UNIVERSITY OF SOUTHERN QUEENSLAND

Faculty of Engineering and Surveying

MARKET SEGMENTATION FOR IMPROVED EFFICIENCY OF IPSWICH WATER SUPPLY SYSTEM

A dissertation submitted by

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ABSTRACT

Urban water supply systems are becoming under increasing pressure as a result of dwindling water resources and increasing population. Efficiency has become vital in being able to maintain a sustainable water supply to society. This research investigates the Ipswich water market, and identifies ways of classifying water customers by critical supply. This sets the basis for market segmentation, which will allow Ipswich Water to prioritise water failure response and to identify the need for water infrastructure maintenance and renewal.

The use of risk analysis to segment customers by level of risk has been determined as the most effective means of determining customer criticality. Essentially the objective of risk analysis is to distinguish between high and low risk customers so that priorities of risk management can be established. The risk assessment process involves identifying potential hazards, developing risk criteria, and finally undertaking a risk evaluation. This research sets the foundation for market segmentation by risk analysis for implementation into Ipswich Water's management strategy.

The outcome of this project has achieved a framework for future water policies and management strategies. This framework will be influential in providing Ipswich Water with a smooth transition through the SEQ Water Reform, and improving the organisation as a commercial entity. Further work is required in developing the risk assessment process to achieve its full potential as an effective management tool; this will involve more thorough data analysis and investigation of the water supply system.

ENG4111 & ENG4112 *Research Project*

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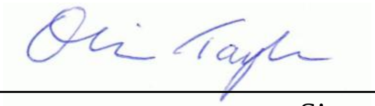

Signature

29th of October 2009

Date

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Key Terms

Business Continuity – the requirement of water supply to maintain functions critical for a business's operation.

Consequence – outcome or impact of an event in relation to inadequate water supply.

Customer – the individual or organisation who receives services from the water provider.

Customer Base – the entire group of customers that are provided with water supply.

Customer Criticality – the risk associated with a customer.

Efficiency – relationship of outputs to input, increases are achieved by the same outputs with fewer resources or more outputs for the same amount of resources.

Functional Role – the requirement of water supply to maintain functions of an organisation that provides an important service that maintains social welfare.

Hazard – a source of potential harm in the urban water supply system.

Hazard Identification – the process of determining what, where, when, why and how a hazard will occur in the urban water supply system.

Likelihood – used as a general description for the probability or frequency (may be expressed qualitatively or quantitatively) of an inadequate water supply event.

Market Segmentation – the process of dividing up the water market into subgroups with similar levels of risk.

Qualitative – to express an attribute or classification in terms of a non-numerical description.

Quantitative – to express an attribute or classification in terms numerical measurement.

Risk – the chance of something happening that will have an impact on system objectives.

Risk Analysis – systematic process to understand the nature of and to deduce the level of risk in the water supply system.

Risk Evaluation – process of comparing the level of risk against risk criteria, assists in decisions about risk treatment.

Risk Assessment – the overall process of risk identification, risk analysis and risk evaluation.

Risk Criteria – terms or reference by which the significance of risk is assessed.

Risk Management – the culture, processes and structures that are directed towards realising potential opportunities whilst managing adverse effects.

Risk Matrix – a tool used in the risk assessment process, allowing the severity of risk for an inadequate supply event to be determined.

Supply Failure – a case of inadequate or unacceptable water supply.

Supply Network – the urban water distribution system.

Sustainability – development which meets the needs of the present without compromising the ability of future generations to meet their own needs.

Urban Water Supply System – a system of headworks and distribution systems that supplies the urban water market.

Water Market – the group of customers that have a demand for water supply.

Water Market Reform – a range of structural and regulatory reforms implemented to improve the way water services are provided in the water market.

Water Resources – sources of water that are useful or potentially useful to society.

Water Supply – the service of water provided to the water market through the supply network.

1. INTRODUCTION

1.1. OUTLINE OF STUDY

This research investigates the use of market segmentation of water supply customers through the use of risk analysis to identify critical customers. It anticipates providing framework for future government water policies and setting the foundation for more efficient water supply systems. It aims to achieve this by means of determining immediate response criticality in the event of supply failure, as well as identifying the need for water infrastructure maintenance and renewal. This work hopes to make steps towards closing the gap between the advancement of information technology and the lagging development of water management systems which are currently implemented in urban water systems.

1.2. INTRODUCTION

Urban water supply systems are an integral component of infrastructure put in place to provide society with a valuable resource – water, which plays a major role in maintaining the standard of living which we enjoyed today. Associated with the operation of these complex water delivery systems is a dynamic management system that aims to ensure water supply is maintained at a particular level of demand and quality desired by society. Essentially this requires continuous system monitoring, and any deviation away from the defined service standard must be overcome before customers experience a shortfall in their required level of service.

In Australia, most people in the past have taken the urban water supply system for granted, in more recent times this view has gradually began to change. Being one of the driest continents on earth, and with the onset of changing climate patterns, Australia has experienced several severe droughts over the past few decades. This has changed our view on water resources, and much of society now sees the security of a sustainable water supply to be at risk. This change in perception has called for more efficient water policies to be introduced to govern the manner in which we consume this valuable resource (Marsden & Pickering, 2006).

South East Queensland is very much at the forefront of this issue. With increasing population, and dwindling water resources (*see Figure 1.1*), there has never been more pressure on the municipal water supply system. Local governments, over the past decade, have been aiming to increase the sustainability of their water supply systems. The customer has seen evidence of this water 'crunch' through the implementation of strict water restrictions, increased pricing schemes and more widely available water efficient technologies. However, further to these changes, the water management systems that drive our water utilities need to be reshaped to reach better levels of efficiency, and provide customers with better security of water supply.

To date, large amounts of time and funding have been concentrated towards research into minimising direct water consumption throughout the community. Very little work has been concentrated in the area of improving the way in which we manage water supply systems, and in a sense the current management strategies have become out-dated in comparison to the current information technology that is available to drive these systems (Blackmore & Plant 2008). This research aims to contribute to the direction of future water policies, and provide a framework for a revolution in the way in which urban water supply is managed.

FIGURE 1.1: Wivenhoe Dam located in SEQ has seen record low dam levels in recent times (QWC, 2008).

1.3. STUDY AREA

The focus of this research is based on Ipswich City, which is centrally located in booming south east Queensland, west of metropolitan Brisbane (*see Figure 1.2*). It covers 1,090 square kilometres, and is home to a population of 157,700 people, who enjoy a subtropical climate in a safe, friendly and multicultural city (Ipswich City Council, 2009). Ipswich City Council is dominated by sprawling residential estates, thriving industry and a core central business district which is characterised by prosperous commercial activity. Ipswich remains to be an area of growth with ongoing urban development in the western corridor due to the affordable and healthy lifestyle it offers, as well as being a prosperous location for business activity. The Ipswich area is rich in diversity and has become an avenue for future growth and development in south east Queensland, attracting many new residents and businesses.

Ipswich Water is the water service provider for Ipswich City Council, providing an average of 35 megalitres per day of potable water. With a growth rate of 4% per annum it has been predicted that the population will reach 355,000 by the year 2026. With this increased growth in population comes a subsequent demand for water supply, identifying a need for further investment in the development of water infrastructure and service quality (Ipswich Water, 2009b).

Ipswich Water currently obtains its water from SEQWater who source water primarily from Wivenhoe and Somerset Dams. The past decade has seen record low dam levels in the Brisbane River catchment and this has put increasing pressure on the urban water supply system, highlighting the need for research and development into more efficient supply systems. Currently major reform is in progress for the South East Queensland water supply – the SEQ Water Reform, which is due to come into fruition by 1 July 2010. Ipswich Water is likely to experience significant organisational change as a result of the SEQ water reform. The main changes will include the establishment of state owned bulk supply authority, bulk transport authority and a water grid manager, and three combined distribution/retail entities (Qld Water Commission, 2009). This will see Ipswich Water join with Brisbane City Council, Scenic Rim Regional Council, Lockyer Regional Council and Somerset Regional Council water service providers (*see Figure 1.2)* to form a combined water distribution entity. Despite these organisational changes, this research remains relevant to Ipswich Waters' strategic plans, and hopes to contribute to the amalgamation of these water service providers by providing a framework for management strategies and water policies.

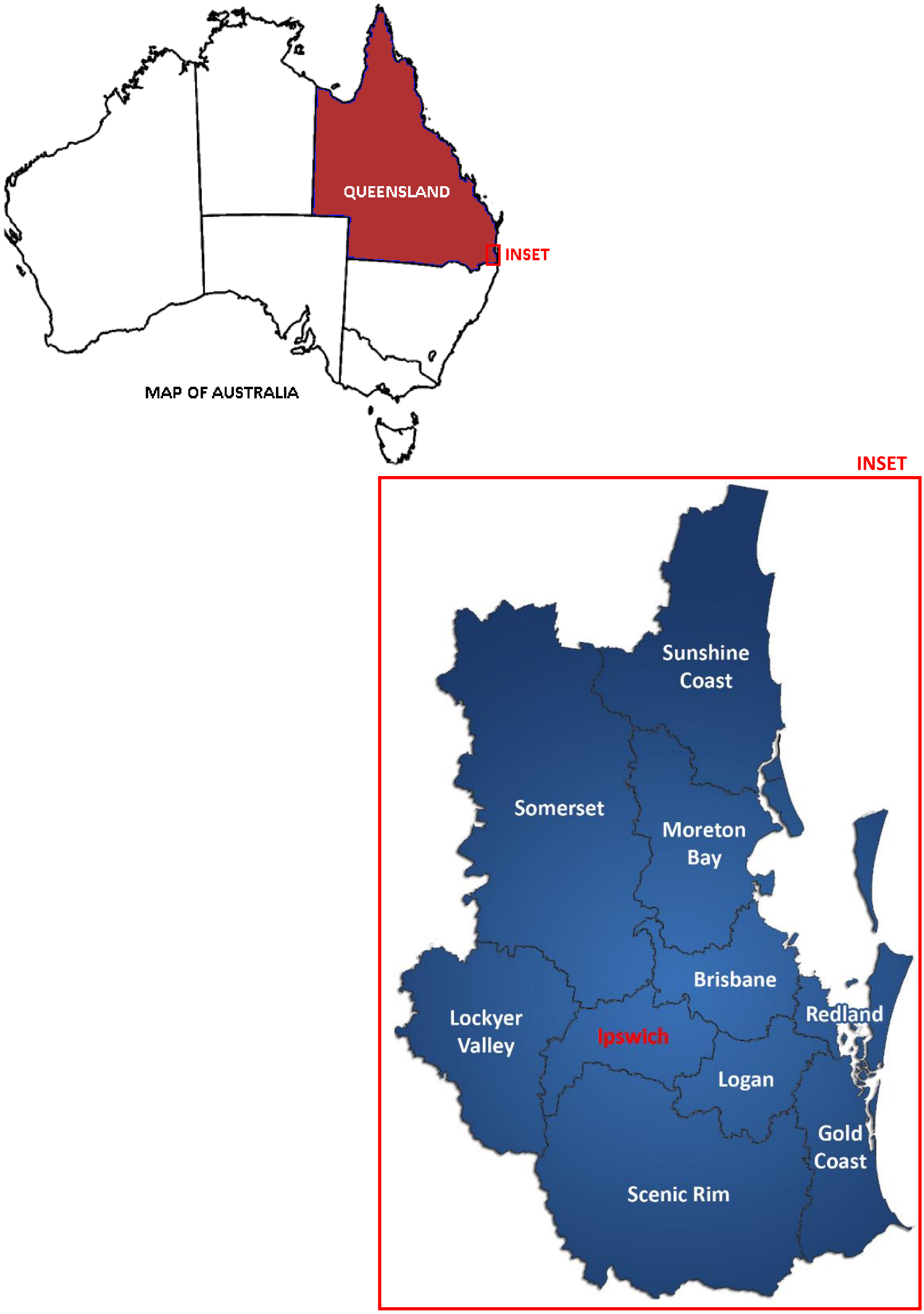

FIGURE 1.2: Locality of Ipswich City Council including surrounding local councils (Ipswich Water, 2009).

1.4. RESEARCH OBJECTIVES

Market Segmentation for Improved Efficiency of Ipswich Water Supply Service aims to classify customers by critical supply. The purpose of this research is to enable water customers to be prioritised, identifying critical system users. This will form the basis for monitoring demands and managing balanced water usage with water customer requirements within the supply system. The results obtained from this will allow Ipswich Water to implement more efficient services planning and maintenance programs. This study involves conducting the following programme:

Review current water policies and management systems related to customer segmentation.

This involves reviewing federal, state and local government policies that control the operation of Ipswich Water. Further to this, it includes reviewing current management systems in place at Ipswich Water that control their business operations.

Define Ipswich Water supply customer base within the context of Ipswich and the Western Corridor.

A study of the water supply customers which Ipswich Water services. This includes identifying general characteristics in terms of their water usage, i.e. residential, industrial, commercial, community organisations, rural, civic services, etc, as well as the quantity and quality requirements of their water supply. Particular attention needs to be focussed on major, high-volume or large business customers, and customers that require water to operate facilities and functions that are vital to the community.

Undertake research into methods of market segmentation for critical water users.

Review of available literature to firstly gain a thorough understanding of segmentation methods, and eventually to refine a method that suits the market segmentation of the Ipswich Water customer base.

Develop risk based criteria for the identification and assessment of critical water customers.

Looking at both quantitative and qualitative measures, criteria will be defined that determines critical water customers. This criteria needs to be effective in identifying all customers in terms of their water requirements for volume, end use and quality, and the value of these requirements in respect to other water customers.

Using the criteria, identify critical users by prioritising them in terms of their water requirements.

Develop a risk matrix using the risk based criteria as the potential consequence of a water supply failure, against the likelihood of such an event occurring, and determine the level of risk of each customer in the supply system. By applying this to the customer base, and determining the level of risk of each customer, market segmentation can be undertaken on the basis of critical need for failure response, program maintenance or infrastructure upgrades.

Present the data to Ipswich Water in a format compatible for implementation into services planning and maintenance programs.

Results from the research are to be presented to Ipswich Water, in a format that allows easy implementation into the development of future water policies and management systems.

As time permits, report on the implementation of any recommendations.

After providing the findings to Ipswich Water, and allowing them to implement these into their operations, a review of operational efficiency gains may be carried out. This is to identify areas of further system improvement, and may open up additional areas of research and development.

2. Literature Review

2.1. Urban Water Management

The modern day management of water resources requires more than simply a sound technical engineering understanding of a system – it involves a comprehensive framework of science, law, finance, public administration and system analysis. In the past water resource management was simply considered an engineering task which involved building dams, laying pipelines, installing pumps and operating systems (Grigg, 1996). This view has changed greatly to the point that today's water resources manager must take on a holistic approach, with a major focus being on sustainable development. Through sustainable development, water management aims to meet the needs of the current generation, without compromising the needs of future generations.

While water resource management encompasses a wide range of water systems, urban water management is the component of particular focus to this research. Urban water management essentially involves the management of municipal water supply and wastewater (the study of wastewater is outside the area of this study). Urban water supply management often involves a high degree of complexity, providing major challenges for water managers to reach the optimum system which will produce balanced water usage outcomes for all customers.

Current urban water management practices are based on the objective of supplying a safe, potable and sufficient water supply, by understanding the availability of water supply, and the current and projected water demands. While water service providers understand that different sectors of the water market may have different requirements, there is a lack of formalised systems that can effectively identify the criticality of particular customers in the market. Future management systems need to have the ability to predict where system shortfalls and failures are likely to occur, and be able to put measures in place to safeguard customers where these problems are identified, or otherwise have contingency plans established.

2.2. SUSTAINABLE SYSTEMS

Sustainability is most commonly defined as *"development which meets the needs of the present without compromising the ability of future generations to meet their own needs"* (National Centre for Sustainability, 2009). The National Centre for Sustainability (2009) recognises this definition as the central aim of producing and maintaining sustainable systems. It promotes sustainability in industry and community through the following principles:

- Recognising ability to act sustainably in all activities;
- Play an active role in promoting more sustainable practices;
- Through education, promote a behavioural change which exemplifies sustainable practices;
- Aims not to compromise the possibilities of future generations through unsustainable activities; and
- Encourages consideration of alternative more sustainable solutions, strategies and perspectives in addressing concepts, problems or issues in business, government and communities.

These principles need to be reflected in the operation of urban water systems in order to develop systems that are capable of maintaining their service well into the future. Sustainable development has been recognised as the key concept in water resource management, and is often considered to be the strongest driving force of the water industry. Sustainability may be achieved through sound water policy that addresses the contemporary and long-term needs of humans as well as the ecological community. This implies that threats to the reliability of water supply are managed in such a way that society is prepared and capable of absorbing them as they occur, and that their frequency and severity decrease over time (Loucks & Gladwell, 1999).

Newman (2000) views sustainability in regard to urban water systems in a similar manner, and identifies the following considerations as being important aspects of developing sustainable systems:

- The need to take the environment seriously, and to integrate this with economic considerations;
- The importance of understanding how infrastructure changes land use;
- The need for more holistic approaches that see the city as an ecosystem; and
- The critical role of local community processes in future management.

In evaluating these ideas of sustainability, there is a clear need to develop an integrated solution for a socially sensitive, economically efficient and environmentally responsible urban water management system. This can be best achieved by through effective planning and forecasting of water supply requirements, and any possible system threats to these requirements. Proactive, rather than reactive measures of system control are the key to sustainable development of water supply systems. These measures include a balance of both structural and non-structural, with particular emphasis on system management as a component of the non-structure measures (Loucks & Gladwell, 1999).

2.3. WATER POLICIES

Ipswich Water is a commercial business of Ipswich City Council, and is governed by a number of legislations and codes, which ultimately defines its operating structure. Principally the business unit is incorporated under the *Queensland Local Government Act 1993* and must therefore comply with all legislative requirements applicable to the Council (Ipswich Water, 2008). Other legislation also have an important application to the operation of Ipswich Water; outlining the way in which the water service provider carries out its operations in supplying water to the people of Ipswich City. Water policies are vital in ensuring that our water resources are managed around the key concept of sustainable development, which involves a balance between economic and environmental goals (Grigg 1996). The following are Queensland State Government policies which are most relevant to Ipswich Water operations:

2.3.1. Water Act 2000

The *Water Act 2000* has the primary purpose of providing for the sustainable management of water resources and the security of these resources into the future. The Act provides the legal basis for water resource plans, resource operations plans, water licences, water allocations, resource operations licences and distribution operations licences, with associated planning and reporting framework (National Water Commission, 2009). The Act identifies regional water security programs to be high on the agenda in regard to sustainable planning of water resources. In relation to such security plans the Act focuses particularly on the development of system operating plans, which aim at meeting level of service objectives. Furthermore the Act sets regulations for water efficiency management plans, which aim at promoting efficient water use by non-residential customers. These plans are required to meet relevant guidelines which aim to increase the efficiency of water use.

