Dolnicar, S 2009 'When Public Opposition Defeats Alternative Water Projects - the Case of Toowoomba Australia' *Water Research*, vol. 44, no. 1, pp. 287-297

Hurlimann, A & Dolnicar, S 2010 'Acceptance of water alternative in Australia – 2009,' *Water Science & Technology*, vol. 61, no. 8, pp. 2137-2142

Hurlimann, A, Dolnicar, S & Meyer, P 2009, 'Understanding behaviour to inform water supply management in developed nations – A review of literature, conceptual model and research agenda,' *Journal of Environmental Management*, vol. 91, no.1, pp. 47-56

Hurlimann, AC & McKay, JM 2006, 'What attributes of recycled water make it fit for residential purposes? The Mawson Lakes experience', *Desalination* , vol. 187, pp.167-177

Hurst, D 2011, 'Bligh backflips on water reforms', *Brisbane Times*, 7 April 2011, viewed 8 November 2011, http://www.brisbanetimes.com.au/queensland/bligh-backflips-on-water-reforms-20110407-1d522.html

Hurst, D & AAP 2011, 'Bligh's 'panic' water plan', *Sydney Moring Herald*, 7 April 2011, viewed 8 November 2011, http://www.smh.com.au/environment/water-issues/blighs-panic-water-plan-20110407-1d5or.html

Hutcheson, G & Sofroniou, N 1999, *The multivariate social scientist: Introductory statistics using generalized linear models*, Sage Publications Ltd, London & Thousand Oaks.

IGEM – see Inspector-General Emergency Management

Inspector-General Emergency Management 2015, '*2015 Callide Creek Flood Review Report'*, Queensland Government IGEM, Chapter 4 Managing Dams, updated 4 June 2015, viewed 7 June 2015, https://www.igem.qld.gov.au/reports-and-publications/callide-review-release.html

Intergovernmental Panel on Climate Change (IPCC) 2014, *Climate Change 2014: Impacts, Adaptation, and Vulnerability: Summary for Policymakers* , IPCC WGII AR5, 31 March 2014, viewed 15 April 2014, http://ipccwg2.gov/AR5/images/uploads/IPCC_WG2AR5_SPM_Approved.pdf

IPCC - see Intergovernmental Panel on Climate Change

IUCN - see International Union for the Conservation of Nature

International Union for the Conservation of Nature (IUCN), United Nations Environment Programme (UNEP) & World Wide Fund for Nature (WWF) 1991, *Caring for the Earth: A Strategy for Sustainable Living*, Gland, Switzerland

Jacquot JE 2007, 'Solving South Australia's Water Shortage with Plastic Bladders?', July 9, *Treehugger*, viewed 20 June 2014, http://www.treehugger.com/clean-technology/solving-south-australias-water-shortage-with-plastic-bladders.html

Jakeman, T, Letcher, R & Chen, S 2007, 'Integrated assessment of impacts of policy and water allocation changes across social, economic and environmental dimensions', in K Hussey & S Dovers (eds.), *Managing Water For Australia*, CSIRO publishing, Collingwood, VIC

Jansen, H 2010, 'The Logic of Qualitative Survey Research and its Position in the Field of Social Research Methods', *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research*, vol. 11, no. 2, viewed 14 October 2015, <http://www.qualitative-research.net/index.php/fqs/article/view/1450/2946>.

Jasch, C 2009, *Environmental and material flow cost accounting: principles and procedures*, Springer, New York

John Holland 2013, *Murrumba Downs Alliance*, John Holland, Brisbane, viewed 8 October 2013, http://johnholland.com.au/Documents.asp?ID=13972&ProjectID=30&ProjCont=Details

Johnson, EM & Pyke, DF 1999, *Supply chain management*, July 27 , The Tuck School of Business, Dartmouth College, Hanover, NH, viewed 25 May 2014, http://logmgt.nkmu.edu.tw/news/articles/supply%20chain%20or%20ms.pdf

Johnstone, C 2008, 'Long-term water plans seem politically diluted', *Brisbane Courier Mail*, 26 November, p.29

Jones, PT 2009, 'Material Flows and Mass Balance Analysis in the United Kingdom: Implications for the 10-Year Horizon of Waste Management', *Journal of Industrial Ecology*, vol. 13, no. 6, pp.843-846

Junior, RM, Best, P & Cotter, J 2013, 'Sustainability Reporting and Assurance: A Historical Analysis on a World-Wide Phenomenon', *Journal of Business Ethics*, vol. 120, pp.1-11

Kenway SJ, Lant P & Priestley T 2011, Quantifying water-energy links and related carbon emissions in cities, *Journal of Water and Climate Change*, vol. 2, pp. 247-259

Khan, S, 2007, *Water recycling in Australia - Caboolture IPR Proposal 1996*, environmental engineering research blog, Sydney, 10 November, viewed 26 May 2014, http://waterrecycling.blogspot.com.au/2007/11/caboolture-ipr-proposal-1996.html

Khan, S, 2014, 'A taste for drinking recycled water', *ABC Environment- Opinion*, 6 May, viewed 16 May 2014, http://www.abc.net.au/environment/articles/2014/05/05/3998201.htm

Killoran, M 2013, 'Desal plant haemorrhaging money', *Gold Coast News*, 6 June 2013, viewed 23 April 2014, http://prelive.goldcoast.com.au/article/2013/06/06/452794_gold-coast-news.html

Killoran, M 2014a, 'Moreton Bay and Logan residents paying premium prices for their water', *The Courier Mail*, 9 February 2014, viewed 18 May 2015 http://www.couriermail.com.au/news/queensland/moreton-bay-and-logan-residents-paying-premium-prices-for-their-water/story-fnihsrf2-1226821487480

Killoran, M 2014b, 'Queensland Urban Utilities' pricing scheme for 2014-15 shoes water price hike for southeast Queensland', *The Courier Mail*, 27 March 2014, viewed 26 May 2014, http://www.couriermail.com.au/news/queensland/queensland-urban-utilities-pricing-scheme-for-201415-shoes-water-price-hike-for-southeast-queensland/story-fnihsrf2-1226866518079

Kirby, T 2011, 'Water accounting in Australia', *Chartered Accountants Journal*, July, pp.38-40, viewed 31 July 2013, http://riskaudit.com.au/wp-content/uploads/2011/07/Water-Accounting-Australia.pdf

KPMG Global Sustainability Services & University of Amsterdam 2005, *KPMG International Survey of Corporate Responsibility Reporting 2005*, viewed 13 September 2008, http://www.kpmg.com/Rut2000_prod/Documents/9/Survey2005.pdf

KPMG, 2008, *International Survey of Corporate Responsibility Reporting 2008*, viewed 22 February 2011, https://www.kpmg.com/Global/en/IssuesAndInsights/ArticlesPublications/Documents/International-corporate-responsibility-survey-2008.pdf

KPMG, 2014, *The KPMG Survey of Corporate Responsibility Reporting 2013*, viewed 24 March 2014, http://www.kpmg.com/Global/en/IssuesAndInsights/ArticlesPublications/corporate-responsibility/Documents/corporate-responsibility-reporting-survey-2013.pdf

KPMG, 2014b, *The KPMG Survey of Corporate Responsibility Reporting 2013 – executive summary*, viewed 24 March 2014, http://www.kpmg.com/Global/en/IssuesAndInsights/ArticlesPublications/corporate-responsibility/Documents/corporate-responsibility-reporting-survey-2013-exec-summary.pdf

Lack, B 2012, *Solar Energy to Power Water Desalination Plants*, 12December, The Energy Collective, Brisbane, viewed 10 June 2014, http://theenergycollective.com/dailyenergyreport/155506/solar-energy-power-water-desalination-plants

Lane, J, de Haas, D & Lant, P 2011, *Life Cycle Assessment of the Gold Coast Urban Water System*, September, Urban Water Security Research Alliance, Brisbane, Technical Report No. 52, viewed 21 May 2014, http://www.urbanwateralliance.org.au/publications/UWSRA-tr52.pdf

Lane, J, de Haas, D & Lant, P 2012, *Life Cycle Assessment Perspectives on Wastewater Recycling*, December, Urban Water Security Research Alliance, Brisbane, Technical Report No. 86, viewed 21 May 2014, http://www.urbanwateralliance.org.au/publications/UWSRA-tr86.pdf

Lane, J & Lant, P 2012a, *Using Life Cycle Assessment to Inform Total Water Cycle Management Planning - an Investigation for the Caboolture Catchment,* December, Urban Water Security Research Alliance, Brisbane, Technical Report No. 85, viewed 21 May 2014, http://www.urbanwateralliance.org.au/publications/UWSRA-tr85.pdf

Lane, J & Lant, P 2012b, *Application of Life Cycle Assessment to Wastewater Systems Planning* , December, Urban water Security Research Alliance, Brisbane, Technical Report No. 97, viewed 21 May 2014, http://www.urbanwateralliance.org.au/publications/UWSRA-tr97.pdf

Lappeman, S 2011, 'Water War win -- councils get power back', *Gold Coast News*, 7 April, viewed 8 November 2011, http://www.goldcoast.com.au/article/2011/04/07/306211_gold-coast-news.html

Law, Y, Ye, L, Pan, Y and Yuan, Z 2012, 'Nitrous oxide emissions from wastewater treatment processes', Philosophical Transactions of the Royal Society B, vol. 367, pp.1265-1277, viewed 7 June 2015, http://www.researchgate.net/profile/Yingyu_Law/publication/221982585_Nitrous_oxide_emissions_from_wastewater_treatment_processes/links/54eb0c710cf27a6de115f4fe.pdf