A State body that has been formed as a result of the *Water Act 2000* is the Queensland Water Commission (QWC), which has a major role in the management and use of water resources in Queensland. *Section 2.4* provides further detail outlining the QWC and the major reform it is currently implementing to the structure of South East Qld water service providers.

The *Water Act 2000* along with the QWC plays an important role in the governance of water resources in Queensland. The Act will inevitably provide an avenue for the development and implementation of more effective management strategies in the future, and this will inevitably change the roles of Ipswich Water as a service provider.

2.3.2. Water Supply (Safety and Reliability) 2008

The *Water Supply (Safety and Reliability) 2008* is relatively new legislation, which has the primary aim of providing a regulatory framework for providing water and sewerage services, recycled water and drinking water quality, regulation of referable dams and flood mitigation responsibilities, as well as, protecting the interests of water customers. The Act outlines many of the regulatory responsibilities and powers that Ipswich Water as a service provider is obligated to fulfil. Of particular interest to this area of study are the provisions for interruptions of water supply to customers by the service provider. The Act stipulates that the service provider has the power to temporarily shut off water supply to perform work on water infrastructure, with the clause that 48 hours prior notice must be given to those customers that would be affected by such an event. However, notice is not required when shutting down supply in the case of a serious public health threat, a likelihood of serious injury to persons or damage to equipment, or any other type of emergency. This research aims to improve the identification of these risks and the determination of their acceptable levels.

The Act also identifies drinking water quality management plans to be another obligation of the service provider. Such a plan requires the identification of hazards or hazardous events to the quality of water supply, and the assessment of risks posed by these. Water service providers are required to have management strategies in place to determine whether water quality is in compliance with quality criteria. Monitoring programs are important in being able to identify the level of water quality; however the risk analysis of customers will allow the service provider to identify the extent of quality decline at which a particular customer reaches an unacceptable level of risk.

The *Water Supply (Safety and Reliability) 2008* outlines the necessity for customer service standards for urban water supply systems. These standards need to include the level of service to be provided, the process for service connections, billing, metering, accounting, customer consultation, complaints and dispute resolution; and any other matter stated in the regulators guidelines. While general service standards consider a single set of standards for all customers, different market segments often have varying degrees of criticality in regard to water supply. Risk analysis would be effective in identifying the varying requirements of customers, allowing for better implementation of the service standard to meet the specific needs of water customers in regard to their required standard of service.

2.3.3. Environmental Protection (Water) Policy 1997

The *Environmental Protection (Water) Policy 1997* applies to all Queensland waters, and aims to provide a framework for identifying environmental values, setting water quality guidelines, promote the efficient use of resources and promote community involvement. This policy provides the basis for much of the environmental protection measures applied by Ipswich Water to the urban water supply system. While the Act is not central to this focus of study, it does outline important concepts of sustainability, and identifies water quality guidelines to be an important aspect of maintaining sustainable water systems.

2.3.4. Integrated Planning Act 1997

The *Integrated Planning Act 1997* provides a framework to integrate planning and development assessment so that development and its affects are managed in a way that is ecologically sustainable. It seeks to do this in the following ways:

- Coordinate and integrate planning at local, state and federal levels;
- Managing the process by which development occurs; and
- Managing the affects of development on the environment.

The Act controls Ipswich Water's operations in the way of ensuring the sustainable use of water resources; ensuring water infrastructure is developed in a way which is accountable, coordinated and efficient; and by ensuring standards of amenity, conservation, energy, health and safety are administered that are cost effective and for the benefit of the public. A central theme of the Act is ecological sustainability, which aims to find a balance between natural systems, economic development and the maintenance of social wellbeing. Ipswich Water aims to reflect similar principles in their management systems, operating in a way which balances its goals as being a lucrative business unit, providing an integral service to the community, and still maintain a sustainable approach.

The Ipswich City Council has the responsibility through the *Integrated Planning Act 1997* to ensure that water infrastructure is integrated appropriately for different land use activities, and ensuring the water infrastructure network is operated safely and efficiently.

2.3.5. Plumbing and Drainage Act 2002

Plumbing and Drainage Act 2002 and *Standard Plumbing and Drainage Regulation 2003* defines and regulates plumbing and drainage, the licensing of plumbers and drainers, on-site sewage facilities, and a number of other purposes. While applicable to Ipswich Water's operations, this policy is not a focus of this work in developing a market segmentation process.

2.4. CURRENT MANAGEMENT SYSTEMS

Ipswich Water is a medium to large water services provider relative to other service providers found in Australia. It aims to provide high quality and cost effective services to Ipswich City from its Wivenhoe and Somerset Dam storages, which are owned and operated by SEQWater (Ipswich Water, 2009a). Its mission, vision, values and strategic objectives reflect the business's intent to be a leading water service provider, supporting regional relationships and initiatives, as well as focusing on providing its customers with a high quality of service (Ipswich Water, 2009b)

As a key player in the South East Queensland (SEQ) water industry, the current management structure is soon to take a new shape as a result of the SEQ water market reform. This reform is an initiative by the Queensland Water Commission in association with the Queensland Government in an effort to create a unified water supply arrangement for the entirety of south east Queensland. The changes will see newly formed entities, including a state owned bulk water supply authority (SEQWater), a bulk water transport authority, a manufactured water authority, a water grid manager, and three combined distribution/retail entities (Ipswich Water, 2009b). The purpose of this reform is to re-align the management of water and streamline the previously complex water system in SEQ, as well as integrating new water assets being built by the Queensland Government. The reform hopes to gain better control over the water market, allowing adequate water supply to be maintained throughout SEQ, efficiency of the water grid to be optimised and the maintenance of water security through operational and financial responsibility (QWC, 2009). By consolidating the water supply throughout SEQ, the following benefits are anticipated to be achieved:

- Better security of water supply;
- Development of consistent service standards;
- Accumulation of technical expertise; and
- Optimisation of network planning;

These changes in the SEQ water market are likely to have significant changes to the operation of Ipswich Water as a water service provider. Ipswich Water will combine with the water service providers for Brisbane City Council, Scenic Rim Regional Council, Lockyer

Regional Council and Somerset Regional Council. This is likely to cause major transformations to the management structure of the current water distribution network servicing the Ipswich Council as it becomes part of a larger service provider. The newly formed service provider will be likely to integrate the management structures from the current entities, in which Ipswich Water hopes to be a leading contributor. The development of risk management for the identification of critical customers could be an effective management tool integrated into the new set of management strategies. For this reason Ipswich Water considers the development of risk analysis for market segmentation to be as important to their operations as ever before.

Current management systems are aimed at providing a smooth transition through the SEQ water industry reform, and improving the organisation as a commercial entity, ultimately for the benefit of the Ipswich community. Ipswich Water (2009b) states its key strategic objectives as the following:

- To deliver quality water services in a sustainable manner;
- To be recognised as a leading water service provider;
- To increase its commercial performance; and
- To be a valued partner in institutional reform.

Ipswich Water has implemented an Integrated Management System (IMS) to provide quality assurance to the community, Council and management itself. Essentially it involves carrying out certification to ensure that requirements are being met for internationally accepted standards of practice. In doing so, it supports improvements in service, increased staff effectiveness and enhanced customer satisfaction. Ipswich Water (2009b) states that surveillance audits are continually conducted to ensure that requirements are met for the certification of:

- ISO 14001:2004 Environmental Management System
- ISO 22000:2005 Food Safety Management System
- ISO 9001:2008 Quality Management System
- National Association of Testing Authorities (NATA) Environmental Laboratory Accreditation (Chemical Testing)

More specifically to risk management is the Water Response and Resolution Standard (*see Table 2.1 or Appendix 1 for more detail*), which has been developed by Ipswich Water to assign a level of priority and its required level of response in the case of a failure in the supply system. The standard takes into consideration the impact on the customer, hazard or risk to the public, environment or property, as well as the type of customer impacted. The standard assigns varying levels of job priority to failure cases, based on the level of risk that is being imposed.

TABLE 2.1: Water Response and Resolution Standard (Ipswich Water, 2009c).

Priority Level	Level of Impact/Risk	Criteria	Response
P1 Red	Significant	Major or critical customers have no water or there is a hazard or risk to the public health, environment or property due to a burst water main.	Within 30 minutes. Restore supply within 1 hour.
P2 Amber	High	Multiple customers have no water or there is a hazard or risk to the public health, environment or property due to a burst water main.	Within 1 hours. Restore supply within 5 hours.
P3 Yellow	Medium	An individual residential customer has no water due to a water service or water meter failure. Water quality problems e.g. taste, smell and dirty water.	Within 3 hours. Restore supply within 24 hours.
P4 Green	Low	There is minimal impact on the customer e.g. water still available at customer's tap.	Within 1 working day. Complete the job within 3 working days.
P5 Blue	Planned or Deferred Job	There is rectification work required however it is not considered urgent.	Within 4 working days. Agree with the customer the rectification timeframe.

This method of identifying customer criticality uses qualitative measures and takes on a multifaceted view. It is however, ineffective in identifying the specific risks that affected customers will experience during a supply failure. Water customers require different levels of service in respect to water volume, the nature of end usage, and water quality. These requirements need to be taken into consideration when determining the level of risk faced by a particular customer. This research aims to establish risk criteria in which each system user can be more effectively identified by their criticality of water supply. This will allow for more efficient water response and resolution, and in doing so, increase the security of water supply to customers, allowing more efficient control of water in the case of a system failure.

2.5. CUSTOMER BASE

Ipswich Water, being the water service provider for the Ipswich City Council, supplies water to a large customer base. Each day it supplies approximately 35 megalitres of quality assured water in order to meet an increasing demand. The customer base it supplies has a vast range of water requirements to meet residential, industrial, and commercial needs, as well as other needs in community organisations, rural uses and civic services (*see Table 2.2*).

TABLE 2.2: Water usage by land use in the financial year of 2007-2008 (Ipswich Water, 2009b).

Land Use	2007-2008
Residential	60%
Industrial	30%
Commercial	6%
Community organisations	1%
Rural	1%
Civic services	1%

Ipswich has a strong customer service culture, and strives to provide a high level of service to all 149,200 customers connected to the distribution network through 53,300 connections. The current business plan aims at further improvement of customer service by implementing specific programs targeted at critical customers.

Ipswich Water (2009b) characterises its customer base by a number of features, which are important to understand in order to undertake effective market segmentation, these include:

- Growth in residential, commercial and industrial connections;
- Reduced per capita demand for water;
- Significant proportion of demand being attributed to a small number of large non-residential customers (*see Appendix 3*);
- Significant number of the industrial and commercial demand attributed to food processing and manufacturing (*see Figure 2.1*); and
- Low seasonal variations in demand.

Future outlook at the customer base provides evidence of continued growth in the Ipswich City Council, and consequently an increasing demand for urban water supply. With a sustained population growth rate of around 4% per annum (*see Table 2.3*), Ipswich is projected to have a population of 355,000 by 2026. The area that will attribute to the greatest increase in demand will be commercial and industrial customers, while it collectively accounts for 36% of the current market; this sector has seen the most significant growth over the past three years, and this growth is expected to continue.

TABLE 2.3: Water Services customers from 2004 to 2008 (Ipswich Water, 2009b)

	2004-2005	2005-2006	2006-2007	2007-2008	3 Year Inc.	3 Year % Inc	Last 12 Month % Inc
Population serviced	136,000	139,000	144,000	149,200	13,200	9.7%	3.6%
Residential properties	48,600	49,700	51,400	53,300	4,700	9.7%	3.7%
Non-residential properties	3,200	4,100	4,600	4,700	1,500	46.9%	2.2%
Total properties receiving water services	51,800	53,800	56,000	58,000	6,200	12.0%	3.6%

These changing demographics will require major infrastructure advancements for urban water supply service to be maintained in the Ipswich area. This identifies the necessity for continued development of Ipswich's water infrastructure and the implementation of improved systems that provides more efficient water services. While this is likely to become the concern of the new water distribution entity, Ipswich Water will play a major role in setting the foundations for future development of water assets.

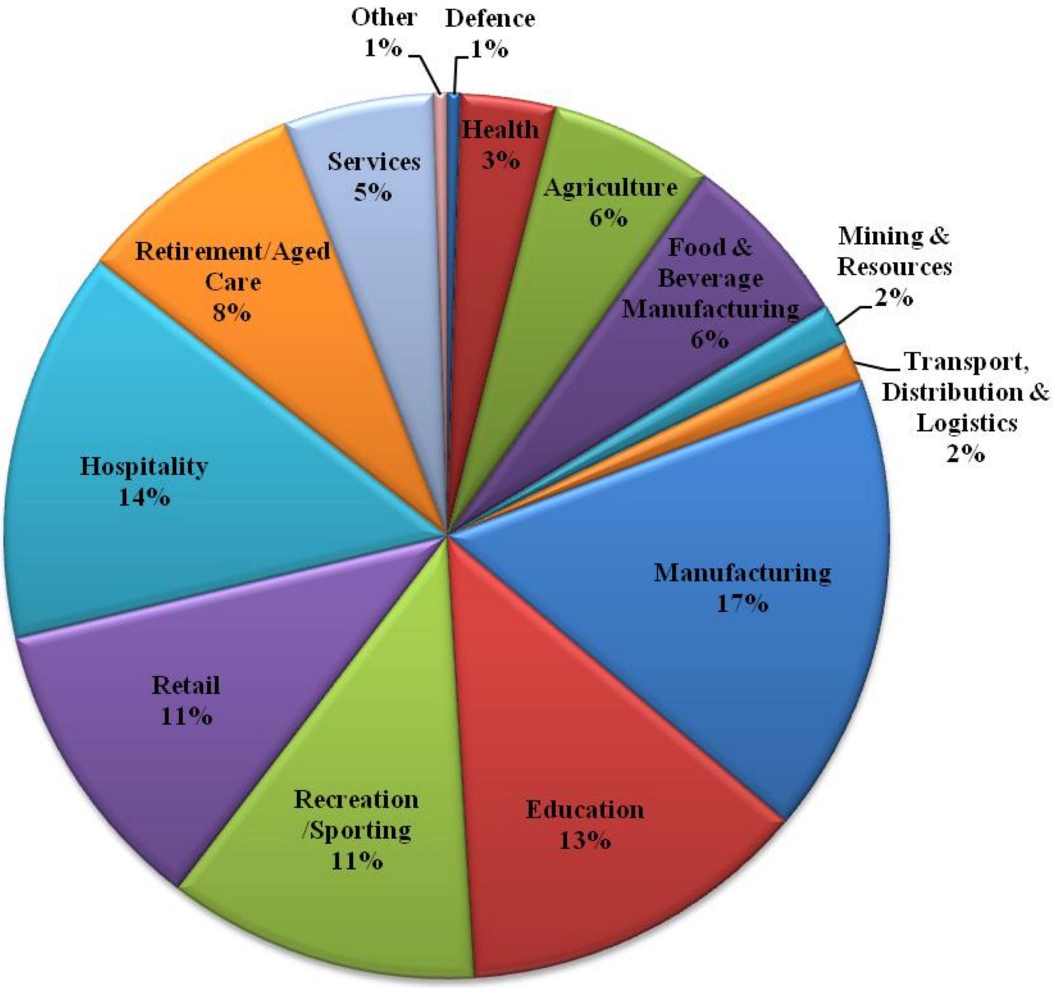

FIGURE 2.1: The Top 200 Water Users by Industry Sector.

2.6. MARKET SEGMENTATION

After gaining an understanding of the Ipswich water market, the development of a methodology for market segmentation can be undertaken. Market Segmentation involves a process of dividing customers into different groups, or segments, based on certain criteria relevant to that market (McDonald & Dunbar 2004). It must be noted here that the better the understanding of the customer base the more effective the segmentation will be.

Ipswich Water needs to be capable of determining the level of service required by customers in the water market to optimise the efficiency of their services. The market segmentation's purpose is to identify which customers have the most critical water requirement in relation to the remainder of the water market. Those considered to be critical in terms of business continuity include large industrial and commercial customers, which would experience large loss of business or productivity if water requirements were not met. Customers considered critical from a functional role perspective may include hospitals, x-ray clinics, doctor surgeries, residential dialysis patients, etc; the loss of water supply to these customers would pose major risk on the welfare of the community. Ideally the segmentation aims to create a prioritised list of customer groups in order of their level of risk in the water market.

In order to carry out a useful market segmentation a criteria needs to be developed that accounts for all the factors that determine critical system users, and the relevant weighting (or importance) of each of these factors. Examination of the water market will identify customers that have particular water requirements, these requirements will become the basis of the risk criteria. The criteria can then be implemented into a risk assessment to identify the level of risk at which a customer exists within the water market. The final outcome will be a number of risk levels; each customer will be assessed and segmented into the appropriate risk level. This method of market segmentation will hopefully be integrated into the management strategies allowing continual risk analysis, which can be used to inform water managers when unacceptable risk arises. The success of the market segmentation as a management tool will rely greatly on the understanding of the characteristics of water consumption by the customer – the more reliable the input data entered into the market segmentation process the more reliable the output will be.

2.7. RISK ANALYSIS

The Australian Standard for Risk Management, AS/NZS 4360:2004 defines risk as the chance of an event occurring that will have an impact on desired objectives. Risk is inherent in any activity, and decisions are continuously made on what is perceived as acceptable risk and what is not. This is the process of risk analysis.

Australia is among one of the first countries to develop an established risk management standard; AS/NZS 4360:2004. It has formed a basis for what is perceived to be an acceptable foundation for risk management. It identifies the risk management process as the controlling, mitigating, monitoring and reassessing of risks to reach a nominated value which is considered to represent an acceptable level of risk (Blackmore & Plant 2008).

Risk analysis has become a vital component in the framework of many organisations. It identifies areas of risk, allowing opportunities to be capitalised on, and threats to be avoided. It is the keystone to the effective, efficient and sustainable operation of an organisation. In order to implement a successful risk management strategy, an organisation needs to establish a system that suits their objectives. AS/NZS 4360:2004 outlines the main elements of a risk management process to be:

- Communication and consultation;
- Establish the context;
- Identify risks;
- Analysis risks;
- Evaluate risks;
- Treat risks; and
- Monitor and review.

These basic steps can be used to establish the structure of a risk management strategy within an organisation. This process can be better understood by the detailed management process shown (*see Figure 2.2*). It is vital to understand the importance in maintaining continual communication and consultation, and monitoring and reviewing; these processes ensure that the risk is always controlled within the system. The primary purpose of the risk analysis is to control risk by implementing measures to reduce unacceptable levels of risk to an acceptable level. By continual risk analysis it is possible to determine if the risk management measures put in place are effective in reducing risk, if they are not then other approaches to risk management may be necessary.

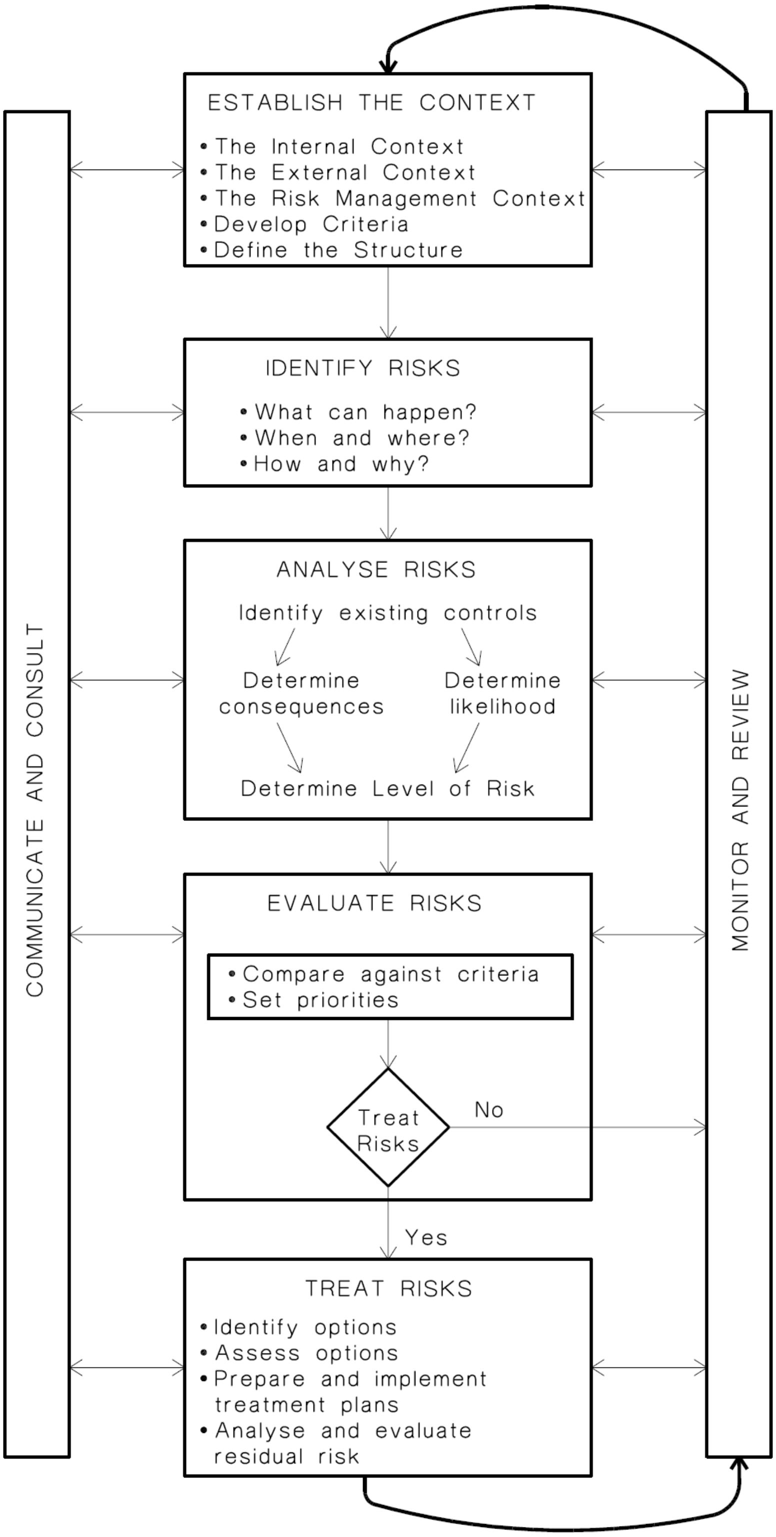

FIGURE 2.2: The Risk Management Process (AS/NZS 4360:2004).

Risk identification is a critical aspect of the risk management process. Once the context of the organisation and its operations has been defined, i.e. the basic parameters in which the risk is to be managed; risks that are capable of impacting on objectives can be determined. While there is a range of tools and techniques that can be implemented, a comprehensive, well-structured systematic process is fundamental.

The next stage in the risk management process involves gaining an understanding of the different levels of risk. Both quantitative and qualitative analysis of the risks can be examined. Quantitative is generally a more accurate measure, as it uses numerical values, as opposed to descriptive scales. Blackmore and Plant (2008) stated that risk can generally be quantified by evaluating a function of the frequency of an event occurring and the magnitude of its consequence. To be able to do this requires a large amount of data analysis, as this is not always possible qualitative scales of measurement are often developed. While this can be fairly subjective, a sound understanding of the system can ensure that a relatively reliable risk analyse can still be achieved.

A risk assessment matrix is a common tool used to weigh the consequence and likelihood of an event against each other to determine a level of risk (*see Table 2.4*).

TABLE 2.4: Exemplary Risk Analysis Matrix.

Likelihood	**Consequence**				
	Extreme	**Major**	**Moderate**	**Minor**	**Insignificant**
Certain	Extreme	Extreme	High	High	Medium
Probable	Extreme	High	High	Medium	Low
Possible	High	High	Medium	Low	Low
Remote	High	Medium	Low	Low	Low
Improbable:	Medium	Low	Low	Low	Low

The final stage involves risk evaluation, which requires defining a tolerable level of risk, and measuring it against the perceived risks from the risk analysis. An evaluation criterion is developed to determine whether a risk needs to be treated, it must be consistent with the defined external, internal and risk management context, and take account of the objectives of the organisation (Standards Australia, 2004). The criteria may be based on financial risk, commercial risk, public health risk, environmental risk, reputation risk and compliance / legal risk.

In urban water systems substantial progress towards risk analysis strategies and decision-making frameworks has been made (Pollard et al 2004). While a large proportion of this development has been in the area of water quality, i.e. protecting the public health from pathogenic and chemical hazards, there is an increasing need to implement risk management into the reliability of supply. The importance of this has been driven by increasing demands as a result of population growth in the face of climate change, pushing urban water resources to its limits (Blackmore & Plant 2008).

Risk assessment is a vital tool for maintenance in urban water systems, as it looks to reduce the threats faced by water users of supply failure. Through the evaluation of water infrastructure assets, the segmentation of the customer base is possible. This aims to select and prioritise critical infrastructure for program maintenance in an effort to yield greater risk reduction per unit resource of maintenance. Risk analysis within a water utility is contingent on institutional capacity, data quality and the requirements of the decision that is reached as a result of the analysis.

3. METHODOLOGY

3.1. INTRODUCTION

Asset management is an integral part of Ipswich Water's function as a water service provider in being able to deliver efficient and reliable water services to its customers. Ipswich Water plans to continue improvement of management practices into the future and this research aims to contribute towards achieving this goal. This work studies the use of risk assessment to prioritise water failure response and to identify the need for maintenance or renewal of water assets.

To achieve Ipswich Water's asset management objectives, market segmentation has been identified as an effective process in gaining system efficiency through directing available resources to the most critical sections of the supply system. While there are numerous methods of carrying out market segmentation, the use of risk assessment to segment customers by level of risk has been determined as the most effective means of identifying particular areas of focus to which resources should be expended. Essentially the objective of risk assessment is to distinguish between high and low risk customers so that priorities of risk management can be established. This is an important function of Ipswich Water who is accountable for providing water services to the community; therefore asset management is critical in their ability to maintain operations as a water service provider. The development of more efficient management tools is reflected as efficiency gains in the operation of Ipswich Water as a business entity and ultimately the supply system.

Risk assessment is system specific, as strategic objectives vary with all systems. Having reviewed current management strategies and water policies, and through examining the customer base, it is possible to establish the risk management objectives that Ipswich Water aims to achieve. To successfully implement risk assessment the characteristics of the supply system need to be understood to identify what hazards may arise, how these hazards create risk and the processes and practices that affect the standard of quality of the service being provided to the customer (ADWG, 2008). This encapsulates the entire supply system including the components of:

- Water sources;
- Storage reservoirs;
- Treatment systems;
- Distribution system; and
- Consumers.

The focus of this work is primarily on the distribution of water supply to the customer, and identifying which hazards put the customer at risk of not obtaining adequate water supply. By examining the characteristics of water consumption in Ipswich six classes of water requirement that form the basis of the risk criteria have been developed, these are:

- Water Volume;
- Business Continuity;
- Functional Role;
- Aesthetic Quality;
- Chemical Quality; and
- Microbiological Quality.

By determining the potential hazards that exist in the supply system it is possible to measure the effect they will have on water requirements, and hence the level of risk that a customer is subject to. Inevitably not all water users are the same, and therefore there is varying degrees at which a hazard will become a risk for different water users. It is the purpose of this risk assessment to identify the level of risk at which individual customers exist, this is not only a function of the hazard itself but also the level of potential, or likelihood of the hazard to a particular consumer. Using a risk matrix the consequence of the identified risks and the likelihood of these risks causing damage can be weighted against each other to output a customer's level of risk. The water market can then be segmented in terms of this risk, providing a valuable tool for risk management.

3.2. HAZARD IDENTIFICATION

Hazard identification is an important step in being able to carry out an effective risk analysis of the customer base. This involves the identification of all hazards and hazardous events and sources that exist in the water supply system, this includes anything that is likely to affect the quality or quantity of water received at the customer's meter. Hazards may arise at a point source or be diffused throughout the distribution network.

A structured approach needs to be adopted for the hazard identification to ensure that anything that may give rise to any form of risk is identified and not overlooked. A comprehensive evaluation of the supply system is required to develop a suitable method of hazard identification, and because all systems are unique, different methods of hazard identification are effective in different situations.

In analysing the Ipswich Water supply system, it is possible to identify those potential hazards that put customers at risk. The system's spatial distribution consists of a central core network in the central business district with outlying residential and industrial centres; however this does not necessarily reflect the nature of the water supply. While the central business district is characterised by high levels of water usage due to the high density of business activity, the primary water consumption is distributed among higher order consumers that are predominately located in industrial areas. Essentially the distribution of supply is characterised by business activity rather than the density of population or business activity. In terms of hazard identification it is important to understand that hazardous events or sources may be just as (or possibly even more) critical in water mains that are located away from the central business areas that appear to be critical areas for the city's function. This is again due to the fact that some of the most critical customers are often located away from the central supply network. For this reason the location of hazardous events and sources is not a function of risk, but rather the characteristics of the water customers.

In carrying out the risk assessment of the water market there are a number of different hazards and hazardous events and sources to take into consideration (*see Table 3.1 and 3.2*). This will often require a thorough investigation into the section of supply network that services each water customer, and may take into account such aspects as the age and condition of the distribution pipe network and any associated appurtenances, as well as any other factors that may affect the supply, i.e. nearby industry or waste disposal areas that may be likely to cause supply contamination. One method that provides a good indication of the supply system is the examination of past records of supply failure, this allows risks that may have caused failures in the past to be analysed in context with the existing system. By taking the time to carefully examine the supply system it is possible to identify all potential hazards.

TABLE 3.1: Examples of potentially hazardous events that occur in water supply systems (ADWG, 2004).

Potential Hazardous Events
Build-up of sediments and slime
Inappropriate materials and coatings or material failure
Aged pipes, infrastructure
Corrosion of reservoirs or pipe systems
Infiltration and ingress of contamination from cross-connections, backflow (soil and groundwater)
Pipe bursts or leaks
Inadequate repair and maintenance, inadequate system flushing and reservoir cleaning
Commissioning new mains
Inadequate disinfection after construction, repairs
Flow variability, inadequate pressures
Treatment dosing failure
Inadequate maintenance of chlorine residual
Formation of disinfection by-products
Failure of alarms and monitoring equipment
Sabotage and natural disasters

TABLE 3.2: Examples of potential water supply hazards (ADWG, 2004).

Potential Sources	Potential Hazards
Sewer overflows	Pathogens, nutrients, turbidity, colour
Stormwater	Lead and zinc from roads, turbidity, colour, petrol/oil products microorganisms, pathogens
Industry	Heavy metals, organic chemicals, specific contaminants (arsenic, copper, cadmium, chromium, etc.)
Septic tanks	Pathogens, nitrates/nitrites
Sewage treatment plants	Pathogens, nutrients

3.3. RISK BASED CRITERIA

Risk based criteria is to be developed for the purpose of assessing critical customers. The criteria will be based on quantitative measures of water demand in terms of both volume and quality, and on qualitative measures of impact to business continuity and functional role. They need to be capable of valuing the position of businesses and service providers in the community, and identify what levels of risk are considered acceptable.

The criteria will be capable of identifying risks that may have an instant affect on a customer, for example a burst water main, or those that may have a gradual affect, for instance the increasing presence of microbiological activity in the water supply. The criteria are to be integrated into a risk matrix, providing both consequence and likelihood scales of risk. While the consequence scale can be defined in relation to the affect of hazards to a customer, the likelihood scale is a bit more difficult to define as it involves determining the probability and frequency of these hazards, for the purpose of this risk analysis a simple subjective scale will be adopted. Using a subjective scale is likely to reduce the accuracy of the risk analysis as it would rely on the judgement of those carrying out the analysis; an accurate likelihood scale could only be developed through a thorough analysis of historical records of past supply failures. Ipswich Water will require further development of the likelihood scale in order to gain full accuracy from the risk assessment process. The primary purpose of this research is to focus on the development of a risk consequent scale which can effectively measure the different levels of risk that water users are subject to. This will set the basis for an effective risk analysis tool that can be implemented into Ipswich Water management system.

Urban water supply systems are exposed to a range of risks that have potential to affect the level of service experienced by the customer. These risks may be classified as any of the following:

- commercial/financial
- organisational
- political
- demand
- public health
- environmental
- security
- infrastructure
- social
- natural disasters
- technological
- operational

However it is more the way this risk is conveyed to the customer that is the central focus to the risk criteria, and to measure this three main categories of water volume (or water demand), end use of the water supply and the required water quality have been established. Further detail is provided on these categories in the following sections, of which some consist of several sub-categories. The final aim is to produce risk criteria that encompasses these categories, and has corresponding levels of risk rating to allow for compatibility into a risk matrix.

3.3.1. Volume/Demand Criteria

Volume of water consumption by water users is identified as a critical requirement for Ipswich Water to meet. It forms an integral component of the risk based criteria, as high water users generally require large volumes of water to maintain business operations. Even a partial loss of supply can be damaging to some consumers which rely on a constant water supply to maintain operations. A supply failure (or partial supply failure) event may result in serious consequence that may cause financial damage, degradation of business reputation, or disruption to business processes. By examining the volumes of annual water consumption from past years, a profile of customers in order of volume of consumption can be developed (*see Appendix 3*). Those higher order consumers are considered to be at the greatest level of risk, as their requirement in the supply system is a larger proportion of the water market compared to small scale consumers.

Ipswich Water holds a responsibility to put management practices in place to minimise the risks faced by water users as a result of inadequate water supply. Such practices need to ensure that the performance of the supply system is capable of maintaining supply, and this may involve having contingent supply available in the form of a second main connection for some higher order users, or backup water sources. The primary objective is to ensure continuous supply is maintained at the required volumes for those customers considered to be critical in terms of water volume.

The risk based criteria for volume is developed by analysing water usage by customers in the water market. Typical values of consumption allow an indication of water usage for different industries (*see Table 3.3*), providing a guide to what levels of water supply are critical for particular water users. Generally a better method of determining water consumption for individual customers is by examining Ipswich Waters' meter readings (*see Appendix 3*). Once a profile of the water consumption by volume per customer is developed, suitable levels of risk at varying degrees of consumption can be determined. This is generally done by identifying the characteristics of customers down the profile, and determining at which critical point the volume of consumption changes the degree of risk faced by the customer. These critical points become the boundaries of different levels of risk rating; these points are based on an assessment of the water customers and are defined at the discretion of the service provider.

TABLE 3.3: Common urban water demand for different developments (DNRM, 2005).

Development	Water Demand (L/day)	Water Demand (ML/year)	Unit
Apartment/Home Unit	300 to 500 550 to 750 700 to 900	0.11 to 0.18 0.20 to 0.27 0.26 to 0.33	1 bed 2 bed 3 bed
Caravan Park	550 to 750	0.20 to 0.27	site
Central Business	14000 to 20000	5.11 to 7.30	ha
Child Care Centre	40 to 70	0.01 to 0.03	staff & pupils
Commercial Premises	500 to 800	0.18 to 0.29	100 sqm GFA*
Convalescent Home	600 to 1100	0.22 to 0.40	bed
Education – Primary School	50 to 80	0.02 to 0.03	staff & pupils
Education – Secondary School	90 to 150	0.03 to 0.05	staff & pupils
Education – Tertiary Institution	90 to 150	0.03 to 0.05	staff & pupils
Food Services	1200 to 2000	0.44 to 0.73	100 sqm GFA
Heavy Industry	10000 to 35000	3.65 to 12.78	ha
Hospital	500 to 1800	0.18 to 0.66	bed
Hotel	700 to 1200	0.26 to 0.44	100 sqm GFA
Light Industry	10000 to 35000	3.65 to 12.78	ha
Major Shopping Development	300 to 800	0.11 to 0.29	100 sqm GFA
Medical Centre	400 to 700	0.15 to 0.26	100 sqm GFA
Motel	300 to 600	0.11 to 0.22	room
Public Building	500 to 600	0.18 to 0.22	100 sqm GFA
Restaurant	800 to 1800	0.29 to 0.66	100 sqm GFA
Retirement Village	300 to 700 500 to 1000 700 to 1400	0.11 to 0.26 0.18 to 0.37 0.26 to 0.51	1 bed 2 bed 3 bed
Shop	600 to 800	0.22 to 0.29	100 sqm GFA

(* GFA – Gross Floor Area) These values are only for indicative purposes.

3.3.2. End Use Criteria

Customers can also be classified in terms of the purpose of their water consumption, as different customers require water supply for a range of different uses. The end use of the water supply has been identified as a measure of criticality of water supply for some customers in the supply system. The development of risk criteria for end use focuses particularly on those customers that carry out business activity or important functional roles that are reliant on water supply. It aims to identify the risk these customers face if they are unable to maintain their business or function as a result of inadequate water supply. To develop an effective criteria a close examination of the customer base is necessary to determine what type of water uses are evident throughout the Ipswich City water market, and identify how these can be defined in terms of critical supply.