Leviston, Z, Nancarrow, BE, Tucker DI & Porter NB 2006, *Predicting community behaviour: indirect potable reuse of wastewater through managed aquifer recharge*, September, CSIRO Land and Water report 29/06, viewed 2 December 2013, http://www.clw.csiro.au/publications/science/2006/sr29-06.pdf

Lewandowsky, S, Gignac, GE & Vaughan, S 2013, 'The pivotal role of perceived scientific consensus in acceptance of science', *Nature Climate Change*, vol.3, pp. 399-404

Lewandowsky, S, Oberauer, K & Gignac, GE 2013, 'NASA Faked the Moon Landing-Therefore, (Climate) Science Is a Hoax: An Anatomy of the Motivated Rejection of Science', *Psychological Science*, vol. 24, pp. 622-633

Lion, P & AAP 2011, 'Tugun Desalination Plant to be mothballed, execs face axe in bid to cut water bills', *The Sunday Mail (Qld)*, 5 December 2011, viewed 17 March 2011, http://www.couriermail.com.au/news/queensland/tugan-desalination-plant-to-be-mothballed-execs-face-axe/story-e6freoof-1225965891248

Lim, M-H & Seah, H 2013, 'NEWater: A key element of Singapore's water sustainability', in Lazarova, V, Asano, T, Bahri, A & Anderson, J (eds), *Milestones in Water Reuse – The best success stories*, IWA Publishing, London

Lewis, R & Belz, P 2011, *Presentation to Australian Water Association technical Meeting*, Queensland Urban Utilities, 9 February 2011, viewed 30 March 2011 http://www.awa.asn.au/uploadedFiles/20110209_AWA_Technical%20Meeting%20%5BCompatibility%20Mode%5D.pdf

Local Government News (admin) 2013, *Regional population growth back on Queensland's agenda – LGAQ*, Local Government News, October 11 2013, viewed 14 October 2013, http://www.lgnews.com.au/regional-population-growth-back-queenslands-agenda-lgaq/

Logan West Leader 2011, 'On the road in Logan today', 11 January 2011, viewed 20 February 2012, http://logan-west-leader.whereilive.com.au/news/story/on-the-road-in-logan-today/

Loomis, JB, 2000, 'Environmental Valuation Techniques in Water Resource Decision Making', *Journal of Water Resources Planning and Management*, November/December pp.339-344

Macpherson, L & Snyder, S (WateReuse) 2012, *Downstream: Research to Shift Community Attitudes on Water Reuse: WRF 09-01: Effect of prior knowledge of unplanned potable reuse on the acceptance of planned potable reuse -Illustrated executive summary*, 16 May, WateReuse Association, Washington, viewed 15 May 2014, https://www.watereuse.org/sites/default/files/u8/Downstream%2520Research_0.pdf

Malhotra, NK 2007 *Marketing Research: An applied orientation*, 5th edn., Pearson Prentice Hall, Upper Saddle River NJ

Marks, JS, Martin, B, & Zadoroznyj, M 2006 'Acceptance of water recycling in Australia: National baseline data', *Water Journal of the Australian Water Association*, vol. 33, pp.151-157

Marks, JS, Martin, B & Zadoroznyj, M 2008 'How Australians order acceptance of recycled water: National baseline data', *Journal of Sociology*, vol. 44, no. 1, pp.83-99

Marks, G & Miller, N 1987, 'Ten years of research on the false consensus effect: an empirical and theoretical review', *Psychological Bulletin*, vol. 102, pp.72-90

Marsden Jacob Associates 2013, *Economic viability of recycled water schemes*, Australian Water Recycling Centre of Excellence, November 2013, viewed 31 May 2015, file:///C:/Users/cjames/Documents/research/2015/to%20add/20131113_Economic+viability+of+recycled+water+schemes+MJA+report.pdf

Marsden Jacob Associates 2014a, *Economic viability of recycled water schemes—Technical Report 1: The value of recycled water infrastructure to the residents of Rouse Hill*, Australian Water Recycling Centre of Excellence, March 2014, viewed 31 May 2015, file:///C:/Users/cjames/Documents/research/2015/to%20add/Value+of+recycled+water+infrastructure+to+the+residents+of+Rouse+Hill%20(1).pdf

Marsden Jacob Associates 2014b, *Economic viability of recycled water schemes—Technical Report 2: Community values for recycled water in Sydney*, Australian Water Recycling Centre of Excellence, March 2014, viewed 31 May 2015, file:///C:/Users/cjames/Documents/research/2015/to%20add/135515141029UW_Class_A+_Recycled_Water_Fact_Sheet_-_residential.pdf

Marsden Jacob Associates 2014c, *Economic viability of recycled water schemes—Technical Report 3 Environmental and social values associated with non-potable recycled water*, Australian Water Recycling Centre of Excellence, March 2014, viewed 31 May 2015, file:///C:/Users/cjames/Documents/research/2015/to%20add/Environmental+and+social+values+associated+with+non-potable+recycled+water.pdf

Matthews, OP, Brookshire, DS. & Campana, ME (eds) 2001, *The Economic Value of water: Results of a workshop in Caracas, Venezuela, November 2000*, August, Water Resources Program, University of New Mexico, Publication No. WRP-4, viewed 20 May 2014, http://www.unm.edu/~wrp/wrp-4.pdf

Maywald, K 2014, Message from the Chair of the National Water Commission Karlene Maywald, *Distilled, ENews letter*, National Water Commission, 16 May, viewed 19 May 2014, http://www.nwc.gov.au/newsletter/may-2014

MBRC – See Moreton bay regional Council

McArdle, P, Gleeson, J, Hammond, T, Heslop, E, Holden, R & Kuczera, G 2011, ‘Centralised urban stormwater harvesting for potable reuse’, *Water Science & Technology*, vol. 63, issue 1, pp16-24.

McConchie R 2015, *Queensland drought spreads to record 80 per cent of the state*, ABC Rural, updated 14 May 2015, viewed 27 May 2015, http://www.abc.net.au/news/2015-05-13/qld-drought-spreads-to-record-80-per-cent/6467438

McCutcheon P 2007 (reporter), *South-east Qld introduces level 5 water restrictions* , television program transcript, 7.30 report, ABC, Brisbane, 10 April, viewed 8 May 2014, http://www.abc.net.au/7.30/content/2007/s1893859.htm

McDonald, RP 1985, *Factor analysis and related methods*, Hillsdale NJ, Erlbaum.

McGregor J & Sturmer J 2014, *UN climate change report card: Scientists predict Australia will continue to get hotter*, ABC News, Monday 24 March 2014, viewed 22 April 2014, http://www.abc.net.au/news/2014-03-23/ipcc-working-group-ii-report-climate-change-australia/5339654

McKinnon, J 1988, ‘Reliability and validity in field research: Some strategies and tactics’, *Accounting, Auditing and Accountability*, vol.1, no 1, pp.34–54

McLeod, DM, Eveland WP & Nathanson AI 1997, ‘Support for censorship of violent and misogynic rap lyrics: An analysis of the third-person effect’, *Communication Research*, vol.24, no 2, pp.153–174, viewed 24 June 2014, Sage Journals, doi:10.1177/009365097024002003

Meadows, DH 2009, *Thinking in Systems: A Primer*, Earthscan, London

Melbourne Water 2015, Sewage treatment process, viewed 7 June 2015, http://www.melbournewater.com.au/whatwedo/treatsewage/wtp/Pages/Sewage-treatment-process.aspx

Menegaki, AN, Mellon, RC, Vrentzou, A, Koumakis G, Tsagarakis, KP 2009, ‘What’s in a name: Framing treated wastewater as recycled water increases willingness to use and willingness to pay’, *Journal of Economic Psychology*, Vol. 30, no. 3, pp. 285-292, viewed 4 June 2014, Science Direct, http://dx.doi.org/10.1016/j.joep.2008.08.007

Merriam, SB 2009, *Qualitative research: A guide to design and Implementation*, 3rd edn, Jossey-Bass, San Francisco

Miles, MB & Huberman, AM 1994, *Qualitative data analysis: An expanded sourcebook*, Sage Publications, Thousand Oaks

Miller, E & Buys, L 2008, 'Water-recycling in South East Queensland, Australia: What do men and women think?', *Rural Society*, vol. 18, no. 3, pp.220-229

MJA – see Marsden Jacob Associates

Mooney, C & Stenekes N 2008, *An analysis of the social aspects of establishing agricultural recycled water schemes; social perspective on water*, 29 August, Australian Government Bureau of Rural Sciences, viewed 19 May 2014, file:///C:/Users/cjames/Downloads/60b7d5141630777180%20(1).pdf

Mooney, C & Tan P 2012, 'South Australia's River Murray: Social and cultural values in water planning', *Journal of Hydrology*, 12 Dec 2012, vol 474 pp.29-37, viewed 2 May 2014, ScienceDirect

Moore, T 2011, 'Council ready to resume water responsibility', *Brisbane Times*, 7 April, viewed 8 November 2011, http://www.brisbanetimes.com.au/queensland/council-ready-to-resume-water-responsibility-20110407-1d5d6.html

Moreton Bay Regional Council 2010a, MBRC, Caboolture, viewed 3 March 2010, https://www.moretonbay.qld.gov.au/general.aspx?id=7421

Moreton Bay Regional Council 2010b, *Caboolture River Recovery Plan – Stage 1: Action Plan*, Moreton Bay Regional Council & Caboolture River Recovery Steering Committee, Caboolture, viewed 6 June 2015, https://www.moretonbay.qld.gov.au/uploadedFiles/common/projects/Caboolture-River-Recovery-Plan.pdf