From analysis of the customer base (*see Section 2.5*), the water market can essentially be segmented into 14 categories based on the end use purpose of their water supply (*see Figure 2.1*). These categories have been defined by key characteristics of the customers' business activity or functional role, which are determined from Ipswich Water's customer industry sectors (*see Appendix 3*). These categories are as follows:

- Agriculture;
- Defence;
- Education;
- Food & Beverage Manufacturing;
- Health;
- Hospitality;
- Manufacturing;
- Mining & Resources;
- Recreation/Sporting;
- Residential;
- Retirement/Aged Care;
- Retail;
- Services; and
- Transport, Distribution & Logistics.

These categories define water usage over a multitude of industry sectors, for the purpose of the risk criteria, end use will be separated into water usage for business continuity and water usage for functional role. Those customers that have water requirements to carry out business activities may be exposed to risk in the form of financial damage, loss of business reputation or disruption to business processes. For this reason those customers with critical business continuity requirements that rely on water supply, need to be identified and assessed in terms of the level of risk that inadequate water supply would expose them to. The development of the risk criteria will require risk ratings to be formed by a measure of the impact or damage that such risks could cause to business activity. The degree of impact or damage can often be defined by the value of monetary loss, loss of business's customers or downtime of business operation. A sound understanding of the economic environment and the nature in which these industries operate is required to define these values, and therefore preliminary criteria in qualitative terms may be simpler to define, and easier to use, despite having shortfalls in accuracy and consistency.

Other categories of water usage provide important functional roles for the welfare of society. Those customers that require water supply to provide important services may experience risk in the form of not being able to maintain a state of welfare in the community, i.e. the maintenance of life supporting services, or other important medical and social functions. The use of risk management for functionally critical customers is undoubtedly of utmost importance for Ipswich Water in maintaining accountability for providing quality services as a water provider. The development of the risk criteria is very difficult to define in quantitative measures; rather it requires a determination of risk ratings based on the nature of the service a customer provides, and the consequence of this service not being available. The criteria aims to segment customers in terms of whether they provide services that are life supporting through to services which have minimal social impacts. Levels of risk for the development of the criteria can be determined by identifying customers that carry out functional roles, defining the importance of their role for social welfare, and determining the risk that exists if water requirements are not sustained to these customers.

3.3.3. Water Quality Criteria

Water quality is another very important requirement of water supply for many customers, and while some users have very specific requirements, others have very minimal. Drinking water guidelines offer indicative levels of quality that are required to maintain a potable water supply, this study refers to the *Australian Drinking Water Guidelines* (2004) as a guideline for water quality. However not all customers are the same, some may be very sensitive to any decrease in quality, while others have a much greater level of tolerance. The standard of water quality that a customer demands is determined by the purpose for which they intend to use their supply for. Customers that have highly specific quality requirements to maintain a function or operation will experience greater levels of risk, as opposed to those customers that have limited quality requirements. Risk analysis is important for identifying those customers that are critical in terms of the quality of water supply, allowing customer specific service levels to be maintained.

Water quality is defined by a wide range of different parameters; the *Australian Drinking Water Guidelines* (2004) outlines acceptable levels of quality for all factors that have so far been identified to affect the quality of drinking water supplies. To develop more effective risk criteria, three sub-categories of water quality have been adopted, with the aim of targeting customer specific quality requirements. These sub-categories have been devised from the ADWG as the three primary components of water quality, they include:

- Aesthetic Quality;
- Chemical Quality; and
- Microbiological Quality.

The first category, aesthetic quality, aims to identify those customers that have particular requirements in terms of the water aesthetics – characteristics that are associated with acceptability of water by the consumer (ADWG, 2004). Those customers that rely on the water supply for its aesthetic appeal are likely to be at the greatest level of risk if these requirements cannot be met. The ability to identify those customers that are critical in terms of aesthetic quality is an important component of risk management for Ipswich Water.

There are a large number of factors that can affect the aesthetic quality of water supply; these are outlined in the ADWG, which provides values of suitable concentrations for these attributing factors (*see Table 3.4*). Aesthetic quality can generally be defined by the following parameters:

- Appearance;
- Taste; and
- Odour.

Appearance is usually measured in terms of colour or turbidity. Colour can be caused by substances in solution, known as true colour, or by substances in suspension known as apparent colour. The standard unit of measurement for colour is Hazen Units (HU), which is defined in terms of a platinum-cobalt standard (Aravinthan & Yoong, 2009). A number of causes can be attributed to undesirable water colour (*see Table 3.4*); these need to be recognised when considering risk in terms of aesthetic quality.

Turbidity is a measure of the light-transmitting properties of water, caused by suspended and colloidal material of clay, silt, colloidal matter, plankton and other microorganisms (Aravinthan & Yoong, 2009). The water treatment plant (Mt Crosby Treatment Plant for Ipswich Water) ensures that sourced water meets acceptable turbidity levels before entering the distribution network, however deteriorating pipelines and system contamination can affect the turbidity after the water has been treated, this is measured in Nephelometric Turbidity Units (NTU). The ADWG outlines an acceptable balance of both colour and turbidity (*see Figure 3.1a and 3.1b*), while these values can be adopted for drinking water purposes, a range of other customers that use water for other purposes may have much lower requirements for appearance.

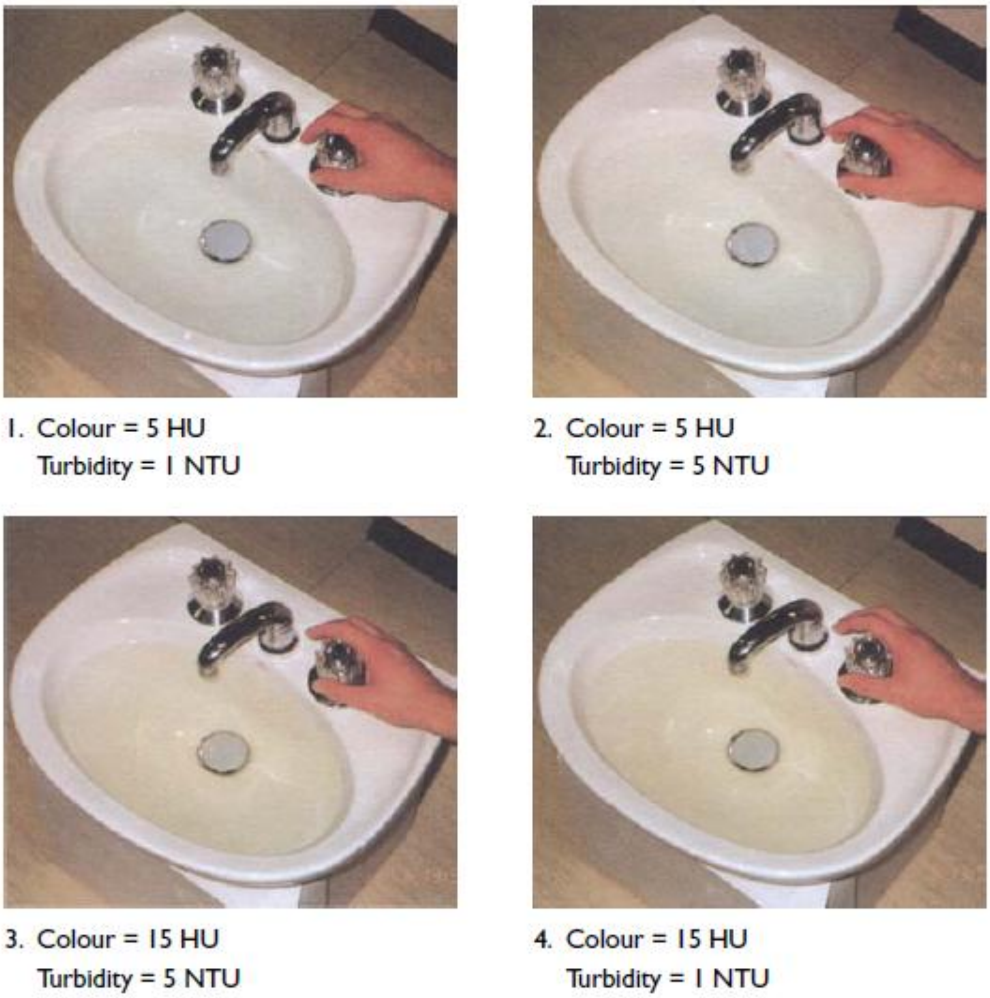

FIGURE 3.1a: Varying degrees of colour and turbidity (ADWG, 2004).

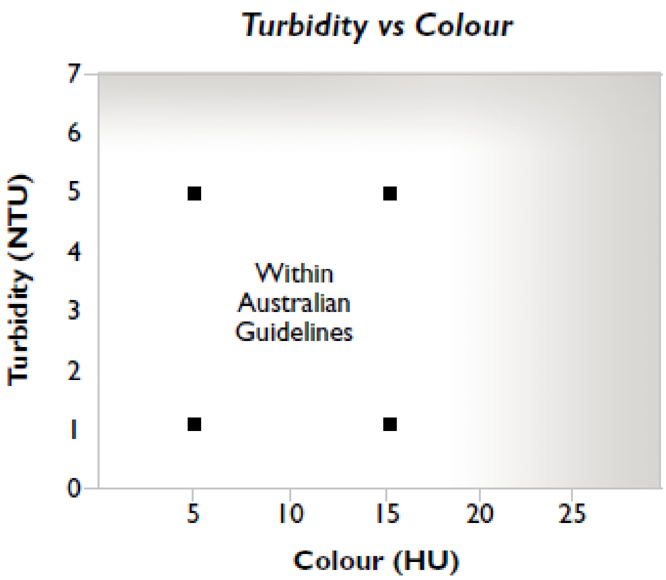

FIGURE 3.1b: Australian guidelines for colour and turbidity (ADWG, 2004).

Taste and odour in the water supply must be acceptable for those consuming the water for drinking purposes; other customers that use the water for alternative purposes may have little or no taste and odour requirements. Odour and taste is the primary criteria consumers use to judge the quality of drinking water, however people's perception of taste and odour vary, therefore guideline values adopt what is considered satisfactory for a significant proportion of customers. Odour and taste in the water supply may indicate a contamination of the supply or a malfunction in the water treatment or distribution network, a range of guideline values for contamination concentrations are adopted to identify taste and odour thresholds (*see Table 3.4 or Appendix 4*) (ADWG, 2004).

To develop risk criteria for aesthetic quality, we need to examine those factors that cause unacceptable appearance, taste or odour, and identify how they relate to the ability of customers in the water market to maintain their function or operation. The degree of risk at which customers exist will be measured by the impact or damage affect of insufficient water quality. Risk rating will be based on the level of water quality required, and the subsequent implications if this standard of quality is not met. High risk users are likely to require the highest standard of drinking water and be susceptible to major ramifications to their functions or operations if these requirements of water supply are not maintained.

TABLE 3.4: Hazards that affect Aesthetic Quality (ADWG, 2004).

Hazard	Description	Threshold Value
Aluminium	Found in water supplies due to the natural leaching from soil and rock. It is also used as a coagulant in water treatment plants, and this can sometimes lead to post-flocculation problems when the soluble aluminium concentration becomes exceedingly high. At these concentrations a white gelatinous precipitate of aluminium hydroxide forms, which can results in milky colour of the water supply. Although health concerns related to aluminium concentrations in water supplies have not been identified, it is still under review, and water authorities are encouraged to maintain concentrations below 0.1 mg/L.	0.2 mg/L
Ammonia	Used in conjunction with chlorine as a disinfectant for water supplies. Generally concentrations are kept below 0.2 mg/L, however when concentrations become greater the risk of copper pipe corrosion increases. Odour problems also arise as concentrations exceed 1.5 mg/L. Australian Drinking Water Guidelines consider concentrations up to 0.4 mg/L to be acceptable, however they are usually kept below 0.2 mg/L. At these levels of concentrations there is no health risks faced by humans.	0.4 mg/L
Chloride	A naturally occurring contaminant in water sources from dissolved salts, or from effluent contamination. Chloride does not pose as a health risk as it is essential in the human body for osmotic activity. Aesthetic concerns arise when concentrations reach 200-300 mg/L, at which point its taste becomes evident, it may also have the affect of causing corrosion of pipes and affect the solubility of metal ions.	250 mg/L
Chlorine Dioxide	Used as a disinfectant in water supplies, and becomes a problem when high levels of concentrations reach a point at which taste and odour becomes detectable.	0.4 mg/L

Chlorobenzene	Generally used as a solvent and will only be found in the water supply through contamination (which is yet to occur in Australia). Taste and odour becomes unacceptable at a high concentration.	0.01 mg/L
Chlorophenols	Occurs in water supplies from chlorination of water that contains phenol or lower chlorophenols. With increased concentration, taste and odour becomes noticeable, with a characteristic antiseptic odour.	0.0001 mg/L to 0.002 mg/L
Colour (True)	The colour after particulate matter has been removed (usually by filtration through a 0.45 micrometer pore size filter). ADWG (2004), makes recommendations on what is perceived to be acceptable colour, most people would probably accept up to 25 HU provided turbidity is low. Australian reticulated supplies vary from 1 HU to 25 HU for filtered or fully treated supplies, and from 1HU to 85 HU for unfiltered supplies.	15 HU
Colour (Apparent)	The colour resulting from both the effect of true colour and any particulate matter, or turbidity. It is a more subjective method of aesthetic quality measurement. Variations in colour are likely to lead to more complaints than a high but consistent colour. Colour is often related to organic content, and therefore does not always raise health concerns; chlorination can produce chlorinated organic compounds as by-products which may affect the effectiveness of the disinfectant, creating a risk of bacterial infection in the water supply. Coloured water may not always raise direct health concerns, however may prompt people to seek other, possible less potable water sources as an alternative.	N/A
Copper	Leaches into water sources from rocks and soils where it exists as carbonate and sulphide minerals. It has a taste threshold of 1-5 mg/L, and concentrations above 1 mg/L cause blue and green staining.	1 mg/L

Dissolved Oxygen	The free and uncombined form of oxygen found in the water supply. The saturation concentration of dissolved oxygen in the supply is determined by the parameters of temperature, total dissolved solids and pressure. The ADWG (2004) provides a guideline for suitable dissolved oxygen saturation based on aesthetic considerations of taste, odour and corrosion prevention. Oxygen concentrations lower than this enable some anaerobic microorganisms to grow, producing by-products that affect the aesthetic quality of the water and increase corrosion of pipes and fittings. This has indirect effects of higher concentrations of heavy metals such as lead, copper and cadmium.	85% saturation.
Ethylbenzene	Occurs naturally in crude oil and to a small extent in petrol, and may contaminate the water supply. Acceptable concentrations are based on taste and odour considerations.	0.003 mg/L
Hardness	Caused primarily by the presence of calcium and magnesium ions, although cations such as strontium, iron, manganese and barium also contribute. Total hardness is the sum of the concentrations of calcium and magnesium ions expressed as a calcium carbonate equivalent. High concentrations may lead to excessive scaling of pipes, and cause blockages in hot water systems.	200 mg/L
Hydrogen Sulphide	Formed in the water supply from the hydrolysis of soluble sulphides, or the reduction of sulphate by action of microorganisms. At excessive concentrations, taste and odour become evident, with a characteristic 'rotten egg' odour.	0.05 mg/L
Iron	Leaches into water sources as it is naturally found in soils and rocks as oxide, sulphide and carbonate minerals. High concentrations cause water supplies to have a rust-brown appearance, as well as taste and odour problems.	0.3 mg/L

Manganese	Found naturally in water sources, with high concentrations evident in anoxic conditions. These high levels of concentration are likely to cause undesirable taste and stains to plumbing fixtures.	0.5 mg/L
pH	A measure of hydrogen ion concentration in water supplies. pH should be maintained within a suitable range to avoid corrosion and encrusting of pipes. A relationship between pH and health issues has not been determined, as it is closely associated with other aspects of water quality.	6.5 to 8.5
Sodium	Commonly found in water supplies due to the high solubility of sodium salts. Sodium as sodium salts such as sodium chloride and sodium sulphate provide a noticeable taste with high levels of concentrations. No health based guideline value has been established, but it has been linked to congestive heart failure.	180 mg/L
Styrene	May be found in water supplies due to contamination from industrial areas occurs. Its taste threshold becomes more prevalent at lower temperatures (ranging between 0.02 mg/L and 2.6 mg/L).	0.004 mg/L
Sulphate	Found naturally in many minerals, and can leach into water sources. In anoxic conditions the reduction of sulphate to sulphide by bacteria can cause undesirable taste and odour due to the release of hydrogen sulphide, it may also cause an increase in pipe corrosion.	250 mg/L
Toluene	As a component of crude oil toluene can enter water supplies by atmospheric deposition, leaching from synthetic coatings in storage tanks or by point source pollution. Taste and odour becomes noticeable with increasing concentrations.	0.025 mg/L

Total Dissolved Solids (TDS)	Includes all inorganic salts and small amounts of organic matter that are dissolved in water. At high concentrations of TDS scaling of pipes may occur, along with excessive corrosion. Acceptable levels of TDS are generally based on taste considerations.	500mg/L
Trichlorobenzenes	Usually found as by-products of industrial activities, and may leach into water supplies. The acceptable limits of concentration are based on taste and odour considerations.	0.005 mg/L
Turbidity	Caused by fine suspended matter such as clay, silt, colloidal particles, plankton and other microscopic organisms in the water supply. The result of turbidity is a 'muddy' or 'milky' appearance of the water. ADWG (2004) provides guidelines on acceptable levels of turbidity for desirable aesthetic quality. For disinfection to be carried out, turbidity is required to be less than 1 NTU.	5 NTU
Xylenes	A component of crude oil, and can enter water supplies through point source pollution. Acceptable concentrations in the water supply are based on taste and odour considerations.	0.02 mg/L
Zinc	Found naturally in small quantities of most rocks, and can therefore leach into water sources. The allowable concentration is based on its taste threshold.	3 mg/L

Chemical quality is another important consideration for water quality, those customers that rely on a potable water supply, require that the supply meets appropriate drinking water standards; other customers may have other specific chemical quality requirements. The *Australian Drinking Water Guidelines* (2004) outlines acceptable chemical characteristics for potable water supply (*see Table 3.5*), and this has been adopted to set the standard of chemical quality at Ipswich Water. If customers experience a shortfall in this accepted level of chemical quality in the water, there is varying degrees of possible outcomes depending on the nature of the customer. Those customers that are likely to experience major health or operational consequences are to be classified as high risk, and therefore are critical in terms of chemical quality. On the other hand, some customers may notice very minimal effects if they do not receive water supply that meets the standard outlined by the ADWG (2004). This vary degree of impact on the customer is the basis of the risk criteria for chemical quality.

Ipswich Water aims to maintain an acceptable standard of potable water to all customers; risk is therefore defined by the susceptibility of a customer if this level of quality cannot be maintained. The risk criteria is therefore a function of the resilience of a customer to a decline in chemical quality, this is measured in terms of health implications or the impact on operations. The levels of risk rating are formed by determining at which point the implication on health or operation becomes increasingly more critical. These are established by considering what is deemed acceptable in context with the Ipswich water market.