Moreton Bay Regional Council 2013, *Caboolture River Recovery Plan*, MBRC, Caboolture, viewed 8 January 2013, http://www.moretonbay.qld.gov.au/general.aspx?id=89942&libID=95840

Moreton Bay regional Council, 2015, '*Community profile- Caboolture District (2011 census)*', MBRC profile ID, viewed 7 June 2015, http://profile.id.com.au/moreton-bay/about/?WebID=100

Myers, N 1993, 'Environmental Refugees in a Globally Warmed World', *BioScience*, vol. 43, no. 11, pp.752-754 viewed 23 April 2014, EBSCOhost MegaFILE Complete, Academic Search Complete, item: AN9403310150

Nancarrow, BE, Leviston, Z, Tucker, D, Greenhill MP, Price, J & Dzidic P 2007, *Community acceptability of the indirect potable use of purified recycled water in south east Queensland and preferences for alternative water sources: A baseline measure*, November, Urban water Security Research Alliance, Brisbane, Technical Report No. 1, viewed 19 May 2014, http://www.urbanwateralliance.org.au/publications/UWSRA-tr1.pdf

National Greenhouse and Energy Reporting Act 2007 (NGER Act), Australian Government Commonwealth Law, viewed 9 June 2014, http://www.comlaw.gov.au/Series/C2007A00175

National Water Commission 2008, *Urban Water pricing: National Water Commission Position*, 27 August, NWC, Canberra, viewed 28 September 2015, http://archive.nwc.gov.au/__data/assets/pdf_file/0019/9730/7._Urban_Water_Pricing_-_PS1.pdf

National Water Commission 2011a, *Review of pricing reform in the Australian water sector, NWC, Canberra*, 18 April 2011, viewed 28 September 2015, http://archive.nwc.gov.au/__data/assets/pdf_file/0019/18055/review_of_pricing_reform.pdf

National Water Commission 2011b, *National Water Initiative*, NWC website, Viewed 14 March 2011, http://www.nwc.gov.au/www/html/117-national-water-initiative.asp

National Water Commission 2011c, *Water Accounting Development Committee*, NWC, viewed 18 March 2011, http://www.nwc.gov.au/www/html/246-water-accounting-development-committee.asp?intSiteID=1

National Water Commission 2013, *Strategic Plan 2013-16*, NWC, 11 July, Viewed 9 May 2014, http://www.nwc.gov.au/__data/assets/pdf_file/0011/23213/Strategic-Plan-2013-16.pdf

National Water Initiative - see Council of Australian Governments 2004

Newman, C & McArdle M 2014 (QLD Premier & Minister for Energy and Water Supply), *Changes to Wivenhoe Dam operations*, joint media statement, 1 April, viewed 7 May 2014, http://statements.qld.gov.au/Statement/2014/4/1/changes-to-wivenhoe-dam-operations

News.com.au 2014, 'El Niño has been forecast to return in 2014 and it could be a big one', 8 May, viewed 9 May 2014, http://www.news.com.au/technology/environment/el-nio-has-been-forecast-to-return-in-2014-and-it-could-be-a-big-one/story-fnjwvztl-1226910244082

Nickerson, R 1998, 'Confirmation Bias: A Ubiquitous Phenomenon in Many Guises', *Review of General Psychology*, vol. 2, no. 2, pp.175-220, viewed 18 May 2014 , http://psy2.ucsd.edu/~mckenzie/nickersonConfirmationBias.pdf

NWC – see National Water Commission

NWI – see National Water Initiative (and Council of Australian Governments 2004)

Oels, A & Zelli, F 2015, *Lessons from international relations theories*, video file in Climate Change: a question of justice?, Lund University infernum MOOC Unit 2, International climate governance: understanding the deadlock, 17 September 2015, University of Lund and FernUniversität in Hagen, viewed 5 October 2015, https://www.youtube.com/watch?v=CpyCzwiz4H4

Office of Government Commerce (OGC) 2007 , *Managing Successful Programmes*, The Stationery Office (TSO), London

Oreskes, N & Conway, E.M. 2010, *Merchants of Doubt: How a handful of scientisits obscured the truth on issues from tobacco smoke to global warming,* Bloomsbury, New York.

Oxford University Press (OUP) 2016, Oxford Dictionaries Language Matters, OUP, Oxford, viewed 3 June 2016, http://www.oxforddictionaries.com/definition/english/social

Pagell, M & Wu, Z 2009, 'Building a more complete theory of sustainable supply chain management using case studies of ten exemplars', *Journal of Supply Chain Management*, vol. 45, no. 2, pp.37-56

Pallant, J 2011, *SPSS Survival Manual: A Step by Step Guide to Data Analysis Using the SPSS Program*, 4th edn, Allen & Unwin, Crows Nest NSW

Palmer, B. 2009, *Water Accounting – Climate Change Factsheet 1*, Institute of Chartered Accountants in Australia (ICAA), 10 September 2009,viewed 29 April 2014, file:///C:/Users/cjames/Downloads/WaterAccountingFactsheet%20(1).pdf

Pattberg, P & Widerberg, O 2015, 'Theorising Global Environmental Governance: Key Findings and Future Questions', *Millennium: Journal of International Studies,* vol. 43, no. 2, pp.684-705, viewed 6 October 2015, http://mil.sagepub.com/content/43/2/684.full.pdf+html

Patton, MQ 2002, *Qualitative Research & Evaluation Methods,* 3rd edn, Sage Publications Inc, Thousand Oaks

Pawsey, N & Crase, L 2013, 'The Mystique of Water pricing and Accounting' *Economic Papers*, Vol.32, no.3. pp. 328-339, viewed 5 May 2014, EBSCOhost MegaFILE Complete, Academic search Complete, item: AN: 90429724

Peattie, K 2011, 'Developing and delivering social science research for sustainability', in Franklin, A & Blyton, P (eds), *Researching Sustainability: A guide to social science methods, practice and engagement'*, Earthscan, London

Phillips, S 2013, 'Abbott's climate change strategy holds no surprises', ABC News - The Drum TV, September 20, viewed 26 June 2016, http://www.abc.net.au/news/2013-09-20/phillips-abbott-environment-no-surprises/4970328

Pipe-Martin, C, Reungoat, J & Keller, J 2010, *Dissolved Organic Carbon Removal by Biological Treatment*, The Cooperative Research Centre for Water Quality and Treatment, research report 76, viewed 26 May 2014, file:///C:/Users/cjames/Downloads/report76_DOC_removal.pdf

Po, M, Kaercher, J & Nancarrow, B 2003, 'Literature review of factors influencing public perceptions of water reuse', *CSIRO Land and Water Technical Report 54/03,* December, viewed 18 May 2009, http://www.clw.csiro.au/publications/technical2003/tr54-03.pdf

Porter, M 1980, *Competitive Strategy*, The Free Press, New York

Porter, RC 2002, *The Economics of Waste*, Resources For the Future (RFF) Press, Washington

Prevos, P 2013, *The Yuck Factor: The Psychology of Drinking Recycled Water*, 27 May, The Invisible Water Utility, viewed 4 June 2014, http://water.prevos.net/yuck-factor/

Price, J, Fielding, K, Leviston, Z, Bishop, B, Nicol, S, Greenhill, M & Tucker, D 2010, *Community Acceptability of the Indirect Potable Use of Purified Recycled Water in South East Queensland: Final Report of Monitoring Surveys*, June, Urban Water Security Research Alliance, Technical Report No. 19, viewed 21 May 2014, http://www.urbanwateralliance.org.au/publications/UWSRA-tr19.pdf

Price, J, Green, M, Gardner, J, Leviston, Z & Fielding, K 2012, *Communication and Community Responses to Recycled Water Study 2: The Role of Issue Relevance and Risk/Benefit Information*, December, Urban Water Security Research Alliance, Brisbane, Technical Report No. 98, viewed 21 May 2014, http://www.urbanwateralliance.org.au/publications/UWSRA-tr98.pdf

Productivity Commission 2011, *Australia's Urban Water Sector*, Australian Government Productivity Commission Inquiry Report, 31 August, vol. 1, no. 55, viewed 19 may 2014, http://pc.gov.au/projects/inquiry/urban-water/report

QCA – see Queensland Competition Authority

QGSO - see Queensland Government Statistician's Office

Queensland Government Statistician's Office 2014, *Population growth, Regional Queensland, 2012-13*, Queensland Treasury and Trade, QGSO (ABS 3218.0) 3 April 2014, viewed 23 April 2014, http://www.qgso.qld.gov.au/products/reports/pop-growth-reg-qld/pop-growth-reg-qld-2012-13.pdf

Queensland Water Commission 2008a, *Water Efficiency Management Plans*, QWC, Brisbane, viewed 5 November 2008, http://www.qwc.qld.gov.au/Information+and+resources+-+Water+Efficiency+Management+Plans

Queensland Water Commission 2008b, *Water for today, water for tomorrow: South East Queensland Water Strategy (Draft)*, QWC, Brisbane, viewed 18 May 2009, http://www.qwc.qld.gov.au/myfiles/uploads/SEQWS/SEQWaterStrategy-Draft.pdf

Queensland Water Commission 2010, *South East Queensland Water Strategy*, QWC, Brisbane, viewed 15 May 2011, http://www.qwc.qld.gov.au/planning/pdf/seqws-full.pdf

Queensland Water Commission 2010b, *Water Reform*, QWC, Brisbane, updated 17 September 2010, viewed 15 March 2011, http://www.qwc.qld.gov.au/reform/seq.html

Queensland Water Commission 2011a, *Bulk Water prices*, QWC, Brisbane, viewed 16 March 2011, http://www.qwc.qld.gov.au/reform/bulkwaterprices.htm

Queensland Water Commission 2011b, QWC, Brisbane, viewed 15 April 2011, http://www.qwc.qld.gov.au/

Quiggin, J 2011, ‘Murray-Darling Basin – Future in the balance for nation’s breadbasket’, *Connections*, Issue 1, The University of Queensland Faculty of Business, Economics and Law

QWC -see -Queensland Water Commission

Rahmstorf, S 2013, *Sea level in the 5th IPCC report*, 15 October 2013, RealClimate, viewed 5 May 2014, http://www.realclimate.org/index.php/archives/2013/10/sea-level-in-the-5th-ipcc-report/

Readfearn, G 2014, ‘What does Australian prime minister Tony Abbott really think about climate change?’, *The Guardian (Australia Edition)*, 16 June, viewed 26 June 2016, https://www.theguardian.com/environment/planet-oz/2014/jun/16/what-does-australian-prime-minister-tony-abbott-really-think-about-climate-change

Recycled water in Australia 2014, *Environmental allocation*, viewed 15 May 2014, http://www.recycledwater.com.au/index.php?id=38

Reed, MS, Graves, A, Dandy, N, Posthumus, H, Hubacek, K, Morris, J, Prell, C, Quinn, CH & Stringer LC 2009, ‘Who’s in and why? A typology of stakeholder analysis methods for natural resource management’, *Journal of Environmental Management*, vol. 90, no.5, pp. 1933-1949, viewed 3 June 2014, Sciencedirect, Item http://dx.doi.org.ezproxy.usq.edu.au/10.1016/j.jenvman.2009.01.001

Reungoat, J, Macova, M, Escher, BI, Carswell, S, Mueller, JF & Keller, J 2010a, 'Removal of Micropollutants and reduction of biological activity in a full scale reclamation plant using ozonation and activated carbon filtration', *Water Research*, vol. 44, no. 2, pp. 625-37

Reungoat, J, Macova, M, Carswell, S, Escher, BI, Mueller, JF, Gernjak, W & Keller, J 2010b, 'Effective Removal of pathogens and micropollutants by Ozone and GAC’, *Water*, vol. 37, no. 1, pp.69-72

Reungoat, J, Escher, B, Macova, M, Farré, M.J, Argaud, FX, Rattier, M, Gernjak, W & Keller, J 2012a, *Wastewater Reclamation using Ozonation combined with Biological Activated Carbon Filtration*. Urban Water Security Research Alliance Technical Report No. 69, Brisbane, viewed 19 May 2014, http://www.urbanwateralliance.org.au/publications/UWSRA-tr69.pdf

Reungoat, J, Escher, BI, Macova, M, Argaud, FX, Gernjak, W & Keller, J 2012b, ‘Ozonation and biological activated carbon filtration of wastewater treatment plant effluents’ *Water Research*, vol. 44, 1 March 2012, pp.863-872, viewed 7 June 2015, Science Direct, DOI: 10.1016/j.watres.2011.11.064

Roberts, G 2009, ‘Spilt sewage in Queensland fuels fears on recycled water’, *The Australian*, January 30, viewed 27 May 2014, http://www.theaustralian.com.au/archive/news/spilt-sewage-fuels-water-fears/story-e6frg6oo-1111118706158

Rogers, EM 1962 , *Diffusion of Innovations*, Free Press of Glencoe, New York

Rogers, EM 2003, *Diffusion of Innovations*, 5th ed., Free Press, New York

Russell, S. & Fielding, K. 2010, 'Water demand management research: A psychological perspective', *Water Resources Research*, vol. 46, no.5, viewed 13 May 2014, American Geophysical Union Digital Library, Wiley Online Library, item W05302: DOI:10.1029/2009WR008408

Russell, S & Lux, C 2009, 'Getting over yuck: moving from psychological to cultural and sociotechnical analyses of responses to water recycling', *Water Policy*, vol. 11, no. 1, pp. 21-35, viewed 4 June 2014, Academic Search Complete, doi:10.2166/wp.2009.007

Saunders, M, Lewis, P & Thornhill, A 2007, *Research Methods for Business Students,* 4th edn, Prentice Hall Inc., Englewood Cliffs N.J.

SA Water 2013, *Pricing Policy Statement Recycled Water and Stormwater* , SA Water, Adelaide, 27 May, viewed 16 May 2014, http://www.sawater.com.au/NR/rdonlyres/88CA5154-2389-4E0B-9B5F-6019B9016DE8/0/PricingPolicyStatementRecycledandStormwater.pdf

Schatzman, L& Strauss, A 1973, *Field Research – Strategies for a Natural Sociology*, Prentice Hall Inc., Englewood Cliffs N.J.

Seager, TP 2008, 'The sustainability spectrum and the sciences of sustainability', *Business Strategy and the Environment*, vol. 17, pp.444-453

SEQWater 2009a, *Business Water Efficiency Program (BWEP),* SEQWater, Brisbane, viewed 17 May 2009, http://oldsite.seqwater.com.au/files/pdf/1725-SEQ-WaterEffecRegBroc[web].pdf

SEQWater 2009b, *News*, SEQWater, Brisbane, viewed 17 May 2009, http://210.247.169.26/newsite/

SEQWater 2010, SEQWater, Brisbane, viewed 28 September 2010, http://www.seqwater.com.au/public/home

SEQWater 2011, *Latest dam levels*, SEQWater, Brisbane, viewed 14 April 2011, http://www.seqwater.com.au/public/dam-levels

SEQWater 2014, *Latest dam levels- Water security & consumption update - 9 May 2014*, SEQWater, Brisbane, viewed 12 May 2014, http://www.seqwater.com.au/latest-updates/news/2014/05/09/water-security-consumption-update-9-may-2014

SEQWater 2014b, *Water Outlook for South East Queensland*, SEQWater, Brisbane, December 2014, viewed 31 May 2015, http://www.seqwater.com.au/sites/default/files/PDF%20Documents/Publications/2014%20Water%20Outlook%20-%20FINAL.pdf

SEQWater 2015, *Desalination*, SEQWater, Brisbane, viewed 28 September 2015, http://www.seqwater.com.au/water-supply/water-treatment/desalination

Seuring, S 2004, ‘Integrated chain management and supply chain management comparative analysis and illustrative cases’, *Journal of Cleaner Production*, vol. 12, pp.1059-1071

Shatanawi M & Naber S 2011 ‘Valuing water from social, economic and environmental perspective’, in Junier S, El Moujabber, M, Trisorio-Liuzzi, G, Tigrek, S, Serneguet, M, Choukr-Allah, R, Shatanawi M & Rodríguez, R (eds), *Dialogues on Mediterranean water challenges: Rational water use, water price versus value and lessons learned from the European Water Framework Directive*. Bari : CIHEAM, 2011. p. 109-117. (Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 98) viewed 2 May 2014, http://om.ciheam.org/om/pdf/a98/00801473.pdf

Silby, H 2006, ‘Efficient Urban Water pricing’, *The Australian Economic Review*, vol.39, no. 2, pp. 227-37, EBSCHost, Academic Search Complete, AN: 21194540, viewed 5 may 2014

Skipworth, P, Cashman, A, Saul, A, Walters, G, Savic, D & Engelhardt, M 2002, *Whole Life Costing for Water Distribution Network Management*, Thomas Telford Ltd, London

Smith, C 2014, ‘National Water Commission releases final report, warns government not to backtrack on water reform’, *ABC News*, 20 October 2014, viewed 31 May 2015, http://www.abc.net.au/news/2014-10-20/final-national-water-commission-report-advises-against-changes/5826790

Söderqvist, T & Soutukorva, Å 2009, ‘On how to assess the quality of environmental valuation studies’, *Journal of Forest Economics*, vol. 15, pp.15-36

Spencer, L 2013, ‘160 jobs to go in Amcor paperboard mill closure’, *Print 21*, 18 February, viewed 29 May 2014, http://print21.com.au/amcor-closes-queensland-paperboard-mill/56738

Stake, RE 1995, *The art of case study research*, Sage, Thousand Oaks, CA

Stern, N 2006, *Stern Review on the Economics of Climate Change*, HM Treasury, UK 30 October 2006, viewed 1 May 2014, http://www.webcitation.org/5nCeyEYJr

Stern, Sir Nicholas 2013, *Our time is now or never*, online video of talk by Nicholas Stern, Greening Campaign, FilmingTheWorld73, published 2 April 2013, viewed 10 April 2014, http://www.youtube.com/watch?v=0S-QcOsOoRs

Strand, R 2009, ‘Corporate Responsibility in Scandinavian Supply Chains’, *Journal of Business Ethics*, vol. 85, pp.179-185

Stolz, G 2010, ‘Tanks still rusting at Tugun desalination plant’, *Courier Mail*, 27 April 2010, viewed 21 October 2012, http://www.couriermail.com.au/news/queensland/tanks-still-rusting-at-tugun-desalination-plant/story-e6freoof-1225858506567

Stolz, G 2012, ‘Dud desalination plant at centre of $8.2 million lawsuit as operators take on Lloyds of London’, *Courier Mail*, 8 September 2012,viewed 21 October 2012, http://www.couriermail.com.au/news/national/dud-desalination-plant-at-centre-of-82-million-lawsuit-as-operators-take-on-lloyds-of-london/story-fndo1yus-1226467596650

Strand, R 2009, ‘Corporate Responsibility in Scandinavian Supply Chains’, *Journal of Business Ethics*, 2009, vol. 85, pp.179-185