TABLE 3.5: Hazards that affect Chemical Quality (ADWG, 2004).

Hazard	Description	Threshold Value
Acrylamide	Minor impurity of polyacrylamide, which is often used as a flocculate aid.	0.0002 mg/L
Aldrin and dieldrin	Formally used in agriculture as an insecticide, still may exist in the environment, and may leach into water sources.	0.0003 mg/L
Antimony	Pollution of water sources from lead or copper smelting operations.	0.003 mg/L
Arsenic	Naturally occurring, and may enter the water supply from the dissolution of minerals and ores, industrial effluent or atmospheric deposition.	0.007 mg/L
Atrazine	Used as herbicide, and has a high mobility enabling it to spread in from soil into water sources.	0.04 mg/L
Barium	Occurs naturally, with barium salts being soluble in water, leaching into water sources may occur.	0.7 mg/L
Boron	Leaching from boron-containing minerals, or by contamination of water sources.	4 mg/L
Bromate	Formed from bromide during ozonation.	0.02 mg/L
Cadmium	Impurities from zinc in galvanised pipes which may contaminate the water supply.	0.002 mg/L
Carbon tetrachloride	Can be present in chlorine used as a disinfectant.	0.003 mg/L
Chlordane	A formally used broad spectrum insecticide, which is readily absorbed by soils, and is resistant to degradation.	0.001 mg/L

Chlorite	Forms from chlorine dioxide, which is used as a disinfectant in water treatment.	0.3 mg/L
Chlorine	A disinfectant used in sewage and waste water, swimming pool water and industrial cooling water.	5 mg/L
Chloroacetic acids	A by-product of the reaction between chlorine and humic or fulvic acids.	0.1 mg/L
Chromium	Occurs in rocks and soils as chromium oxide, and weathering, oxidation and bacterial action convert this insoluble compound into soluble salts.	0.05 mg/L
Cyanide	Can enter the water supply from contamination or through natural deposition from some plant species.	0.08 mg/L
Cyanogen chloride	A by-product of chloramination.	0.08 mg/L
2,4-D	A synthetic herbicide that can leach into water sources.	0.03 mg/L
DDT	Non-synthetic contact insecticide which can contaminate the water supply attached to soil or clay particles.	0.02 mg/L
Dichloroethanes	May occur in the water supply as a result of industrial effluent contamination.	0.003 mg/L
Epichlorohydrin	Used to manufacture glycerine and unmodified epoxy resins, and may enter the water supply through contamination.	0.0005 mg/L
Fluoride	Occurs naturally in seawater, soils and air, and is added to some water supplies for its dental benefits.	1.5 mg/L
Formaldehyde	May exist in the water supply from the ozonation of humic material, accidental contamination or by deposition from the atmosphere.	0.5 mg/L

Heptachlor	A broad spectrum insecticide which is very resistant to degradation, and may leach into the water supply.	0.0003 mg/L
Iodide	Naturally present in seawater, nitrate minerals and seaweed, and may leach into the water supply.	0.1 mg/L
Lead	May enter the water supply from dissolution of naturally occurring sources, or from some household plumbing systems.	0.01 mg/L
Lindane	Used as an insecticide, and may enter the water supply by direct application for the control of mosquitoes.	0.02 mg/L
Mercury	Occurs naturally at very low levels, contamination of the water supply may occur from industrial emissions or spills.	0.001 mg/L
Molybdenum	Found in ground and surface water at very low concentrations, mining operations, power stations and fertiliser applications often increase concentrations.	0.05 mg/L
Monochloramine	A disinfectant used in water supplies.	3 mg/L
Nickel	Can enter the water supply when prolonged contact between water and nickel-plated plumbing occurs.	0.02 mg/L
Plasticisers	May enter the water supply as a result of prolonged contact between water and polyvinyl chloride products, or by industrial spills.	0.01 mg/L
Radionuclides	Naturally occurring isotopes potassium-40, lead-210 and radium-228 emit radionuclides which may enter the water supply.	0.5 Bq/L

Radium-226 and radium-228	Radium isotopes are formed from the radioactive decay of uranium-238 and thorium-232, which are naturally occurring.	0.5 Bq/L
Radon-222	A radioactive gas produced from the decay of radium-226 in soils and minerals.	100 Bq/L
Selenium	Found naturally, as well as from the burning of coal, and may enter into water sources.	0.01 mg/L
Silver	Occurs naturally in very low concentrations, and may also be used as a disinfectant.	0.1 mg/L
Trichloroacetaldehyde	A by-product of chlorination of water containing organic matter, and may also enter the water supply through industrial spills.	0.02 mg/L
Trihalomethanes	A by-product of chlorination and chloramination.	0.25 mg/L
Uranium	Occurs in the environment from the leaching of natural sources, release in mill tailings, combustion of coal and other fuels, and the use of phosphate fertiliser.	0.02 mg/L

Microbiological quality is another important component of water quality, as the water supply should be free of any microbiological activity that is disease producing. The *Australian Drinking Water Guidelines* (2004) defines microbiological quality by the four types of disease causing microorganism, these are:

- Bacteria (*see Table 3.6*) – single-celled microorganisms which feed on soluble organic and inorganic matter, and reproduce in specific conditions by binary fission;
- Protozoa (*see Table 3.7*) – single-celled aquatic microorganisms with complex digestive systems which feed on solid organic matter and replicate by binary fission;
- Toxic algae (*see Table 3.8*) – the intracellular toxins produced by cyanobacteria, which have the ability to damage liver, nerve, kidney, gastrointestinal tract and blood vessels ; and
- Viruses (*see Table 3.9*) – microorganisms which consist of a core nucleic acid surrounded by a protein coat, they lack the ability to self-reproduce, only replicating in host cells.

If populations of these different types of microorganisms multiple in the water supply than consumers may face serious health risks. Generally these health concerns only affect those customers that use the water supply for drinking purposes, or for other food manufacturing and processing purposes that would allow the microorganisms to enter the body. The outbreak of microorganism populations can often be widespread in the supply system, having extensive impact on human health. For this reason, risk analysis in terms of microbiological quality is important for Ipswich Water in identifying those customers that would be at the greatest risk if such an outbreak occurred.

The development of risk criteria aims to identify those customers that are at the greatest level of risk of being affected by microbiological activity. By examining the customer base we are able to identify those customers whose water usage involves human consumption and those who do not. The criteria can then be formed on the degree of health implication that microbiological activity would potentially have on those customers using water for human consumption. The risk ratings can then be established as varying levels of severity of the health implication on the consumer. This will allow for the most severely affected customers to be identified at the greatest level of risk, and those customers that are likely to see little or no affect from microbiological activity to be identified in the low risk range.

TABLE 3.6: Hazards that affect Microbiological Quality (Bacteria) (ADWG, 2004).

Hazard	Description
Aeromonas	Normally inhabits fresh water, but may be found generally in the water supply, as well as food and soil. While it is known to cause health problems in humans, an acceptable guideline value has not been established as correlations between its existence in the water supply and the subsequent affect on human health is yet to be determined.
Burkholderia pseudomallei	Commonly found in soil and muddy water of the tropics, and can exist in water sources for long periods even in the absence of nutrients. It has been attributed in causing the disease melioidosis, which can be potentially fatal, a guideline has not been determined as there is limited evidence that water supplies transmit *B. pseudomallei*.
Campylobacter	Generally transmitted in animals, however waterborne outbreaks have been recorded in the past. Generally the risk of an outbreak increases with unchlorinated or inadequately chlorinated surface waters. Any outbreaks in piped water systems suggest poor system design or inadequate management of the system. *Campylobacter* is capable of causing acute gastroenteritis, however the infectious dose required is yet to be determined, and therefore no guideline value for acceptable concentration has been established.
Escherichia coli and thermotolerant coliforms	Capable of aerobic and facultative anaerobic growth, and are usually found in large numbers in human and other warm-blooded animal faeces. The presence of *E. coli* in water supplies indicates faecal contamination, and poses great risks to the quality of the water supply. *E. coli* causes many health concerns to humans, and therefore water quality guidelines state that it should not be present in a minimum 100 mL sample of the water supply.

Klebsiella	Exists in the environment, and can often be associated with the roots of plants. Generally they are found to exist in raw water and disinfection of the water supply is considered an effective method of control. No guideline value has been specified for *Klebsiella*, as it should be established on a system specific basis.
Legionella	Found widespread across natural freshwater sources, and may also exist in some soils. They infect humans by inhalation, meaning their presence in the water supply is irrelevant until amplified growth occurs in thermal enriched conditions that allow infective aerosols and droplet nuclei to form. Guideline values have not been established, however warm-water systems are considered to be at risk of contamination.
Mycobacterium	Water supplies have been commonly known to harbour *Mycobacterium*, and it is considered to be one of the most commonly occurring species. Some evidence suggests a relationship between human disease and the presence of the bacteria in the water supply. Some cases have associated the presence of the organism on cooling structures.
Pseudomonas aeruginosa	Common in faeces, soil, and sewage, and usually present in water supplies. While the bacteria can cause health concerns in humans, its widespread occurrence and a lack of evidence suggesting its presence in a water supply is related to health issues, it has made it difficult to establish a guideline value.
Salmonella	Found throughout the environment, and can enter water supplies through faecal contamination from livestock, native animals, drainage water and inadequately treated waste water and sewage discharges. *Salmonella* can infect humans, and while a specific guideline value has not been established, it should be tested for when contamination is suspected and relevant health authorities should be consulted.

Shigella	Infection from waterborne outbreaks is not common. Major outbreaks that have occurred in water supplies have been the result of faecal contamination. The bacteria can give rise to serious health concerns to humans even at low infective doses. Its volatility depends on the strain involved, the numbers and the susceptibility of the population.
Vibrio	Some species such as Cholera (*V. Cholerae*) can be waterborne, and pose serious health risks if major outbreaks occur in the water supply. While forms of the species are commonly found in water sources, guidelines state that the *V. Cholerae* must be completely absent in the water supply.
Yersinia	Growth occurs in specific conditions, generally at low temperatures, and they survive for long periods of time if these conditions are right. Some strains of the bacteria cause health concerns to humans, while infectious doses have not been established, guidelines state that these particular strains should not be present in the water supply.

TABLE 3.7: Hazards that affect Microbiological Quality (Protozoa) (ADWG, 2004).

Hazard	Description
Acanthamoeba	Common in aquatic environments as well we in soils, it is capable of causing both cerebral and corneal infections in humans. With the widespread occurrence of the protozoa in soil, airborne dust and water, it is unknown the significance of the water supply as a source of infection, for this reason a guideline value is yet to be proposed.
Cryptosporidium	Considered to be the most important waterborne human pathogen, as it can cause major health concerns to those infected, and may be life threatening depending on age and immune status. Generally multiple barrier preventive methods are implemented to minimise the risk of contamination. Monitoring of water supplies is difficult as impractically large volumes of the water supply would require testing for meaningful indications to be obtained. Any detection of *Cryptosporidium* requires immediate consultation with relevant health authorities.
Giardia	There are a number of species that are infectious to humans, and can cause serious health complications. Monitoring of the water supply is difficult to undertake, any detection of *Giardia* requires consultation with relevant health authorities.
Naegleria fowleri	Causes the waterborne disease primary amoebic meningoencephalitis (PAM), which is a rare but fatal condition. It usually has an irregular distribution and is dependent on relatively high water temperatures. A density of 2 organisms per litre is considered to be an appropriate threshold for which action should be taken to consult with relevant health authorities.

TABLE 3.8: Hazards that affect Microbiological Quality (Toxic Algae) (ADWG, 2004).

Hazard	Description
Cylindrospermopsin	Produced by freshwater cyanobacteria, of which some strains will have some degree of toxicity. This toxicity has a number of implications to humans that come in contact with the algae, however insufficient toxicity data has meant that acceptable concentrations are yet to be established.
Microcystins	Produced by cyanobacteria, with varying levels of toxicity depending on the species producing it. The toxins are largely water-soluble and are generally unable to easily penetrate biological membranes, nevertheless still raise health concerns to humans. For this reason, the concentration of microcystins in the water supply should not exceed 1.3 μg/L.
Nodularin	Produced specifically by the cyanobacterium *Nodularia spumigena*. While the level of toxicity is variable, there have been no reports of human health effects from the consumption of water supplies containing Nodularin. With insufficient toxicity data, no guideline value has been established, however in the event of the detection of Nodularin it is advised that relevant health authorities be consulted.
Saxitoxins	There are several types of saxitoxins of varying degrees of toxicity. No evidence suggests that human health effects are caused directly by consuming water supply containing the saxitoxin producing cyanobacteria. Acceptable concentrations of saxitoxins are yet to be established, however if blooms are detected then relevant health authorities should be advised.

TABLE 3.9: Hazards that affect Microbiological Quality (Viruses) (ADWG, 2004).

Hazard	Description
Adenovirus	Waterborne transmission occurs by the faecal-to-oral route, by inhalation of adenovirus aerosols, and by eye contact. The infectious dose for many viruses may be as low as one particle. Many guidelines give a figure of one particle to 1000 litres of water, but due to difficulty in testing for viruses and variability of results no acceptable guideline has been established.
Enteroviruses	The viruses are transmitted by the faecal-oral route. There is insufficient evidence that the virus is spread by infection of the water supply, however it is a probable means of transmission. Due to difficulties faced in testing for the viruses, and variability in results guideline values have not been established.
Hepatitis viruses	There are several viruses known to cause hepatitis, with Hepatitis A and Hepatitis E being the most common waterborne. There is a large range of health complications that these cause to humans, and infectious doses can be as low as one particle. No specific guideline has been established; however any detection requires immediate consultation with relevant health authorities.
Norwalk virus	Not overly common, but needs to be recognised as a potential health risk in the water supply. Due to difficulties in testing for Norwalk virus, and variability of results, an acceptable level of concentration is yet to be established, rather the need to advise health authorities in the event of detection.
Rotavirus, para-rotaviruses and reovirus	Among the most widespread viruses in the environment. They are transmitted through faeces, and therefore contamination of water supplies generally occurs as a result of faecal contamination or by discharge of sewage effluent. They have been proved to cause disease in humans with infectious doses as low as one particle.

3.3.4. Likelihood Criteria

The likelihood scale attributes the level of probability or frequency of a customer experiencing an identified risk consequence. Any risk in the abovementioned water volume criteria, end use criteria or water quality criteria needs to be measured in terms of its likelihood to identify the true level of criticality at which a water customer exists. While the consequence of a particular risk to a customer may be high, the likelihood of them actually being subjected to the risk may vary for different customers.

Likelihood is difficult to determine, and is very system specific. In the risk assessment process the probability of failure to meet water requirements of particular customers needs to be identified to determine their level of criticality. With a lack of information and data on supply failures, assumptions must be made on suitable levels of likelihood rating. The risk criteria development for likelihood in this research is not well defined and would require fairly subjective judgement when carrying out a risk assessment. To develop a more effective likelihood scale a thorough investigation into historical records of supply system failures and an appropriate statistical analysis would be required. This will be up to Ipswich Water's management to define more suitable measures of likelihood consistent with the supply system if they are to use risk analysis to the full extent of its effectiveness as a management tool.

The risk criteria developed for likelihood has been established on simple measures of probability, qualitative measures are provided to set the basis of the likelihood scale, this scale has a logarithmic distribution, and therefore a typical quantitative log scale is also provided in the criteria for guidance. The adoption of a log scale is common in risk assessments as it reflects a small probability for cases being considered rare and a high probability of cases being considered almost certain. In reality the level of risk rating for likelihood may not match this scale, and it is for this reason that further development of the likelihood risk criteria is necessary.

3.4. RISK ASSESSMENT

Having developed risk criteria in terms of the consequence and likelihood of a supply failure, the risk assessment of the customer base can be carried out. Each water customer can be assessed against each of the criteria, which involves combining consequence and likelihood to produce a level of risk. A customer may be subjected to multiple consequences that affect different requirements they may have, the assessment is concerned primarily with the most critical.

A risk matrix, as shown earlier (*see Table 2.4*), may be developed to allow the risk assessment to be carried out with greater ease. The risk matrix assigns a level of risk for each risk consequence rating at each likelihood rating. This level of risk needs to be defined based on Ipswich Water's objectives, which essentially identifies what levels of risk would be deemed acceptable for the segmentation of the water market.

3.5. MARKET SEGMENTATION

With the completion of the risk assessment of the customer base, risk evaluation is the final step in the risk analysis process. Using risk analysis, Ipswich Waters objective is to divide the water market into subgroups in terms of the risk faced by each customer. The risk assessment assigns a level of risk to each customer, and hence the water market can be segmented in terms of this risk. This allows an order from extreme risk customers through to low risk customers to be established, therefore allowing the management of resources to focus on priority customers that have been identified as critical.

The risk analysis process is a continual cycle, and so too will the market segmentation, areas of high risk can be identified, treated and then reassessed. By continual system monitoring and treatment of risk, Ipswich Water will be able to achieve maximum levels of system efficiency.

4. RESULTS AND DISCUSSION

4.1. VOLUME / DEMAND CRITERIA

4.1.1. Risk Criteria by Water Volume

The criteria for water volume has been derived from examining the customer base, and determining which levels of water consumption define varying degrees of critical supply. It was found that the majority of customers consume volumes below 1 megalitre per annum, and would not be considered critical system users on the basis of water volume. These customers have been defined as having an insignificant risk rating (5). On the other end of the scale those customers that are highly critical by water volume consume 100+ megalitres per annum; this includes only the top 11 water consumers. They include very large food manufacturers and processors, defence, electricity generation and other large paper, veneer and plywood manufacturers (*see Appendix 3*). These customers rely on near absolute water supply continuity for their operations. A failure to supply adequate water volume would have the potential to cause large financial or asset damage, loss of important business reputation or major disruption to business processes, and hence have a catastrophic risk rating (1). Moving down the risk criteria for water volume, major risk rating (2) consist of the next 19 highest water consumers, and moderate risk rating (3) with the following 55 water consumers. The minor risk rating (4) customers take up a larger segment of the water market with 1 to 5 megalitres per annum, these are the users that are above the average residential water consumption but still considered low order consumers (*see Table 4.1*).

TABLE 4.1: Risk criteria by water volume.