Stripple, J 2015, Shaping the low carbon self, video file in Climate Change: a question of justice?, Lund University infernum MOOC Unit 4, Carbon markets, 19 October 2015, University of Lund and FernUniversität in Hagen, viewed 19 October 2015, https://www.youtube.com/watch?v=-8ipwiehFQE

Sydney Water 2014, *Desalination: changing ocean water into drinking water – How is desalination powered?*, Sydney Water, Parramatta, viewed 10 June 2014, http://www.sydneywater.com.au/sw/teachers-students/facts-about-water/secondary-students/how-does-water-get-to-our-taps-/desalination/index.htm

Taylor, A 2010, *SEQ population trends update*, Queensland Treasury Office of Economic and Statistical Research, 11 May 2010, viewed 31 March 2011, http://www.oesr.qld.gov.au/products/presentations-papers/seq-pop-trends-update/seq-pop-trends-update.pdf

Teddlie, C & Tashakkori, A 2009, *Foundations of Mixed Methods Research*, Sage Publications, Thousand Oaks, CA

The Age 2007, ‘Drought puts pressure on electricity’, 19 May, viewed 15 April 2014, http://www.theage.com.au/news/national/drought-threat-to-power-supply/2007/05/19/1179497318748.html

The Age 2014, ‘Changing climate: from debate to leadership,’ The Age Comment, 4 April, viewed 10 April 2014, http://www.theage.com.au/comment/the-age-editorial/changing-climate-from-debate-to-leadership-20140403-361lq.html

The Chronicle 2011, ‘Recycled water poll: five years on’, The Chronicle, 13 August, viewed 6 May 2014, http://www.thechronicle.com.au/news/toowoomba-recycled-water-poll-five-years-later/1066451/

The Sunday Mail (Qld) 2014, ‘US President Barack Obama’s Brisbane Speech at the University of Queensland’, 15 November, edited transcript of speech by Barack Obama, viewed 8 October 2015, http://www.couriermail.com.au/news/queensland/us-president-barack-obamas-brisbane-speech-at-the-university-of-queensland/story-fnmd7bxx-1227124334189

The Sydney Morning Herald 1947, ‘Worst Queensland Floods for Fifty Years’, SMH, 27 January , viewed 9 May 2014, http://trove.nla.gov.au/ndp/del/article/18011184

The Treasury 2015, *2015 Intergenerational Report Executive Summary*, Australian Government The Treasury, 5 March 2015, viewed 4 June 2015, http://www.treasury.gov.au/PublicationsAndMedia/Publications/2015/2015-Intergenerational-Report

Thomas, H 2011, ‘Engineer's emails reveal Wivenhoe Dam releases too little, too late’, *The Australian*, Melbourne, 21 January 2011, viewed 16 March 2011, http://www.theaustralian.com.au/in-depth/queensland-floods/engineers-emails-reveal-wivenhoe-dam-releases-too-little-too-late/story-fn7iwx3v-1225991990957

Trenwith, C 2012, ‘We want to drink recycled water: survey’, *WA Today*, 23 March, viewed 15 May 2014, http://www.watoday.com.au/wa-news/we-want-to-drink-recycled-water-survey-20120323-1vpct.html

Tucker, SN 2001, ‘Life Cycle Costing of Urban Water Systems’, *CSIRO Forum*, Melbourne

Tucker, SN, Mitchell, VG & Burn, LS (CSIRO) 2000, ‘Life Cycle Costing of Urban Water Systems’, *Water: Journal of the Australian Water Association*, vol. 27, no. 5

Tuttiet, H & Killoran, M 2011, ‘How the water war is unfolding’, *Gold Coast News*, 4 February 2011, viewed 14 march 2011, http://www.goldcoast.com.au/article/2011/02/04/289401_news.html

Tversky, A & Kahneman, D 1974, ‘Judgement under uncertainty: Heuristics and biases’, *Science*, vol. 185, pp.1124-1130

UEA - see -Urban Ecology Australia

UNFCCC: United Nations Framework Convention on Climate Change 2008, *Australia*, viewed 1 May 2008, http://maindb.unfccc.int/public/country.pl?country=AU

UNFCCC: United Nations Framework Convention on Climate Change 2012, *Benefits of the Clean Development Mechanism 2012*, viewed 32 January 2013, http://cdm.unfccc.int/about/dev_ben/ABC_2012.pdf

United Nations Climate Change Clean Development Mechanism 2013, *Kyoto Protocol’s clean development mechanism surpasses 6,000 projects*, CDM News Release, Bonn, 30 January 2013, viewed 31 January 2013, https://cdm.unfccc.int/press/releases/2013_01.pdf

United Nations Climate Change Clean Development Mechanism 2015, *CDM Projects*, viewed 31 May 2015, http://cdm.unfccc.int/index.html

Uhlmann, V & Head, BW 2011 *Water Recycling: Recent History of Local Government Initiatives in South East Queensland*, Urban Water Security Research Alliance Technical Report No. 45, Brisbane, viewed 19 May 2014, http://www.urbanwateralliance.org.au/publications/UWSRA-tr45.pdf

UnityWater 2010a, *Recycled Water*, Fact Sheet, 29 July 2010, viewed 31 July 2010, http://www.unitywater.com/media/scripts/doc_download.aspx?did=159

Unitywater 2011, *Murrumba Downs Sewage Treatment Plant Upgrade*, Unitywater, Caboolture, viewed 31 January 2011, http://www.unitywater.com/Murrumba-Downs-Sewage-Treatment-Plant.aspx

Unitywater 2014, *No change to structure for water and sewerage services*, media release, 10 March, Unitywater, Caboolture, viewed 9 May 2014, http://www.unitywater.com.au/news.aspx?NewsID=383

UnityWater 2014b, *Recycled Water*, Fact Sheet, 21 July 2014, viewed 16 September 2014, http://unitywater.com/Water-services/Using-recycled-water.aspx

University of Queensland 2014a, Think 101 Episode 10 – Applied Thinking: Conversation with Stephan Lewandowsky, uploaded 11 May, online video, viewed 18 May 2014, https://www.youtube.com/watch?v=c7CwGHtU2U4

University of Queensland 2014b, Think 101 Episode 10 – Applied Thinking: Belief in conspiracy theories, uploaded 11 May, online video, viewed 18 May 2014, https://www.youtube.com/watch?v=k7kUWilEPvU

UNWCED: United Nations World Commission on Environment and Development 1987, *Our Common Future [Brundtland Report]*, Oxford University Press, Oxford, UK, viewed 15 April 2014, http://www.un-documents.net/wced-ocf.htm or http://www.un-documents.net/our-common-future.pdf

Urban Ecology Australia 2006, *Water costing*, updated 13 June 2006, viewed 11 June 2008, http://www.urbanecology.org.au/topics/watercosting.html (quoting Tucker, SN, Mitchell, VG & Burn, LS, *Life cycle costing of urban water systems*, CSIRO).

Urban Ecology Australia 2007, *Water pricing*, updated 2 July 2007, viewed 11 June 2008, http://www.urbanecology.org.au/topics/waterpricing.html

UrbanUtilities 2014, *Frequently asked questions - Water restrictions*, Queensland UrbanUtilities, Fortitude Valley, Brisbane, viewed 8 May 2014, http://www.urbanutilities.com.au/FAQs/Water_restrictions/

Urban Water Security Research Alliance 2012, *5 Years of Urban Water Research in South East Queensland 2007-12*, UWSRA, Brisbane, viewed 20 May 2014, http://www.urbanwateralliance.org.au/publications/UWSRA-final-synthesis-report.pdf

UWSRA - see Urban Water Security Research Alliance

Van der Stede, WA, Young, SM & Chen, CX 2007, 'Doing Management Accounting Survey Research', in Chapman, CS, Hopwood, AG & Shields, MD (eds), *Handbook of Management Accounting Research*, vol. 1, pp.445-478, Elsevier Ltd, Oxford.

Vidot, A 2014a, 'National Water Commission abolished', *ABC Rural*,13 May, viewed 13 May 2014, http://www.abc.net.au/news/2014-05-13/budget-water/5430960

Vidot, A 2014b, 'Conservation Foundation wants Water Commission reprieve, *ABC Rural*, 22 April, viewed 13 May 2014, http://www.abc.net.au/news/2014-04-22/acf-water-commission/5403944

Vogler, S 2013, 'Southeast Queensland water restrictions lifted but higher use will cost residents', *The Courier-Mail,* 2 January, viewed 9 May 2014, http://www.couriermail.com.au/news/queensland/southeast-queensland-water-restrictions-lifted-but-higher-use-will-cost-residents/story-e6freoof-1226546322363

Vogler, S 2014, 'State Government investigating building new dams, raising Wivenhoe Dam wall to prevent flooding in Brisbane, Ipswich', *The Courier-Mail,* 2 April, viewed 7 May 2014, http://www.couriermail.com.au/news/queensland/state-government-investigating-building-new-dams-raising-wivenhoe-dam-wall-to-prevent-flooding-in-brisbane-ipswich/story-fnihsrf2-1226871546760

Ward, FA, Roach, BA & Henderson, JE 1996, 'The Economic Value of Water in Recreation: Evidence from the California Drought', *Water Resources Research,* vol. 32, no.4, pp.1075-1081, Wiley Online Library, viewed 6 June 2014, DOI: 10.1029/96WR00076

WASB – see Water Accounting Standards Board

Water Accounting Standards Board 2009, *Water Accounting Conceptual Framework for the Preparation and Presentation of General Purpose Water Accounting Reports*, WASB, Australian Government Bureau of Meteorology, viewed 19 May 2014, http://www.bom.gov.au/water/standards/wasb/documents/WACF_August09.pdf

Water Accounting Standards Board 2012, *Australian Accounting Water Standards 1 – Preparation and Presentation of General Purpose Water Accounting Reports*, Australian Government Bureau of Meteorology, WASB 21 September 2012, viewed 30 April 2014 http://www.bom.gov.au/water/standards/documents/awas1_v1.0.pdf

WaterLink International 2011, *Water Footprint of Energy*, 29 March 2011, WaterLink International, Netherlands, viewed 1 April 2011, http://www.waterlink-international.com/news/id1791-Water_Footprint_of_Energy.html

Water Services Association of Australia (WSAA) 2014, *Gold Coast City Council – Further action to tackle water prices Feb 2014*, WSAA, Melbourne, viewed 16 May 2014, https://www.wsaa.asn.au/NewsAndMedia/MemberNews/Pages/Gold-Coast-City-Council.aspx#.U3VVAPmSx1Y

Water Technology 2014, *Perth Seawater Desalination Plant, Australia*, London & Melbourne, viewed 10 June 2014, http://www.water-technology.net/projects/perth/

WBCSD see World Business Council for Sustainable Development

Wiernik, BM, Ones, DS & Dilchert, S 2013, 'Age and environmental sustainability: a meta-analysis', *Journal of Managerial Psychology*, vol. 28, iss. 7/8, pp. 826-856

Whetton, P 2007, '*Stronger evidence for human-induced climate* change', CSIRO Media Release, 2 February 2007, viewed 1 April 2011, http://www.csiro.au/news/ps2q9.html

Whiteoak, K, Jones, P & Pickering, P (Marsden Jacob Associates) 2012, *Progress against the national target of 30% of Australia's wastewater being recycled by 201 - Report prepared for the Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC)*, December, Marsden Jacob Associates, Melbourne, viewed 15 May 2014, http://discoverypointwater.com.au/media/filecontent/recycled-water-target-final-report.pdf

Whitlock, DD, Daigger, GT & McCoy, N 2007, 'The future of sustainable water management: using a value chain analysis to achieve a zero waste society', *Proceedings of the* Water Environment Federation Annual Technical Exhibition and Conference *(WEFTEC 07)*, Sessions 31 - 40, pp. 2672-2691, viewed 25 May 2014, http://www.ingentaconnect.com/content/wef/wefproc

Withey, A 2013, '*Government lifts water restrictions across south-east Qld*', ABCNews, 2 January, viewed 12 May 2014, http://www.abc.net.au/news/2013-01-02/government-lifts-water-restrictions-across-south-east-qld/4450044

Wikipedia 2011, *Wivenhoe Dam*, last modified on 2 April 2011, viewed 14 April 2011, http://en.wikipedia.org/wiki/Wivenhoe_Dam

Wong, P (Minister for Climate Change and Water) 2008, '*Water for the Future'*, Speech to the 4th Annual Australian Water Summit, Sydney Convention and Exhibition Centre,29 April 2008, viewed 16 may 2009, http://www.environment.gov.au/minister/wong/2008/pubs/sp20080429.pdf

World Business Council for Sustainable Development 2003, *Striking the Balance: Sustainable development reporting*, WBCSD, viewed 9 May 2014, http://www.wbcsd.org/web/publications/striking_the_balance.pdf

World Business Council for Sustainable Development 2006, *Business in the world of water: WBCSD Water Scenarios to 2025*, August 2006, viewed 1 May 2008, http://www.wbcsd.org/DocRoot/Q87vukbkb5fNnpbkbLUu/h20-scenarios.pdf

World Business Council for Sustainable Development 2007, *Reporting: What? How much? To whom?*, WBCSD 2 July 2007, viewed 1 May 2008, http://www.wbcsd.org/plugins/DocSearch/details.asp?type=DocDet&ObjectId=MjUzMzE

World Business Council for Sustainable Development 2012, *Water valuation Building the business case*, WBCSD December 2012, viewed 4 June 2015, http://www.wbcsd.org/Pages/EDocument/EDocumentDetails.aspx?ID=15099&NoSearchContextKey=true

Wu, S, Hrudey, S, French, S, Bedford, T, Soane, E, &Pollard, S 2009, 'A role for human reliability analysis (HRA) in preventing drinking water incidents and securing safe drinking water', *Water Research*, vol. 43, no.13, pp.3227-3238, viewed 29 May 2014, Science Direct, item 10.1016/j.watres.2009.04.040

Wuth, R 2010, 'Water rip-off a drop in the ocean', *Gold Coast News*, 15 November 2010, viewed 14 March 2011, http://www.goldcoast.com.au/article/2010/11/15/270875_robyn-wuth-opinion.html

Zadek, S 1998, ‘Balancing Performance, Ethics, and Accountability’, *Journal of Business Ethics*, vol. 17 pp.1421-1441, viewed 5 may 2014, EBSCOhost MegaFILE Complete, Business Source Complete , item: AN12145984

Zadek, S 2013, ‘Reshaping the Political (Green) Economy, *Journal of Corporate Citizenship*, vol. 51 pp.5-16, viewed 5 may 2014, EBSCOhost MegaFILE Complete, Business Source Complete , item: AN94230473

Zhu, Q, Sarkis, J & Lai, K 2008, ‘Confirmation of a Measurement Model for Green Supply Chain Management Practices and Implementation’, *International Journal of Production Economics*, vol. 111, pp.261-273

Zikmund, WG, Babin, BJ, Carr JC & Griffin M 2013, *Business Research Methods*, 9th edn, South-Western Cengage Learning, Mason OH

Recycled Water Questionnaire, 2012

You are being invited to take part in a survey on the use of recycled water conducted by a researcher at the University of Southern Queensland. I would really appreciate your views, and there is a prize draw for all those completing the survey who wish to enter (total prize value $200). There is no further obligation on your part and the survey is anonymous. If you prefer, this survey may also be completed online:
URL: https://www.surveymonkey.com/s/SLHV2NG

The University of Southern Queensland

This project forms part of the researcher's PhD programme. The purpose of this project is to investigate and report on the costs of recycled water. It is hoped that this will provide information that will aid future decisions about methods chosen for water recycling, and inform water pricing decisions. The study is also seeking consumer and other stakeholder opinions and views about recycled water use and pricing.
You are invited to participate in the project by completing the attached/following questionnaire.
The research results will be de-identified and included in aggregate in a final report. No individuals will be identified. The data in anonymous and aggregate form may also be used in refereed academic publications.
If you have any questions concerning this research, please e-mail Christina James-Overheu, Lecturer in Accounting at the Faculty of Business and Law at christina.james-overheu@usq.edu.au or, alternatively contact the Secretary, Human Research Ethics Committee, Registrar's Office, University of Southern Queensland, West Street, Toowoomba, Qld, 4350 (telephone number 4631 2690).
A Participant Information Sheet has been enclosed for your information.

Thank you and I look forward to your participation.

Christina James-Overheu, Lecturer in Accounting ,University of Southern Queensland
PO Box 4196, Springfield, Qld
Phone: 07 34704546 Fax 61 7 347 04501
christina.james-overheu@usq.edu.au

You may complete this survey and return it in the reply paid envelope, or you may complete it online at the following URL: https://www.surveymonkey.com/s/SLHV2NG

NOTE: The survey is anonymous and is administered by the researcher, not Unitywater. Any person responding to the survey may enter the prize draw by giving contact details at the end of the survey. However, no personal details will be retained. There will be two winners each receiving a $100 shopping voucher. As this is a small survey, the chances of winning are better than most raffles!

Section A – Respondent information

1) Please indicate your gender

☐ Male ☐ Female ☐ Decline to answer

2) What is your year of birth? ☐

3) In total, how many members are there in your household? ☐

4) Please indicate the **number** of adults and children in your household in the following categories (please write the actual number in the boxes)

☐ Adults aged over 50 ☐ Adults aged 30-50 ☐ Adults aged 18-29

☐ Children aged 12 or over ☐ Children aged under 12 ☐ Decline to answer

5) Please indicate your highest formal education level completed

☐ Primary-Year 10 ☐ High School/TAFE/Other certificate ☐ University/Postgraduate degree

☐ Unsure ☐ Decline to answer

6) Please indicate the type of building you live in/occupy (for business users state type of business in 'other')

☐ Unit ☐ House ☐ Other ________________ ☐ Decline to answer

7) Do you rent or own the property you live in/occupy? (Please treat a long term lease – more than 5 years - as owning)

☐ Rent ☐ Own ☐ Other _____________ ☐ Decline to answer

8) Please tick the corresponding boxes if your household/business has any of the following water efficient devices (you may tick more than one box i.e. tick all that apply)

☐ Water efficient shower heads ☐ Front loading washing machine

☐ Rainwater tank for external water use ☐ Rainwater tank for internal household water use

☐ Dual flush (low flush) toilets ☐ Other (please specify)

____

☐ Decline to answer

9) Are you, or have you been in the last 5 years, concerned about water supply shortages?

☐ A great deal ☐ A little ☐ Not at all ☐ Unsure

10) Have you considered the need for new sources of water in Australia?

☐ A great deal ☐ A little ☐ Not at all ☐ Unsure

11) Are you a member of, or do you make donations to, any environmental group?

☐ Yes ☐ No ☐ Decline to answer

Section B: Recycled water – non drinking standard

12) Would you regard your ***total*** water consumption compared to other households/businesses of a similar size to be

☐ Low ☐ Medium ☐ High ☐ Unsure

13) What do you believe you use the most water for? Please rank the following activities in terms of use of water using "1" to indicate the activity for which you think your household uses the most water to "6" to indicate the activity for which you use the least water in total.