Criteria	Description	Rating	Definition
Volume / Demand			
a. Water Volume	The volume of water consumed by the customer on a ML per year basis.	**1.**	**100+ ML / year**
		2.	**20 – 100 ML / year**
		3.	**5 – 20 ML / year**
		4.	**1 – 5 ML / year**
		5.	**0 – 1 ML / year**

4.1.2. Water Volume Criteria Application

The water volume criteria when applied to the water market, identifies customers in order of volumetric demand. The customer profile at the varying levels of risk rating includes:

- Rating 1 – high demand for very large manufacturing and processing uses, as well as power generation and defence bases.
- Rating 2 – other large manufacturers and processors, and customers with high social importance such as hospitals, shopping centres and clubs.
- Rating 3 – smaller scale manufacturers, agricultural uses, retirement and aged care customers, recreation facilities, large accommodation providers and large educational institutions.
- Rating 4 – includes small manufacturing operations, other recreational facilities, the majority of the hospitality industry, medical services, aged care services, smaller educational providers, and a number of other services.
- Rating 5 – the remainder of small scale users, primarily including small businesses, residential dwellings, and other small civic services.

TABLE 4.2: Examples of typical customers that define each risk rating for water volume (Hester, 2009)

	Customer	**Industry Sector**	**Characteristics**
Rating 1	Abattoir	Food Processor	Boiler/process feedwater. A/C cooling towers. 24 hour or extended shift operations.
Rating 2	Hospital	Health Services	Large number of patients. Medical equipment feedwater. 24 hour operation. A/C cooling towers.
Rating 3	Nursing Home	Aged Care	Large number of residents. Continuous operation.
Rating 4	Paver and Brick Manufacturer	Manufacturing	Manufacturing process feedwater.
Rating 5	Residential Dwelling	Residential	Low domestic requirements.

4.2. END USE CRITERIA

4.2.1. Risk Criteria by Business Continuity

The criteria development for business continuity is based on qualitative measures as it is difficult to measure due to variations in business activity in the water market. Those businesses that have specific water requirements to sustain large scale economic activity are likely to be at the highest risk rating (1), as they may experience extensive financial impacts and damage to reputation. On the other hand those customers whose water requirements have minimal impact on the operation of their business will be at the lowest risk rating (5). The degrees of risk in will change for different customers according to the impact of inadequate water supply on business performance (*see Table 4.3*).

TABLE 4.3: Risk criteria by business continuity.

Criteria	Description	Rating	Definition
End Use			
a. Business Continuity	The effect of failure to meet water requirements on maintaining business activity.	**1.**	**Critical business failure, causing very large financial or reputational damage.**
		2.	**Breakdown of key activities leading to a reduction in business performance.**
		3.	**Impact on business causing reduced performance.**
		4.	**Some impact on business activity, including delays and reduced system quality.**
		5.	**Minimal impact on non-core business operations.**

4.2.2. Business Continuity Criteria Application

The application of the business continuity criteria identifies customers in terms of the effect on business performance. Customer characteristics which correspond with different levels of risk rating are as follows:

- Rating 1 – large industrial or commercial customers, who have large amounts of capital invested, have high revenues and provide employment to a large number of people, it primarily includes customers in defence, manufacturing and energy and resources.

- Rating 2 – significant industrial and commercial customers with high turnovers, such as large shopping centres and medium-sized manufacturers and processors.
- Rating 3 – includes customers that operate mid-sized businesses, typified by those in the hospitality industry.
- Rating 4 – smaller businesses that have scheduled activity, such ash clinics and restaurants, that may temporarily lose business, or inconvenience their customers.
- Rating 5 – other customers whose business is unlikely to be affected, including most retail and service providers not reliant on water supply.

TABLE 4.4: Examples of typical customers that define each risk rating for business continuity (Hester, 2009).

	Customer	Industry Sector	Characteristics
Rating 1	Air Base	Defence	High value operations. High value equipment. Large employer.
Rating 2	Shopping Centre	Commercial	Large number of patrons. High value activity. Extended operating hours.
Rating 3	Large Inner City Motel	Motel Accommodation	High value activity. Large number of patrons.
Rating 4	Dental Practice	Health	Scheduled activity.
Rating 5	Hardware Store	Commercial	Water requirements independent of business performance.

4.2.3. Risk Criteria by Functional Role

The risk criteria for functional role has also been developed on qualitative measures, as it is difficult to measure the significance of a customer's functional role, however it still remains an important risk factor. Those customers that have specific water requirements to provide critical social welfare services will exist at the highest risk rating (1); these generally include higher order medical service providers such as hospitals. Conversely those with little or no water requirements to maintain social functions will have the lowest risk rating (5). This will allow all those water users that have particular water requirements for their functional role to be identified, and assigned a level of risk in terms of their criticality (*see Table 4.5*).

TABLE 4.5: Risk Criteria by functional role.

Criteria	Description	Rating	Definition
End Use			
b. Functional Role	The effect of failure to meet water requirements on the maintenance of social welfare.	**1.**	**Failure to be able to provide critical services that allow the maintenance of life.**
		2.	**Failure to be able to provide services that are vital for social welfare.**
		3.	**Impact on social welfare that may result in injury or medical complications.**
		4.	**Some impact on social welfare that may cause inconveniences and disruption to the public.**
		5.	**Minimal impact to social functions.**

4.2.4. Functional Role Criteria Application

The functional role criteria when applied to the water market, identifies customers in order their importance in maintaining social welfare. Customer characteristics which define the varying levels of risk rating include:

- Rating 1 – customers that provide high level medical services, primarily hospitals.
- Rating 2 – other medical services that are critical to societies needs, this includes services such as x-ray clinics, doctor surgeries, etc.
- Rating 3 – includes customers that may experience adverse medical affects or other social complications, notably residential renal dialysis patients.
- Rating 4 – customers that have other social functions, including education providers, correctional services, aged care services, child care services, wastewater treatment and disposal services, sewage and drainage services.
- Rating 5 – customers that may be associated with social aspects but do not have critical functions, primarily recreation and sporting facilities.

TABLE 4.6: Examples of typical customers that define each risk rating for functional role (Hester, 2009).

	Customer	Industry Sector	Characteristics
Rating 1	Hospital	Health Services	Life supporting function. Important medical services. Large number of patients.
Rating 2	X-Ray Clinic	Health	Important medical service. Water reliant equipment. Scheduled activity.
Rating 3	Renal Dialysis Residence	Residential	High potential health impact customer. Service continuity requirements. Scheduled health activity.
Rating 4	Primary School	Education	Large number of students. Provides for social needs.
Rating 5	Fitness Centre	Recreation and Sporting	Only for recreational purposes.

4.3. WATER QUALITY CRITERIA

4.3.1. Risk Criteria by Aesthetic Quality

The criteria for aesthetic quality has been developed through defining varying levels of aesthetic quality requirements that reflect the potential risk a customer may face. *Australian Drinking Water Guidelines* (2004) set the basis for the acceptable aesthetic quality of the water supply, considering a range of contributing factors. The criteria defines risk ratings on a customer's sensitivity to a decline in the standard of acceptable quality and the associated implication of this to the customer. If true colour increases above 15 HU, turbidity increases above 5 NTU, or any of the taste and odour threshold limits are exceeded, then a customer's susceptibility to this will define their level of risk. A customer assigned to the highest risk rating (1) would experience major impacts at the slightest decline in aesthetic quality; this is mainly concerned with those users that require water supply for food and beverage manufacturing. Whereas a customer at the lowest risk rating (5) would experience insignificant affects in the same scenario, and these are generally industrial customers (*see Table 4.7*).

TABLE 4.7: Risk Criteria by aesthetic quality.

Criteria	Description	Rating	Definition
Water Quality			
a. Aesthetic Quality	The aesthetic requirements of the water supply required by a customer.	**1.**	**Very high level of aesthetic quality required, failure to meet this results in drastic ramifications.**
		2.	**High level of aesthetic quality required, and any shortfall has major ramifications.**
		3.	**Certain level of aesthetic quality required, and a shortfall has considerable effects.**
		4.	**Consistent level of aesthetic quality required, and a shortfall has noticeable effects.**
		5.	**Minimal level of aesthetic quality required, and a shortfall has minor effects.**

4.3.2. Aesthetic Quality Criteria Application

The aesthetic quality criteria when applied to the water market, identifies customers in terms of required water aesthetics. The customer profile expected for different levels of risk rating for this criteria are as follows:

- Rating 1 – consists of those customers in manufacturing and processing where the water quality directly affects the aesthetics of their product, primarily beverages.
- Rating 2 – customers involved with the manufacturing and processing of products for human consumption, mainly being food products.
- Rating 3 – includes customers in the hospitality industry, such as motels and restaurants, whose quality of service to their patrons may be reduced.
- Rating 4 – customers that not necessarily require high quality but rather a consistence quality, this applies to a large portion of the water market, including residential customers.
- Rating 5 – includes all non-food manufacturers and other industrial customers which have minimal aesthetic requirements.

TABLE 4.8: Examples of typical customers that define each risk rating for aesthetic quality (Hester, 2009).

	Customer	Industry Sector	Characteristics
Rating 1	Water Bottling Company	Beverage Manufacturer	Human consumption of product. Product quality reliant on water aesthetics. High value operation.
Rating 2	Biscuit Manufacturer	Food Processor	Human consumption of product. High value operation.
Rating 3	Large Inner City Motel	Motel Accommodation	Service quality related to water aesthetics. Large number of patrons.
Rating 4	Residential Dwelling	Residential	Acceptability of water based on consistent aesthetics.
Rating 5	Aluminium Anodiser	Manufacturing	Minimal aesthetic requirements.

4.3.3. Risk Criteria by Chemical Quality

The development of criteria for chemical quality identifies those customers that are critical in terms of the chemical quality of the water supply. It defines varying levels of risk rating on the basis of the affect that a decrease in chemical quality in the water supply will have on a customer. *Australian Drinking Water Guidelines* (2004) set the basis for the acceptable chemical quality of the water supply. A customer considered to be at the highest risk rating (1) will be likely to suffer major impacts from a decrease in the required standard of chemical quality; this is primarily concerned with high order medical services that preserve life, such as hospitals. Whereas a customer at the lowest risk rating (5) will experience little or no affects for the same reduction in chemical quality, this generally includes industrial customers, with the exception of those who require feedwater for air conditioning cooling towers, which have chemical quality specifications (*see Table 4.9*).

TABLE 4.9: Risk criteria by chemical quality.

Criteria	Description	Rating	Definition
Water Quality			
b. Chemical Quality	The chemical quality requirements of the water supply required by a customer.	**1.**	**Chemical quality below acceptable guideline values will result in loss of life.**
		2.	**Chemical quality below acceptable guideline values will be detrimental to health, or seriously impact operations.**
		3.	**Chemical quality below acceptable guideline values will cause immediate health or operational concerns.**
		4.	**Chemical quality below acceptable guideline values will raise longer term health or operational concerns.**
		5.	**Chemical quality below acceptable guideline values will raise minor health or operational concerns.**

4.3.4. Chemical Quality Criteria Application

The chemical quality criteria when applied to the water market, identifies customers in terms of susceptibility to an increase in chemical impurities in the water supply. Customer characteristics which are attributed to the different levels of risk rating are as follows:

- Rating 1 – customers that provide high level medical services, primarily hospitals.
- Rating 2 – other major medical service providers such as medical clinics, as well as residential renal dialysis patients, and large food manufacturing and processing customers.
- Rating 3 – includes commercial and industrial customers that require acceptable chemical quality to operate A/C cooling towers, which are critical for business.
- Rating 4 – other susceptible customers including child care services, aged care services and education providers.
- Rating 5 – customers with minimal chemical quality requirements, including industrial customers not reliant on cooling towers, in particular those in the energy and resources sector.

TABLE 4.10: Examples of typical customers that define each risk rating for chemical quality (Hester, 2009).

	Customer	Industry Sector	Characteristics
Rating 1	Hospital	Health Services	Important medical services. A/C cooling towers. Large number of patients.
Rating 2	Renal Dialysis Residence	Residential	High potential health impact customers. Quality of supply requirements.
Rating 3	Shopping Centre	Commercial	A/C cooling towers. Large number of patrons.
Rating 4	Primary School	Education	Young children susceptible to chemical quality.
Rating 5	Coal Mine	Resources	Wash plant has minimal quality requirements.

4.3.5. Risk Criteria by Microbiological Quality

The development of the microbiological quality criteria is similar to that of chemical quality, however considers the risk of the customer in terms of the affect that microbiological activity in the water supply will have on them. The *Australian Drinking Water Guidelines* (2004) identifies those microorganisms that pose a threat to the health of water consumers; any increase in the population of microorganisms that have identified health implications is likely to put some customers at risk. The levels of risk rating are determined by varying degrees of susceptibility to microbiological activity. Those customers at the highest risk rating (1) will be likely to experience life threatening risk, which is mainly confined to hospitals due to the highly susceptible of their patients. The lowest risk rating (5) customers will see minimal health affects with an increase in microbiological activity in the water supply; this includes customers that require supply for non-consumption purposes, with the exception of those who require feedwater for air conditioning cooling towers, which have microbiological quality specifications (*see Table 4.11*).

TABLE 4.11: Risk criteria by microbiological quality.

Criteria	Description	Rating	Definition
Water Quality			
c. Microbiological Quality	The microbiological quality requirements of the water supply required by a customer.	**1.**	**Microbiological activity will result in loss of life.**
		2.	**Microbiological activity will result in major health or operational concerns.**
		3.	**Microbiological activity will result in significant health or operational concerns.**
		4.	**Microbiological activity will result in some health or operational concerns**
		5.	**Microbiological activity will result in a minor health or operational issue.**

4.3.6. Microbiological Quality Criteria Application

The application of the microbiological quality criteria identifies customers in terms of susceptibility to microbiological activity. Customer characteristics which are attributed to the different levels of risk rating include:

- Rating 1 – customers that provide high level medical services, primarily hospitals.
- Rating 2 – other highly susceptible customers such as medical clinics, residential renal dialysis patients and aged care.
- Rating 3 – includes customers that have a large number of patrons such as shopping centres, education providers, accommodation providers and defence bases.
- Rating 4 – includes customers with a medium number of customers, such as restaurants, recreational facilities and clubs, as well as those customers that require water supply for livestock operations.
- Rating 5 – the remainder of the customer base, primarily in the industry sector where water is not used for human consumption, in particular non-food manufacturing, energy and resources.

TABLE 4.12: Examples of typical customers that define each risk rating for microbiological quality (Hester, 2009).

	Customer	Industry Sector	Characteristics
Rating 1	Hospital	Health Services	Sterile medical activities. A/C cooling towers. Large number of patients.
Rating 2	Nursing Home	Aged Care Facility	Low susceptibility to microorganisms. Large number of residents.
Rating 3	Shopping Centre	Commercial	Large number of patrons. A/C cooling towers.
Rating 4	Saleyards	Agriculture/Commercial	Susceptibility of livestock.
Rating 5	Power Station	Electricity Generation	No human consumption.

4.4. LIKELIHOOD CRITERIA

The development of the likelihood scale requires estimates to be made on the basis of statistical analysis for the probability of a customer not receiving adequate water requirements. Without obtaining reliable data on the supply system, subjective estimates can be adopted which aim to reflect what is believed to be acceptable scales of likelihood. For the purposes of this research the latter has been adopted, further development of the likelihood criteria is at the discretion of Ipswich Water, and is highly advised.

The likelihood criteria developed is essentially based on subjective qualitative measures, which is accompanied by a logarithmic scale of probability for guidance purposes, however this may not necessarily reflect realistic values of likelihood. The criteria may have shortfalls in its ability to accurately measure likelihood of risk to a given customer, as it does not relate the likelihood to the specific context of the supply system. However it is still effective in attributing increasing likelihood of inadequate water supply to an increasing level of risk (*see Table 4.13*). A customer that is has the highest risk rating (A) will almost certainly experience risk, however the lowest risk rating (E) will only in the exceptional case experience the same risk.

TABLE 4.13: Risk Criteria by risk likelihood.

Likelihood	Description	Rating	Definition
	The probability of water supply requirements for a customer not being met.	A.	**Almost Certain – is certain to happen (up to 100% chance of occurring).**
		B.	**Probable – is likely to happen (up to 10% chance of occurring).**
		C.	**Possible – could happen (up to 1% chance of occurring).**
		D.	**Improbable– has the potential to happen (up to 0.1% chance of occurring).**
		E.	**Rare – has never happened (up to 0.01% chance of occurring).**

4.5. RISK MATRIX

The risk matrix combines consequence and likelihood to produce a level of risk – this is the primary objective of the risk assessment. The formation of the risk matrix involves placing the risk ratings for the consequence scale across the top *x* axis and the risk ratings for the likelihood scale down the left *y* axis. This creates a five by five matrix, which represents varying levels of risk, increasing in magnitude from the bottom right corner to the top left corner (*see Table 4.14a*). The value of risk is at the discretion of Ipswich Water, and is based on their perception of risk for each consequence/likelihood combination. The levels of risk shown on the matrix (*see Table 4.14b*) have been assumed, but are typical for this form of risk assessment.

The purpose of the risk matrix is to allow easy determination of the risk rating for each customer. While the single likelihood scale will be applied to all cases, different consequence scales can be adopted for water volume, end use or water quality, to identify a customer’s most critical level of risk. When the risk has been determined for each customer, the market segmentation is a simple process of grouping customers in terms of the risk rating output by the risk matrix (from extreme risk through to low risk).

TABLE 4.14a: Risk matrix.

		CONSEQUENCE RATING				
		1. Catastrophic	**2. Major**	**3. Moderate**	**4. Minor**	**5. Insignificant**
LIKELIHOOD RATING	**A. Almost Certain**	1 (E)	3 (E)	5 (H)	7 (H)	11 (S)
	B. Probable	2 (E)	4 (E)	8 (H)	12 (S)	16 (M)
	C. Possible	6 (H)	9 (H)	13 (S)	17(M)	20 (L)
	D. Improbable	10 (H)	14 (S)	18 (M)	21 (L)	23 (L)
	E. Rare	15 (S)	19 (M)	22 (L)	24 (L)	25 (L)

TABLE 4.14b: Risk ratings.

Risk Matrix Result	**Risk Rating**	
1 to 4	1	Extreme Risk
5 to 9	2	High Risk
10 to 15	3	Significant Risk
16 to 19	4	Moderate Risk
20 to 25	5	Low Risk

5. CONCLUSION

5.1. RESEARCH OUTCOMES

Market segmentation by risk analysis has been identified as an important management tool for any urban water supply systems. It provides an effective means of identifying customer criticality in the water market, hence allowing water service providers to maintain adequate water supply to customers, optimise efficiency in the supply network and ensure water security into the future.

In the context of Ipswich Water, the integration of market segmentation has many foreseeable benefits that will allow the service provider to align its management strategies with the SEQ Water Reform, as well as make steps towards providing a sustainable service to a growing water market.

The specific outcome of this research is to provide a framework for market segmentation by risk analysis for implementation into future water policy development, and new management strategies that will come into place as a result of the SEQ Water Reform. Current risk management implemented by Ipswich Water is relatively primitive in its ability to effectively identify critical customers and does not align with current information technologies, such as GIS systems. The combined affect of overcoming these system deficiencies will hopefully allow for more effective resource expenditure and close the gap between advanced information technology and less developed water management systems.