Use of water:	**Rank from 1 to 7 where 1 is 'uses most water' and 7 is 'uses least water'**
Tap use	
Toilet flushing	
Clothes washing	
Shower or bath use	
Irrigation (garden & outside use)	
Pool	
Other use (please specify)	

14) What is your primary source of ***drinking*** water?

☐ Mains tap (town) water ☐ Filtered tap water ☐ Filtered rain water ☐ Bottled water

☐ Other (please specify)_______________________________________

15) How do you rate your *mains tap water supply* in terms of the following (please tick only one box per line).

Mains tap water	**Very good**	**Good**	**N/A or Don't know**	**Bad**	**Very bad**
Overall quality					
Taste					
Colour					
Smell					
Safety – germs in drinking water					
Safety – chemicals in drinking water					

One way to save water is to use recycled water or alternative water sources to conserve drinking water supplies. Water that is safe to drink (free from pollution, harmful organisms and impurities) is often called 'potable' water. In developed countries most water supplied to households/industry is of drinking standard, even though very little of this is actually consumed or used for food preparation. Many other uses for water need not use water that is of such a high quality and in such cases non-drinking water *could* be used. The use of non-drinking water for other functions therefore conserves drinking water. This alternative water can be sourced in a number of ways e.g.

- Purified recycled water from treated wastewater (Such schemes have dual reticulation with a second separate pipe (dual) network supplying Class A+ recycled water, usually coloured purple for easy identification. Class A+ water is the highest quality recycled non-drinking water that looks and smells like mains tap water. In QLD this system is already used in some new housing in Caboolture and in the Pimpama Coomera region on the Gold Coast).
- Reclaimed stormwater (water drained from streets and other areas)
- 'Greywater' re-use (re-use wastewater from showers/baths/hand basins/laundry tubs/washing machines)
- Rainwater tank collection
- Desalinated seawater

16) Please indicate (tick) which of these you *have heard of* **and** any that you *currently use* (if any). Tick all that apply:

	Have you *heard* of this type of recycled water?		**Do you *use* of this type of recycled water?**		
Source of RECYLCED Water	**YES**	**NO**	**Yes**	**No**	**Don't know**
Recycled water from treated wastewater					
Reclaimed stormwater					
Grey water re-use					
Rainwater tank					
Desalinated seawater					

17) Did you answer "Yes- currently use" for ANY of the above sources of recycled/alternative water?

☐ Yes - currently use some recycled water – *please go to question* ***19***, otherwise continue to 18.

18) If you **do not use** recycled/alternative water at all, please state if this is by choice, or if you would use recycled water for non-drinking purposes if it was available to you, or make any other comment you wish

☐ I choose not to use recycled water

☐ I would use recycled water if it was available to me

Other comment:

____

____

____

____

____

____

please now go to question **28** in ***Section C: Recycled water - drinking standard p.8*** below

19) You answered "Yes- currently use" for at least one of the sources of recycled/alternative water.

How long have you been using recycled/alternative water?

☐ More than 2 years ☐ 1-2 years ☐ Less than one year ☐ Unsure

20) Would you regard your volume of **drinking** water consumption to be:

☐ Low (<350L/ day) ☐ Medium (351-550L/day) ☐ High (>550 L/ day) ☐ Unsure

21) Would you regard your recycled/alternative water consumption to be

☐ Low (<150L/ day) ☐ Medium (151- 500 L/day) ☐ High (>500 L/day) ☐ Unsure

22) Please indicate (tick) which uses you have made (if any) of recycled/alternative water in your household/business **(tick all that apply)**:

Use of RECYLCED/alternative Water	**YES I/we have used recycled water for this**	**NO I/we have not used recycled water for this**	**Don't know**
Toilet flushing			
Garden watering			
Car washing			
Clothes washing			
Drinking			
Cooking			
Showering			
Other (please specify)			

If you answered "**no**" for toilet flushing and/or garden watering, please let us know why not.

____
____
____
____
____
____

23) Do you use Purified Recycled Water (PRW) from treated wastewater (as used in the 'purple pipe' dual reticulation schemes in Caboolture)?

☐ No - *I do not have dual reticulation water supply to my home/business (lilac/purple pipes) – please go to* go to question **28** in ***Section C: Recycled water - drinking standard p.8*** below ⇨

☐ Yes - *I have dual reticulation water supply to my home/business (lilac/purple pipes) – please continue with* ***question 24***.

24) How do you rate your *current recycled water (PRW) supply* in terms of the following (please tick only one box per line):

Recycled water (PRW)	**Very good**	**Good**	**N/A or Don't know**	**Bad**	**Very bad**
Overall quality					
Taste					
Colour					
Smell					
Safety – germs in drinking water					
Safety – chemicals in drinking water					

25) For any of the following uses, have you any positive comments or concerns about using your current supply of recycled water (PRW)?

Use of RECYLCED (PRW) Water	**Positive comments/Concerns**
Toilet flushing	
Garden watering	
Car washing	
Clothes washing	
Drinking	
Cooking	
Showering	
Swimming pool	

26) Please rate your degree of satisfaction with the recycled water you use on a scale of 0 to 10, where 0 = not at all satisfied and 10 = extremely satisfied, by ***circling the appropriate number***.

	Not at all satisfied					**Neither satisfied nor dissatisfied**					**Extremely satisfied**
I am:	0	1	2	3	4	5	6	7	8	9	10

27) Please tick to show whether or not you agree with the following statements

Statement	Agree	Somewhat agree	Neither agree nor disagree	Disagree somewhat	Disagree
I enjoy living in a community that actively contributes to environmental sustainability	❑	❑	❑	❑	❑
I believe that the dual water scheme may have a negative impact on the environment	❑	❑	❑	❑	❑
The threat of climate change is a concern to me	❑	❑	❑	❑	❑
I would prefer it if the water system was standard – no dual water supply	❑	❑	❑	❑	❑
I avoid using the lilac/purple (recycled water) taps whenever possible	❑	❑	❑	❑	❑

Statement	Agree	Somewhat agree	Neither agree nor disagree	Disagree somewhat	Disagree
I save money by using recycled water	❑	❑	❑	❑	❑
I am confident there are no health risks associated with the dual water supply system	❑	❑	❑	❑	❑
Environmental benefits of dual water supply are more important than financial benefits	❑	❑	❑	❑	❑
I am happy with the operation of the recycled water system	❑	❑	❑	❑	❑
I think there is adequate regulation to ensure safe use of recycled water	❑	❑	❑	❑	❑
I trust the water authority to ensure recycled water quality	❑	❑	❑	❑	❑
The cost of non-drinking recycled water should be *slightly* less than drinking water	❑	❑	❑	❑	❑
The cost of non-drinking recycled water should be *significantly* less than drinking water	❑	❑	❑	❑	❑
Recycled water use should not be subject to water use restrictions	❑	❑	❑	❑	❑
The potential to save money associated with the dual water supply system contributed to my decision to live here	❑	❑	❑	❑	❑
The dual water supply system adds value to my property	❑	❑	❑	❑	❑
I prefer my supply of non drinking recycled water to be high quality and therefore cost only slightly less than drinking water	❑	❑	❑	❑	❑
Charging for recycled water should be based on treating the wastewater to a high (Class A) standard and transport or delivery via pipe work to customers	❑	❑	❑	❑	❑
Charging for recycled water should be based on treating the wastewater to a high (Class A) standard, transport or delivery via pipe work to customers, *plus* part of the cost of building the treatment plant	❑	❑	❑	❑	❑

Section C: Recycled water - drinking standard (potable)

It is possible to treat recycled wastewater to a standard suitable for <u>*drinking (potable)* water</u>, to meets all the requirements for good quality drinking water of *The Australian Drinking Water Guidelines,* based on scientific evidence.

Using wastewater as the source of recycled water *may* have the benefit of reducing the volume of effluent discharged into natural waterways/outfalls like Moreton Bay, lowering the level of nutrients and other compounds that could have harmful environmental effects. Local Recycled Water use reduces power consumption and greenhouse gas emissions (less power to pump water long distances) and decreases water supply vulnerability as it is less impacted by climate (if sourced from treated wastewater).

Purified recycled water (PRW) is defined in this section as wastewater that has been treated to a very high standard using advanced technology through an Advanced Water Treatment Process, which generally includes microfiltration, reverse osmosis (RO) and advanced oxidation. Reverse osmosis (RO) is a filtration method that removes large molecules and ions from solutions by applying pressure to the solution prior to passing through a selective membrane. It produces water to a high standard but may be more energy intensive. A possible alternative to reverse osmosis is to use biologically activated carbon (BAC) to remove impurities, an organic method. All advanced water treatment plants include a suite of different processes or barriers to purify the water.

This purified recycled water (PRW) can then be used *indirectly* to supplement drinking water supplies. This means that the purified recycled water is added to another water supply source such as a dam. The blended water taken from the dam then passes as normal through a drinking water treatment plant before distribution to consumers.

<u>**Questions for this section: Assume that the purified recycled water (PRW) source is of drinking (potable) standard and that water restrictions are in place due to water shortages:**</u>

28) In these circumstances, would you support the use or recycled water for indirect drinking water use (recycled water added to the dam)? **(Please circle one answer)**

No	**Yes**	**I am unsure/don't know**

29) The following question is about your perception of risk for various possible uses of **drinking standard** recycled water. Please rate your view of the risk on a scale of 0 to 10, where 0 = not at all risky and 10 = extremely risky.