The future of urban water management needs to be one of sustainability that allows service providers to meet the specific needs of customers with limiting water resources. While this may seem increasingly more difficult as dwindling water supplies coupled with increasing population growth becomes of greater concern, it is important for today's water managers to take the initiative to implement management strategies that are focused on a pro-active approach to sustainability. While further research and development in risk management may be required, it is evident that it has an important role to play in the management of urban water supply systems.

5.2. MARKET SEGMENTATION OF IPSWICH WATER

The market segmentation of Ipswich Water's customer base has clear advantages in its ability to identify customer criticality for immediate supply failure response, as well as prioritising water infrastructure maintenance and renewals. While this research only provides a framework for the market segmentation, preliminary conclusions in terms of customer criticality can be drawn from the development of the risk criteria.

In relation to critical water volume customers, it could be seen that a very small proportion of the customer base consumed a very large proportion of the water supply. These customers were typically in the heavy industry sector, and included customers operating in manufacturing and processing, energy and resources, as well as defence. Characteristics which were common among these customers included the requirement of feedwater for air conditioning cooling towers and other industrial processes, and 24 hour or extended operations.

The end use criteria identified two particular areas of importance to customer criticality. Firstly those customers likely to be at risk due to business continuity requirements were characterised as large industrial and commercial customers that invest large amounts of capital into their operations, have high revenues and are generally large employers. These customers were usually involved with defence, manufacturing and processing as well as those in the energy and resources sector. Functional role of a customer was also considered important in determining customer criticality. These were generally those customers that provide high level medical services, primarily hospitals and other services such as x-ray clinics and doctor surgeries.

Water quality has also been identified as an important requirement for customers. The criteria for aesthetic quality identified that customers involved with the manufacturing and processing of food and beverages, where product quality was directly related to the water supply aesthetics, may be at risk if specific requirements were not met. Chemical quality was an important requirement for health services and food and beverage manufacturers, where health risks are a major concern. Finally microbiological quality, which identified outbreaks of microorganisms to have potentially serious widespread affects in the supply system; susceptible customers at the greatest level of risk includes hospitals, nursing homes, etc. These customers are likely to have the lowest immunity and be at the greatest risk of health complications.

The development of the risk criteria proved to be effective in identifying all those customers that have critical water supply requirements. The most critical customer for Ipswich Water appeared to be hospitals and large scale industrial and commercial customers particularly those involved in food and beverage manufacturing and processing, as these customers are consistently rated high risk in a number of categories. While these customers are those which would be expected to be the most critical of water supply, the market segmentation provides a credible platform for which to identify the risk faced by all customers, and provides a means of reassessing risk after treatment measures are implemented to reduce unacceptable risk.

5.3. RISK MANAGEMENT

The purpose of undertaking a market segmentation of the customer base is to allow for the effective management of Ipswich Water's resources. The segmentation prioritises customers in terms of their level of risk of not receiving adequate water requirements. This allows resources in terms of financial and operational capacity to be used more effectively in those areas of the system that are in critical need.

Risk management is centred on implementing preventative measures for the identified risks, whereby the level of protection is proportional to the associated risk. AS/NZS 4360 outlines the following risk treatment process in the risk management process:

- Identifying options;
- Assess options;
- Prepare and implement treatment plans; and
- Analyse and evaluate residual risks.

Risk management would be the preceding process after the market segmentation, and involves establishing supply failure response priority for customers as well as identifying required infrastructure renewals and maintenance planning. The risk treatment process requires a large degree of system analysis, this is outside the scope of this research, and therefore recommendations for risk management have not been made.

5.4. ASSESSMENT OF CONSEQUENTIAL EFFECTS

Sustainability has been identified as an important concept in the management of water resources. With increasing challenges it is continually becoming more difficult for the water manager to integrate sustainable practises into water management strategies. The use of market segmentation will allow efficiency gains to be made in the supply system, and this will inevitably have positive effects on the sustainability of urban water supply.

The primary outcome of this work involves reshaping management strategies and water policy; therefore no direct environmental impacts are likely. Any infrastructure development that may be an indirect result will be carried out adhering to the appropriate environmental protection policies as it would have before the implementation of market segmentation into the management strategy. Therefore, the foreseeable impacts of this work will be mainly restricted to increases in sustainability of water supply, and is not likely to have any environmental impacts.

5.5. FURTHER WORK

This research work provides framework for the development of policies and management strategies. Therefore further development of the risk criteria would be required to achieve the full potential of risk analysis as an effective management tool. To further develop the risk criteria in relation to the Ipswich Water supply system would require considerably greater investigation of the water market and further analysis of available supply system data. While this is at the discretion of Ipswich Water, it must be noted that risk analysis within a water utility is contingent on its institutional capacity, the quality of data available and the requirements of the decision that is reached as a result of the analysis.

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APPENDIX 1

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project
PROJECT SPECIFICATION

FOR: **OLIVER TAYLOR**

TOPIC: MARKET SEGMENTATION FOR IMPROVED EFFICIENCY OF IPSWICH WATER SUPLY SYSTEM

SUPERVISORS: Dr. David Thorpe - USQ, Senior Lecturer, Springfield Campus
Col Hester - Ipswich Water, Manager Water Services

SPONSORSHIP: Ipswich Water

PROJECT AIM: This project aims to classify water users by critical supply, enabling priority water users to be identified and their demands monitored and managed to balance water usage with business continuity or functional requirements, allowing for improved program maintenance, and hence, increased quality of service.

PROGRAMME: **(Issue B, 6 April 2009)**

1. Review current water polices and management systems related to customer segmentation.
2. Define Ipswich water supply customer base within the context of Ipswich and the Western Corridor.
3. Undertake research into methods of market segmentation for critical water users.
4. Develop risk based criteria for the identification and assessment of critical water customers.
5. Using the criteria, identify critical users by prioritising them in terms of business continuity or functional role.
6. Present the data to Ipswich Water in a format compatible for implementation into services planning and maintenance programs.
7. Submit an academic dissertation on the research.

As time permits:

8. Report on the implementation of any recommendations.

AGREED: ____________ (Student)
O. Taylor
Date: 5 / 5 / 2009

____________ (Supervisor)
D. Thorpe
Date: 7 / 5 / 2009

____________ (Supervisor)
C.Hester
Date: / / 2009

Examiner/Co-examiner: ____________

APPENDIX 2

Ipswich Water	WATER RESPONSE & RESOLUTION SERVICE STANDARDS	Doc No: IW.CS.WI.7036 Issue: 2 Date: 11 May 2009 Page: Page 1 of 3

These service standards take a multi faceted view of the requests to enable the assigning of a priority. It considers not only the impact on the customer, hazard or risk to the public, property and environment but also takes into account the type of customer impacted. This ensures that Ipswich Water responds differently to a water main failure in the CBD or the failure of a major wastewater pump station as compared to responding to a leak on a water service to a single customer or a choke in the wastewater system where service has not been interrupted.

Job Priority

P1 Red (Critical) Significant Impact / Risk – where major or critical customers have no water or there is a hazard or risk to the public health, environment or property due to a burst water main, damage to property etc. Typically applicable to critical trunk water supply feeds. Ipswich Water's aim is to respond within 30 minutes and restore supply within 1 hour from notification of interruption of supply or when supply has been interrupted.

P2 Amber (Critical) High Impact / Risk – where multiple customers have no water or there is a hazard or risk to the public health, environment or property due to a burst water main, damage to property etc. Applicable to trunk water supply feeds with limited rerouting capability. Ipswich Water's aim is to respond within 1 hours and restore supply within 5 hours from notification of interruption of supply or when supply has been interrupted.

P3 Yellow (Critical) Medium Impact / Risk – where an individual residential customer has no water due to a water service or water meter failure. Water quality problems eg. taste, smell and dirty water. Ipswich Water's aim is to respond within 3 hours and restore supply within 24 hours of Ipswich Water receiving the job.

P4 Green (Critical) Low Impact / Risk – where there is minimal impact on the customer eg. water still available at customer's tap. Ipswich Water's aim is to respond within 1 working day and complete the job within 3 working days.

P5 Blue Planned or Deferred Jobs – Where there is rectification work required however it is not considered urgent. Ipswich Water's aim is to respond within 4 working days and agree with the customer the rectification timeframe.

Ipswich Water	WATER RESPONSE & RESOLUTION SERVICE STANDARDS	Doc No: IW.CS.WI.7036 Issue: 2 Date: 11 May 2009 Page: Page 2 of 3

PRIORITY 1	Customer Segments	Impact of customer	Risk Hierarchy	Maximum Response Time	Maximum Tolerable Outage
	Hospitals, Medical Centres, Large Commercial Customers, CBD, Large Town Centres, Large Shopping Precincts, Major Roads, Dialysis	No water to critical customers	**Significant** impact/risk	30 minutes	1 hour
		Hazard or risk to public health or property	**Significant** impact/risk	30 minutes	1 hour
		Hazard or risk to environment	**Significant** impact/risk	30 minutes	1 hour

PRIORITY 2	Customer Segments	Impact of customer	Risk Hierarchy	Maximum Response Time	Maximum Tolerable Outage
	Medium Commercial Customers, Medium Shopping Precincts,	No water to multiple customers	**High** impact/risk	1 hour	5 hours
		Hazard or risk to public property	**High** impact/risk	1 hour	5 hours
		Hazard or risk to environment	**High** impact/risk	1 hour	5 hours

PRIORITY 3	Customer Segments	Impact of customer	Risk Hierarchy	Maximum Response Time	Return of Supply
	Small Businesses, Residential Customers,	No water for an individual customer or water quality	**Medium** impact/risk	3 hours	24 hours
		Hazard or risk to public property	**Medium** impact/risk	3 hours	24 hours
		Hazard or risk to environment	**Medium** impact/risk	3 hours	24 hours

PRIORITY 4	Customer Segments	Impact of customer	Risk Hierarchy	Maximum Response Time	Return of Supply
	Small Businesses, Residential Customers	Water still available at customer tap, minimal impact (No loss of service)	**Low** impact/risk	1 Working Day	3 working days
		Hazard or risk to public property	**Low** impact/risk	1 Working Day	3 working days
		Hazard or risk to environment	**Low** impact/risk	1 Working Day	3 working days

Ipswich Water	WATER RESPONSE & RESOLUTION SERVICE STANDARDS	Doc No: IW.CS.WI.7036 Issue: 2 Date: 11 May 2009 Page: Page 3 of 3

	Customer Segments	Impact of customer	Risk Hierarchy	Response Time	Return of Supply
PRIORITY 5	All	Minor maintenance, planned maintenance (not considered urgent), minor restoration footpath or private property (No loss of service)	Very Low	4 working days	Agreed time for rectification
		Hazard or risk to public property	Very Low	4 working days	Agreed time for rectification
		Hazard or risk to environment	Very Low	4 working days	Agreed time for rectification

Date of approval	Approving Manager	Review Timeframe	Review Date:
11 May 2009	Manager Field Services	Annually	11 May 2010

APPENDIX 3

Table A3.1: Top 200 Water Users in Ipswich Water by Volume of Consumption

#	Assessment	2008 - 2009 Water Consumption (kL)	Industry Sector
1	151156	1153657	Meat Manufacturing
2	151151	207370	Poultry Processing
3	151160	199050	Sanitary Paper Product Manufacturing
4	150762	196792	Meat Manufacturing
5	151162	187723	Veneer and Plywood Manufacturing
6	151169	163773	Other Electricity Generation
7	151149	159386	Defence
8	151158	135546	Soft Drink, Cordial and Syrup Manufacturing
9	151170	134991	Milk and Cream Processing
10	151150	116927	Soft Drink, Cordial and Syrup Manufacturing
11	151166	111430	Veneer and Plywood Manufacturing
12	151155	75950	Meat Manufacturing
13	151144	63593	Hospitals (Except Psychiatric Hospitals)
14	151152	58557	Correctional and Detention Services
15	150648	54235	Beer Manufacturing
16	156660	54030	Aluminium Rolling, Drawing, Extruding
17	151164	51233	Cured Meat and Smallgoods Manufacturing
18	38921	45346	Laundry and Dry-Cleaning Services
19	157366	42093	Drive in Shopping Centre
20	151159	39818	Sanitary Paper Product Manufacturing
21	151171	34018	Drive in Shopping Centre
22	151165	32507	Drive in Shopping Centre
23	46981	29876	Prepared Animal and Bird Feed Manufacturing
24	151163	27350	Other Electrical Equipment Manufacturing
25	37016	25695	Rigid and Semi-Rigid Polymer Product Manufacturing
26	75475	24550	Veneer and Plywood Manufacturing
27	37011	24341	Biscuit Manufacturing (Factory based)
28	77409	22464	Drive in Shopping Centre
29	158652	20928	Clubs (Hospitality)
30	150750	20326	Drive in Shopping Centre
31	77460	19429	Corrugated Paperboard & Paperboard Container Manufacturing
32	87121	16221	Caravan Park - Mobile Home Park
33	49044	15270	Soft Drink, Cordial and Syrup Manufacturing
34	136097	14879	Aged Care Residential Services

35	91657	13255	Concrete Product Manufacturing
36	39399	13050	Hospitals (Except Psychiatric Hospitals)
37	115327	12641	Poultry Farming
38	151154	10960	Cattle holding yard
39	150657	10808	Residential Property Operators - Semi retired
40	64196	9755	Nursery Production (Outdoors)
41	8575	9516	Club and Sporting Ovals
42	49320	9402	Horse Racing Administration & Track Operation
43	128056	9190	Residential Property Operators- Semi retired
44	88766	8985	Secondary Education
45	159836	8930	Residential Property Operators- Semi retired
46	8570	8627	Concrete Product Manufacturing
47	15746	8564	Vegetable Growing (Outdoors)
48	37012	8509	Steel Pipe and Tube Manufacturing
49	37215	8447	Combined Primary and Secondary Education
50	89337	8398	Human Pharmaceutical & Medicinal Product Manufacturing
51	42964	8359	Aged Care Residential Services
52	120124	8278	Ready-Mixed Concrete Manufacturing
53	151157	8109	Railway Rolling Stock Manufacturing & Repair Services
54	42716	7656	Accommodation
55	92000	7638	Poultry Farming (Meat)
56	122725	7614	Club and Sporting Ovals
57	130814	7564	Sports & Physical Rec.Venues Ground & Facilities Op.
58	7367	7530	Concrete Product Manufacturing
59	1468	7385	Sports & Physical Rec.Venues Ground & Facilities Op.
60	154219	7304	Sports & Physical Rec.Venues Ground & Facilities Op.
61	13797	7271	Aged Care Residential Services
62	55860	7257	Aged Care Residential Services
63	48498	6976	Concrete Product Manufacturing
64	56048	6744	Combined Primary and Secondary Education
65	138666	6719	Public Pool
66	98854	6625	Secondary Education
67	133352	6622	Car washing facility
68	45247	6609	Aged Care Residential Services
69	37015	6535	Iron and Steel Casting
70	16481	6520	Concrete Product Manufacturing
71	64674	6513	Drive in Shopping Centre
72	91748	6448	Human Pharmaceutical & Medicinal Product Manufacturing
73	113688	6390	Sports & Physical Rec.Venues Ground & Facilities Op.
74	38809	5951	Aged Care Residential Services

75	105143	5921	Residential Institution - Aged Units
76	156250	5847	Pastry and Cake Manufacturing
77	99605	5596	Sports & Physical Rec.Venues Ground & Facilities Op.
78	151167	5591	Technical and Vocational Education and Training
79	66880	5578	Car washing facility
80	31379	5572	Drive in Shopping Centre
81	127282	5517	Accommodation
82	115704	5269	Drive in Shopping Centre
83	41684	5092	Sports & Physical Rec.Venues Ground & Facilities Op.
84	100034	5075	Primary Education
85	23537	5033	Rigid and Semi-Rigid Polymer Product Manufacturing
86	68042	4993	Clay Brick Manufacturing
87	141146	4964	Rigid and Semi-Rigid Polymer Product Manufacturing
88	56055	4928	Sports & Physical Rec.Venues Ground & Facilities Op.
89	48147	4881	Sports & Physical Rec.Venues Ground & Facilities Op.
90	7385	4868	Concrete Product Manufacturing
91	96783	4817	Drive in Shopping Centre
92	124922	4816	Aged Care Residential Services
93	7397	4726	Accommodation
94	37472	4724	Drive in Shopping Centre
95	4347	4663	Drive in Shopping Centre
96	36194	4630	Drive in Shopping Centre
97	88716	4561	Primary Education
98	44648	4415	Primary Education
99	7342	4405	Rigid and Semi-Rigid Polymer Product Manufacturing
100	48519	4366	Sports & Physical Rec.Venues Ground & Facilities Op.
101	151145	4216	Hospitals (Renal)
102	151074	4174	Waste Treatment and Disposal Services
103	15154	3989	Sports & Physical Rec.Venues Ground & Facilities Op.
104	48489	3980	Sports & Physical Rec.Venues Ground & Facilities Op.
105	7373	3947	Metal Coating and Finishing
106	145795	3931	Aged Care Residential Services
107	39433	3925	Sports & Physical Rec.Venues Ground & Facilities Op.
108	113758	3900	Pubs, Taverns and Bars
109	151377	3787	Combined Primary and Secondary Education
110	44562	3717	Pubs, Taverns and Bars
111	49260	3680	Cafes and Restaurants
112	160749	3677	Drive in Shopping Centre
113	153325	3627	Shop
114	125036	3593	Secondary Education

115	115589	3519	Aged Care Residential Services
116	136098	3457	Beef Cattle Farming (Specialised)
117	66944	3451	Primary Education
118	38736	3446	Justice
119	155517	3410	Sports & Physical Rec.Venues Ground & Facilities Op.
120	143896	3354	Secondary Education
121	48496	3326	Landscape Construction Services
122	115452	3309	Accommodation
123	75998	3219	Aged Care Residential Services
124	145753	3189	Drive in Shopping Centre
125	41681	3179	Veneer and Plywood Manufacturing
126	38638	3176	Aged Care Residential Services
127	37834	3095	Cafes and Restaurants & Accommodation
128	5162	3087	Secondary Education
129	128141	3083	Cafes and Restaurants & Accommodation
130	46996	3075	Unspecified
131	99305	3073	Sports & Physical Rec.Venues Ground & Facilities Op.
132	17086	3011	Accommodation
133	61371	3001	Ready-Mixed Concrete Manufacturing
134	60922	2987	Sewerage and Drainage Services
135	37022	2928	Concrete Product Manufacturing
136	32322	2855	Semi retired Residential
137	57039	2845	Pubs, Taverns and Bars
138	12797	2816	Nature Reserves and Conservation Parks Operation
139	38709	2811	Other Health Care Services n.e.c.
140	62928	2698	Railway Rolling Stock Manufacturing & Repair Services
141	12008	2664	Aged Care Residential Services
142	47443	2545	Sports & Physical Rec.Venues Ground & Facilities Op.
143	12723	2504	Primary Education
144	60092	2484	Nursery Production (Outdoors)
145	138691	2458	Clubs (Hospitality)
146	38716	2435	Cafes and Restaurants
147	61381	2427	Clay Brick Manufacturing
148	65824	2426	Secondary Education
149	7402	2351	Primary Education
150	146047	2331	Clubs (Hospitality)
151	15044	2315	Beef Cattle Farming (Specialised)
152	99410	2289	Secondary Education
153	1467	2261	Sports & Physical Rec.Venues Ground & Facilities Op.
154	66882	2216	Cafes and Restaurants