Use of RECYLCED (PRW) Water	**No risk 0**	**1**	**2**	**3**	**4**	**Medium risk 5**	**6**	**7**	**8**	**9**	**Extreme risk 10**
Garden watering – public e.g. parks/golf courses	0	1	2	3	4	5	6	7	8	9	10
Garden watering – private	0	1	2	3	4	5	6	7	8	9	10
Toilet flushing	0	1	2	3	4	5	6	7	8	9	10
Street cleaning	0	1	2	3	4	5	6	7	8	9	10
Car washing	0	1	2	3	4	5	6	7	8	9	10
Public fountains and water features	0	1	2	3	4	5	6	7	8	9	10
Vegetable growing	0	1	2	3	4	5	6	7	8	9	10
Clothes washing	0	1	2	3	4	5	6	7	8	9	10
Wash hands	0	1	2	3	4	5	6	7	8	9	10
Drink – indirectly	0	1	2	3	4	5	6	7	8	9	10
Shower	0	1	2	3	4	5	6	7	8	9	10
Drink – directly	0	1	2	3	4	5	6	7	8	9	10

30) In these circumstances how would you prefer that the PRW had been processed? (please tick one)

A multi barrier process including reverse osmosis (RO)	A multi barrier process including biologically activated carbon (BAC)	It does not matter provided the PRW meets the Australian standards	It should be decided on cost provided both meet Australian standards	I would not drink any PRW	I am unsure /don't know

31) Please tick to show whether or not you agree with the following statements

Statement	Agree	Somewhat agree	Neither agree nor disagree	Disagree somewhat	Disagree
Saving energy is more important than saving water	❑	❑	❑	❑	❑
Saving energy is a way of saving water	❑	❑	❑	❑	❑
I trust the scientific evidence about the safety of Purified Recycled Water	❑	❑	❑	❑	❑
The threat of climate change is a concern to me	❑	❑	❑	❑	❑
I think the present water quality system in Queensland is good	❑	❑	❑	❑	❑
We need to use recycled water for the future's sake	❑	❑	❑	❑	❑
People in SE QLD are influenced by the negative messages about Purified Recycled Water in the media	❑	❑	❑	❑	❑
I am influenced by the negative messages about Purified Recycled Water in the media	❑	❑	❑	❑	❑
The likelihood of an incident leading to a health risk from Purified Recycled Water is small	❑	❑	❑	❑	❑
An advantage of using Purified Recycled Water is that it may mean less need to build dams	❑	❑	❑	❑	❑
I feel that I have enough information to made a decision about using PRW	❑	❑	❑	❑	❑
My household uses less than the average amount of water per day for my area	❑	❑	❑	❑	❑

Statement	Agree	Somewhat agree	Neither agree nor disagree	Disagree somewhat	Disagree
Recycled water use should not be subject to water use restrictions	❑	❑	❑	❑	❑
The Purified Recycled Water treatment just speeds up the natural water recycling process	❑	❑	❑	❑	❑
All water is recycled	❑	❑	❑	❑	❑
An advantage of using Purified Recycled Water is that it may allow more dam capacity to be used for flood mitigation	❑	❑	❑	❑	❑
Charging for recycled water should be based on treating the wastewater to a high (Class A) standard, transport or delivery via pipe work to customers, *plus* part of the cost of building the treatment plant	❑	❑	❑	❑	❑
My household uses more than the average amount of water per day for my area	❑	❑	❑	❑	❑
I feel uneasy about human interference in the natural water cycle	❑	❑	❑	❑	❑
Floods also cause water supply problems because they damage infrastructure	❑	❑	❑	❑	❑
I do not think it likely in Australia that there would be an incident using Purified Recycled Water that would lead to a serious health risk	❑	❑	❑	❑	❑
An advantage of using Purified Recycled Water is that there is a constant supply	❑	❑	❑	❑	❑
My household uses an average amount of water per day for my area	❑	❑	❑	❑	❑
I think that there will be droughts in SE QLD again in the near future	❑	❑	❑	❑	❑

Section D: Prices for recycled and drinking (potable) water

Information

Transportation of water

Water is heavy. 1kl (kilolitre) of water weighs approximately 1 tonne, so whilst technological improvements have reduced costs, moving it from one location to another, particularly if this means pumping uphill, can be power intensive and therefore expensive in terms of costs and the environment. Water supply solutions therefore tend to be relatively local. (Zhou, Y. & Tol R. S. J. (2005), Evaluating the costs of desalination and water transport, Water Resources Research, Vol 41)

Explanation of current Water charges (source Unitywater website 2011):

1. Variable Water Usage Charge, calculated on how much water you use. This includes the Government bulk water charge, plus Unitywater's costs of managing the retailing of the supply of drinking quality water, which includes storage, transport, maintaining water quality, managing customer accounts the 24 hour emergency response service.

2. Fixed charges:

- ***Sewerage access charge:*** This is the charge for having your property provided with access to the reticulated or 'town' sewerage network. It covers sewerage infrastructure, including sewer pipes, sewage pump stations, sewage treatment plants and any other associated infrastructure.
- ***Water access charge:*** This is the charge for having your property provided with access to the reticulated or 'town' water network in your area. It covers water supply infrastructure including water mains and pipes, pumping stations, reservoirs, hydrants and any other associated infrastructure.

Prices reflect:

-the true cost of providing and maintaining high-quality water supply and sewerage services, without any previously applied council or state government subsidies.

- the rising cost of bulk water, rising energy costs, and the cost of maintaining, improving or replacing existing infrastructure.

Current charges in the Moreton Bay area for 2011/2012 are:

Moreton Bay Residential - Water	Unit	Price
Fixed Water Access Charges	Per year	$346.02
	Per day	$0.945
Water Usage Tier 1: 0-767 L/day	Per kL (1000L)	$0.176
Water Usage Tier 2: 768-986 L/day	Per kL (1000L)	$0.849
Water Usage Tier 3: above 986 L/day	Per kL (1000L)	$1.305
State Government Bulk Water Charge	Per kL (1000L)	$1.922
Sewerage	**Unit**	**Price**
Fixed Sewerage Access Charges	Per year	$744.88
	Per day	$2.035
TOTAL Water Supply and Sewerage Charges**(Based on water usage for 3 people @ 157.7L per person/day)		$1453.08

Source: http://unitywater.com/My-account/Moreton-Bay.aspx accessed7 Feb 2012

For more information see: http://unitywater.com/pricing

Questions for this section:

32) Please tick to show whether or not you agree with the following statements

Statement	Agree	Somewhat agree	Neither agree nor disagree	Disagree somewhat	Disagree
Historically, do you agree that water in Australia is a scarce resource?	❑	❑	❑	❑	❑
If water prices are subsidised, do you agree that residential customers will use more water?	❑	❑	❑	❑	❑
I would like to have access to purified recycled ***non drinking*** water if it was cheaper than mains tap drinking water to use as I choose	❑	❑	❑	❑	❑
I think it is a good idea to have different rates (tiers) for water usage, so that people using more water are charged more	❑	❑	❑	❑	❑
I think purified recycled ***non drinking*** water should be *slightly* cheaper than mains tap drinking water	❑	❑	❑	❑	❑
I think purified recycled ***non drinking*** water should be *significantly* cheaper than mains tap drinking water	❑	❑	❑	❑	❑
I don't think people will use less water even if they are charged more for usage	❑	❑	❑	❑	❑
I think water charges should be based on actual water costs	❑	❑	❑	❑	❑
I would like to have access to purified recycled ***drinking*** water if using recycled water avoids water restrictions	❑	❑	❑	❑	❑
I would like more information about water costs	❑	❑	❑	❑	❑

Statement	Agree	Somewhat agree	Neither agree nor disagree	Disagree somewhat	Disagree
The **cost** of purified recycled ***drinking*** water would be a factor in my considering whether to use it or not	❑	❑	❑	❑	❑
I think it is a good idea to charge less for fixed water charges and more for water usage to encourage people to save water	❑	❑	❑	❑	❑
I would drink purified recycled ***drinking*** water if it meant the water supply was less effected by droughts	❑	❑	❑	❑	❑
I would drink purified recycled ***drinking*** water if it reduced the cost of the drinking water supply	❑	❑	❑	❑	❑
I think people will use less water if they are charged more for usage	❑	❑	❑	❑	❑
I would **not** drink purified recycled ***drinking*** water even if it meant the water supply was more drought resistant	❑	❑	❑	❑	❑
Water is expensive to transport, so the costs are not the same in all areas	❑	❑	❑	❑	❑
I think everyone in South East QLD (including Brisbane, Gold Coast, & the Sunshine Coast) should pay the same amount per kl for their water	❑	❑	❑	❑	❑
I think water charges should reflect the full cost of supplying the water to encourage sustainable use of water	❑	❑	❑	❑	❑

33) What, in your opinion, should an average quantity user **pay** per kilolitre of potable recycled ***drinking*** water?

☐Unsure

Comment____
____
____

34) What, in your opinion, should an average quantity user **pay** per kilolitre of ***recycled*** non drinking water?

☐Unsure

Comment____
____
____

35) What was your household's average daily usage of water (L) per your most recent bill?

KL or ☐ Don't know because I am not responsible for the bill

☐ Decline to answer

(Note: This number should be shown on page 2 of your last water bill under the heading "Water Meter Details".)

Comment____
____
____

36) Please feel free to make any other comments you wish to make regarding recycled water:

Comment____
____
____
____
____
____
____
____

Thank you for completing the survey! Please enter some contact information *if you wish to enter the prize draw* (phone number or email or mailing address). Please note that **personal details will not be used for *any* purpose other than contacting the prize winners and will not be retained after the draw**.

There will be two winners each receiving a $100 shopping voucher, and the survey is not large, so good luck!

37) Please enter me in the prize draw and contact me if I win:

____

____

____

____

____

____

____

____