155	41584	2207	Pubs, Taverns and Bars
156	64836	2143	Clubs (Hospitality)
157	124514	2108	Combined Primary and Secondary Education
158	12010	2089	Oil/Fuel Depot
159	12712	2080	Nursery Production (Outdoors)
160	99987	2072	Higher Education
161	56765	2062	Nursery Production (Outdoors)
162	66568	2051	Drive in Shopping Centre
163	96592	2043	Drive in Shopping Centre
164	56704	2012	Primary Education
165	100038	2009	Refrigeration
166	122738	1979	Primary Education
167	56991	1960	Drive in Shopping Centre
168	139421	1956	Primary Education
169	114505	1940	Sports & Physical Rec.Venues Ground & Facilities Op.
170	38706	1934	Shop
171	89920	1929	Secondary Education
172	17133	1912	Horse Farming
173	49322	1859	Cafes and Restaurants
174	58431	1856	Concrete Product Manufacturing
175	7347	1843	Other Fabricated Metal Product Manufacturing n.e.c.
176	50367	1841	Clubs (Hospitality)
177	49370	1840	Clubs (Hospitality)
178	49289	1800	Cafes and Restaurants
179	92173	1791	Road Freight Transport
180	159459	1791	Accommodation
181	41878	1788	Accommodation
182	72351	1785	Landscape Construction Services
183	145751	1781	Psychiatric Hospitals
184	151153	1769	Museum Operation
185	14007	1769	Coal Mining
186	111304	1769	Pubs, Taverns and Bars
187	129931	1759	Nursery Production (Outdoors)
188	127975	1757	Clubs (Hospitality)
189	61369	1755	Other Mining Support Services
190	49293	1711	Drive in Shopping Centre
191	144203	1710	Primary Education
192	64680	1704	Primary Education
193	4240	1688	Child Care Services
194	41533	1682	Drive in Shopping Centre

195	45491	1627	Cafes and Restaurants
196	88767	1616	Wooden Furniture & Upholstered Seat Manufacturing
197	124974	1606	Pubs, Taverns and Bars
198	38534	1594	Laundry and Dry-Cleaning Services
199	56061	1580	Sports & Physical Rec.Venues Ground & Facilities Op.
200	79346	1547	Mining and Construction Machinery Manufacturing
201	3146	1541	Drive in Shopping Centre
202	16141	1541	Wine and Other Alcoholic Beverage Manufacturing

Table A3.2: Industry Sector Key

Industry Sector Key
Defence
Health
Agriculture
Food & Beverage Manufacturing
Mining and Resources
Transport, Distribution & Logistics
Other Manufacturing
Education
Recreation & Sporting
Retail
Hospitality
Retirement & Aged Care
Services

APPENDIX 4

Table A4.1: Guideline values for physical and chemical characteristics – Australian Drinking Water Guidelines

Characteristics	Guideline values*		Comments
	Health	Aesthetic[a]	
Acrylamide	0.0002		Minor impurity of polyacrylamide, used sometimes as a flocculant aid.
Aluminium (acid-soluble)	c	0.2	Guideline value based on post flocculation problems; < 0.1 mg/L desirable. Lower levels needed for renal dialysis. No health-based guideline value can be established currently.
Ammonia (as NH_3)	c	0.5	Presence may indicate sewage contamination and/or microbial activity. High levels may corrode copper pipes and fittings.
Antimony	0.003		Exposure may rise with increasing use of antimony-tin solder.
Arsenic	0.007		From natural resources and mining/industrial/agricultural wastes/.
Asbestos	c		From the dissolution of minerals/industrial waste, deterioration of asbestos-cement pipes in distribution systems. No evidence of cancer when ingested (unlike inhaled asbestos).
Barium	0.7		Primarily from natural sources.
Benzene	0.001		Could occur in drinking water from atmospheric deposition (motor vehicle emissions) and chemical plant effluent. Human carcinogen.
Beryllium	c		From the weathering of rocks, atmospheric deposition (burning of fossil fuels) discharges.
Boron	4		From natural leaching of minerals and contamination. < 1 mg/L in uncontaminated sources; higher levels may be associated with seawater intrusion.
Bromate	0.02		Possible byproduct of disinfection using ozone, otherwise unlikely to be found in drinking water.
Cadmium	0.002		Indicates industrial or agricultural contamination; from impurities in galvinised (zinc) fittings, solders and brasses.
Carbon tetrachloride	0.003		Sometimes occurs as impurity in chlorine used for disinfection (it is not a disinfection byproduct).
Chloramine – see monochloramine			
Chlorate	c		Byproduct of chlorine dioxide disinfection.
Chloride	e	250	From natural mineral salts, effluent contamination. High concentrations more common in groundwater and certain catchments.
Chlorinated furanones (MX)	c		Byproduct of Chlorination.
Chlorine	5	0.6	Widely used to disinfect water, and this can produce (free) chlorinated organic byproducts. Odour threshold generally 0.6 mg/L, but 0.2 mg/L for a few

			people. In some supplies it may be necessary to exceed the aesthetic guideline in order to maintain an effective disinfectant residual throughout the system.
Chlorine dioxide	1	0.4	Oxidising agent and disinfectant in water treatment.
Chlorite	0.3		Byproduct of chlorine dioxide disinfection.
Chloroacetic acids chloroacetic acid dichloroacetic acid trichloroacetic acid	 0.15 0.1 0.1		Byproduct of chlorination.
Chlorobenzene	0.3	0.01	Could occur in drinking water from spills or discharges. Taste/odour threshold (0.01 mg/L) is well below health level.
Chloroketones 1,1-dichloropropanone 1,3-dichloropropanone 1,1,1-trichloropropanone 1,1,3-trichloropropanone	 c c c c		Byproduct of chlorination.
Chlorophenols 2-chlorophenol 2,4-dichlorophenol 2,4,6-trichlorophenol	 0.3 0.2 0.02	 0.0001 0.0003 0.002	Byproduct of chlorination of water containing phenol or related chemicals.
Chloropicrin	c		Byproduct of chlorination.
Chromium (as Cr(VI))	0.05		From industrial/agricultural contamination of raw water or corrosion of materials in distribution system/plumbing. If guideline value exceeded, analyse for hexavalent chromium.
Copper	2	1	From corrosion of pipes/fittings by salt, low pH water. Taste threshold 3mg/L. High concentrations colour water blue/green. >1mg/L may stain fittings. >2mg/l can cause ill effects in some people.
Cyanide	0.08		From industrial waste and some plants and bacteria.
Cyanogen chloride (as cyanide)	0.08		Byproduct of chloramination.
Dichlorobenzenes 1,2-dichlorobenzene 1,3-dichlorobenzene 1,4-dichlorobenzene	 1.5 C 0.04	 0.001 0.02 0.003	Could occur in drinking water from spills, discharges, atmospheric deposition, leaching from contaminated soils. Health levels are well above offensive taste/odour thresholds.
Dichloroethanes 1,1-dichloroethane 1,2-dichloroethane	 c 0.003		Could occur in drinking water from industrial effluents, spills, discharges.
Dichloroethenes 1,1-dichloroethene 1,2-dichloroethene	 0.03 0.06		Rarely found in drinking water; found occasionally in groundwater from wells heavily contaminated by solvents.
Dichloromethane (methylene chloride)	0.004		Widely used solvent, commonly found in ground and surface waters overseas. Volatilises from surface waters and biodegrades in the atmosphere.
Dissolved oxygen	Not necessary	> 85%	Low concentrations allow growth of nuisance microorganisms (iron/necessary manganese/sulfate/nitrate-reducing bacteria) causing taste and odour problems, staining, corrosion. Low oxygen concentrations are normal in groundwater supplies and the guideline value may not be achievable.
Epichlorohydrin	0.0005[d]		Used in manufacture of some resins used in water treatment.
Ethylbenzene	0.3	0.003	Natural component of petrol and petroleum products.
Ethylenediamine	0.25		Metal-complexing agent widely used in industry and

tetraacetic acid (EDTA)			agriculture, and as a drug in chelation therapy.
Fluoride	1.5		Occurs naturally in some water from fluoride-containing rocks. Often added at up to 1 mg/L to protect against dental caries. > 1.5 mg/L can cause dental fluorosis. > 4 mg/L can cause skeletal fluorosis.
Formaldehyde	0.5		Byproduct of ozonation.
Haloacetonitriles dichloroacetonitrile trichloroacetonitrile dibromoacetonitrile bromochloroacetonitrile	 c c c c		Byproduct of chlorination.
Hardness (as $CaCO_3$)	Not necessary	200	Caused by calcium and magnesium salts. Hard water is difficult to lather. < 60 mg/L CaCO3 soft but possibly corrosive. 60-200 mg/L CaCO3 good quality. 200-500 mg/L CaCO3 increasing scaling problems. > 500 mg/L CaCO3 severe scaling.
Hexachlorobutadiene	0.0007		Industrial solvent.
Hydrogen sulfide	c	0.05	Formed in water by sulfate-reducing microorganisms or hydrolysis of soluble sulfide under anoxic conditions. Obnoxious 'rotten egg' odour, threshold 0.05 mg/L.
Iodine	c		Can be used as an emergency water disinfectant. Taste threshold 0.15 mg/L.
Iron	c	0.3	Occurs naturally in water, usually at < 1 mg/L, but up to 100 mg/L in oxygen-depleted groundwater. Taste threshold 0.3 mg/L. High concentrations stain laundry and fittings. Iron bacteria cause blockages, taste/odour, corrosion.
Lead	0.01		Occurs in water via dissolution from natural sources or household plumbing containing lead (e.g. pipes, solder).
Manganese	0.5	0.1	Occurs naturally in water; low in surface water, higher in oxygen-depleted water (e.g. groundwater at bottom of deep storages). > 0.1 mg/L causes taste, staining. < 0.05 mg/L desirable.
Mercury	0.001		From industrial emissions/spills. Very low concentrations occur naturally. Organic forms most toxic, but these are associated with biota, not water.
Molybdenum	0.05		Concentrations usually < 0.01 mg/L; higher concentrations from mining, agriculture, or fly-ash deposits from coal-fuelled power stations.
Monochloramine	3	0.5	Used as water disinfectant. Odour threshold 0.5 mg/L.
Nickel	0.02		Concentrations usually very low; but up to 0.5 mg/L reported after prolonged contact of water with nickel-plated fittings.
Nitrate (as nitrate)	50		Occurs naturally. Increasing in some waters (particularly groundwater) from intensive farming and sewage effluent. Guideline value will protect bottle-fed infants under 3 months from methaemoglobinaemia. Adults and children over 3 months can safely drink

			water with up to 100 mg/L nitrate.
Nitrite (as nitrite)	3		Rapidly oxidised to nitrate (see above).
Nitrilotriacetic acid	0.2		Chelating agent in laundry detergents (replacing phosphate). May enter water through sewage contamination.
Organotins dialkyltins tributyltin oxide	 c 0.001		 Stabilisers in plastics, may leach from new poly vinyl chloride (PVC) pipes for a short time. Tributyltins are biocides used as antifouling agents on boats and in boiler waters.
Ozone			As ozone used for disinfection leaves no residual, no guideline value has been established.
pH	c	pH 6.5-8.5	While extreme pH values (< 4 and > 11) may adversely affect health, there are insufficient data to set a health guideline value. < 6.5 may be corrosive. > 8 progressively decreases efficiency of chlorination. > 8.5 may cause scale and taste problems. New concrete tanks and cement-mortar lined pipes can significantly increase pH and a value up to 9.2 may be tolerated provided monitoring indicates no deterioration in microbial quality.
Plasticisers di(2-ethylhexyl) phthalate di(2-ethylhexyl) adipate	 0.01 c		Used in all flexible PVC products, and may leach from these over a long time. Could also occur in drinking water from spills.
Polycyclic aromatic hydrocarbons (PAHs) Benzo-(a)-pyrene	 0.00001 (10 ng/L)		 Widespread. Contamination can occur through atmospheric deposition, or leaching from bituminous linings in distribution systems.
Selenium	0.01		Generally very low concentrations in natural water.
Silver	0.1		Concentrations generally very low. Silver and silver salts occasionally used for disinfection.
Sodium	e	180	Natural component of water. Guideline value is taste threshold.
Styrene (vinylbenzene)	0.03	0.004	Could occur in drinking water from industrial contamination.
Sulfate	500	250	Natural component of water, and may be added via treatment chemicals. Guideline value is taste threshold. > 500 mg/L can have purgative effects.
Taste and odour	Not necessary	Acceptable to most people	May indicate undesirable contaminants, but usually indicate problems such as algal or biofilm growths.
Temperature	Not necessary	No value set	Generally impractical to control; rapid changes can bring complaints.
Tetrachloroethene	0.05		Dry-cleaning solvent and metal degreaser. Could occur in drinking water from contamination or spills.
Tin	e		Concentrations in water very low; one of the least toxic metals.
Toluene	0.8	0.025	Occurs naturally in petrol and natural gas, forest-fi re emissions. Could occur in drinking water from atmospheric deposition, industrial contamination, leaching from

			protective coatings in storage tanks.
Total dissolved solids	Not necessary	500	< 500 mg/L is regarded as good quality drinking water based on taste. 500-1000 mg/L is acceptable based on taste. > 1000 mg/L may be associated with excessive scaling, corrosion, and unsatisfactory taste.
Trichloroacetaldehyde (chloral hydrate)	0.02		Byproduct of chlorination.
Trichlorobenzenes (total)	0.03	0.005	Industrial chemical.
1,1,1-Trichloroethane	c		Could occur in drinking water from contamination/spills.
Trichloroethylene	c		Industrial solvent, cleaning fl uid, metal degreaser. Could occur in drinking water from direct contamination or via atmospheric contamination of rainwater.
Trihalomethanes (THMs) (Total)	0.25		Byproduct of chlorination and chloramination
True Colour	Not necessary	15 HU	15 HU just noticeable in a glass. Up to 25 HU is acceptable if turbidity is low. If colour is high at time of disinfection, then the water should be checked for disinfection byproducts such as THMs.
Turbidity	c	5 NTU	5 NTU just noticeable in a glass. >1 NTU may shield some microorganisms from disinfection. <1 NTU desirable for effective disinfection.
Uranium	0.02		Occurs naturally, or from release from mine tailings, combustion of coal and phosphate fertilizers.
Vinyl chloride	0.0003		From chemical spills. Used in making PVC pipes. Human carcinogen.
Xylene	0.6	0.02	Could occur in drinking water as a pollutant, or from solvent used for bonding plastic fittings.
Zinc	c	3	Usually from corrosion of galvanised pipes/fi ttings and brasses. Natural concentrations generally < 0.01 mg/L. Taste problems > 3 mg/L.

* All values mg/L unless otherwise stated

HU = Hazen units; NTU = nephelometric turbidity units; THMs = trihalomethanes.

a – Aesthetic values are not listed if the compound does not cause aesthetic problems, or if the value determined from health considerations is the same or lower.

b – If present at all in Australian drinking waters, concentrations of all organic compounds other than disinfection byproducts are likely to be very low relative to the guideline value.

c – Insufficient data to set a guideline value based on health considerations.

d – The guideline value is below the limit of determination. Improved analytical procedures are required for this compound.

e – No health-based guideline value is considered necessary.

Note: All values are as ‘total’ unless otherwise stated.

Note: Routine monitoring for these compounds is not required unless there is potential for contamination of water supplies (e.g. accidental spillage).

Note: The concentration of all chlorination byproducts can be minimised by removing naturally occurring organic matter from the source water, reducing the amount of chlorine added, or using an alternative disinfectant (which may produce other byproducts).

Action to reduce trihalomethanes and other byproducts is encouraged, but must not compromise disinfection.

Table A4.2: Guideline values for radiological quality of drinking water – Australian Drinking Water Guidelines

Guideline value
The total estimated dose per year from all radionuclides in drinking water, excluding the dose from potassium-40, should not exceed 1.0 mSv. If this guideline value is exceeded, the water provider, in conjunction with the relevant health authority, should evaluate possible remedial actions on a cost-benefit basis to asses what action can be justified to reduce the annual exposure.
Screening of water supplies
Compliance with the guideline for radiological quality of drinking water should be assessed, initially, by screening for gross alpha and gross beta activity concentrations. The recommended screening level for gross alpha activity is 0.5 Bq/L. The recommended screening level for gross beta activity is 0.5 Bq/L after subtraction of the contribution from potassium-40. If either of these activity concentrations is exceeded, specific radionuclides should be identified and their activity concentrations determined. The concentration of both radium-226 and radium-228 should always be determined, as these are the most significant naturally occurring radionuclides in Australian water supplies. Other radionuclides should be identified if necessary to ensure all gross alpha and beta activity is accounted for, after taking into account the counting and other analytical uncertainties involved in the determination.

Table A4.3 Guideline values for microbial quality – monitoring of *E. Coli* (or thermotolerant coliforms) – Australian Drinking Water Guidelines

Guideline	No sample of drinking water should contain any *E. coli* (or thermotolerant coliforms) (minimum sample 100 mL).
Action	If *E. coli* (or thermotolerant coliforms) are detected, then irrespective of the number of organisms, both the following steps should be taken immediately: 1) Another sample (a repeat sample) should be taken from the same site and from the immediate upstream treated sources of supply and tested for the presence of *E. coli* (or thermotolerant coliforms). – If the additional samples are negative for *E. coli* (or thermotolerant coliforms), then routine sampling can resume, but only after step 2 (below) has been completed. – If any additional sample is positive for *E. coli* (or thermotolerant coliforms), then increased disinfection and a full sanitary survey should be implemented immediately. The sanitary survey should include a review of the integrity of the system. AND 2) Disinfection should be increased and/or an investigation undertaken to determine possible sources of contamination. These might include a breakdown in disinfection, a mains break, interruption to the supply, surges in supply, or deliberate or accidental contamination of the system. The investigation may include a visual inspection of the system and associated service reservoirs by trained personnel. When found, the source of contamination should be eliminated.