University of Southern Queensland

Faculty of Engineering and Surveying

A Cost Benefit Analysis of Rural Residential Water Supply – Constant Flow vs. Full Pressure

A dissertation submitted by

Nicole Dakers

In fulfilment of the requirements of

Course ENG4111 and 4112 Research Project

Towards the degree of

Bachelor of Engineering (Environmental)

Submitted October 2009

Abstract

This project seeks to investigate the costs and benefits of full pressure and constant flow water supply on a rural residential community located in the Lockyer Valley.

The Lockyer Valley Regional Council was formed on the 15th of March 2008 through an amalgamation forced by the State government of the previous Laidley Shire Council and Gatton Shire Council. The amalgamation of the Councils identified large differences in water supply agreement for their rural residential developments. A uniform approach across the newly formed Council was required.

An investigation into the costs of constant flow and full pressure water supply was required before Council could make an informed decision about a new combined policy. A cost benefit analysis of the two existing options has been sponsored by the Lockyer Valley Regional Council in order to regulate water supply infrastructure throughout the region.

The objectives of the project are to:

- Determine the water consumption behaviour of rural residential properties located within the full pressure supply area of Gatton and the constant flow supply area of Regency Downs.
- Investigate trunk infrastructure requirements and maintenance costs for full pressure and trickle feed water supply .
- Investigate and determine the effect of rural residential development and the water supply options on salinity due to ground water table behaviour
- Provide a cost benefit analysis of the two water supply options and provide recommendations which consider economic, social and environmental aspects.

Cost benefit analysis is a critical method of determining costs and benefits of the alternative options in monetary terms, whether those costs or benefits are economic, social or environmental. This research project has been limited to the environmental cost due to salinity and the physical infrastructure costs for the alternatives.

Based on the cost benefit analysis undertaken, it was determined that the supply of full pressure water supply would come at an additional cost of $2,334,566.00 for Council, and $55,417.00 to agricultural yield per farm over a period of twenty years compared to the supply of constant flow water supply. Due to the applicable costs, a recommendation was made to the Lockyer Valley Regional Council that rural residential developments should continue to be supplied with a constant flow water supply, based on the costs to Council and the environment due to the potential for increased dryland salinity.

University of Southern Queensland

Faulty of Engineering and Surveying

ENG 4111 & ENG4112 Research Project

Limitations of Use

The Council of the University of Southern Queensland, its Faulty of Engineering and Surveying, and the staff of the University of Southern Queensland, do not accept any responsibility for the truth, accuracy or completeness of material contained within or associated with this dissertation.

Persons using all or any part of this material do so at their own risk, and not at the risk of the Council of the University of Southern Queensland, its Faulty of Engineering and Surveying or the staff of the University of Southern Queensland.

This dissertation reports an educational exercise and has no purpose or validity beyond this exercise. The sole purpose of the course pair entitled "Research Project" is to contribute to the overall education within the student's chosen degree program. This document, the associated hardware, software, drawings, and other material set out in the associated appendices should not be used for any other purpose; if they are used, it is entirely at the risk of the user.

Prof Frank Bullen
Dean
Faculty of Engineering and Surveying

Certification

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

Nicole Dakers

Student Number: 0050025840

Signature

27th October 2009

Date

Acknowledgement

In preparation of this research project and dissertation, I would sincerely like to thank those staff within the Finance, Rates, Technical Services, Plumbing and Engineering Operations Departments of the Lockyer Valley Regional Council for their endless help and advice in gathering the never-ending amounts of information which I required.

I would especially like to thank my supervisors Mark Porter, Rod Smith, Jim Barton and David Kay. I would like to make a special mention to David Kay, for his support and advice on this dissertation and my career in general.

I would also like to thank my family and friends. They all continually understood my commitments over the last year, and I am grateful for their patience.

Finally I would like to thank my fiancé Mitch. He provided advice and understanding during the many stressful moments over the last year and my entire university degree. His love and cool, calm demeanour has always kept me focused and motivated. I could not have done it without him.

Table of Contents

List of Figures

List of Tables

Chapter One

1.1 Introduction

Lockyer Valley Regional Council was formed on the 15th of March 2008 through a forced amalgamation by the state government of the previous Laidley Shire Council and Gatton Shire Council. The amalgamation of the Councils identified large differences in water supply agreements for their rural residential developments as Gatton supplied all developments with a full pressure supply while Laidley provided a constant flow or "trickle feed" supply of 3-5 litres per minute.

Constant flow water supply, is the supply of reticulated water at a reduced rate which 'trickles' into a dedicated rainwater tank at each individual property. The water is collected within the tank, which acts as a reservoir to ensure adequate supply during peak demand. At 3 litres per minute, each dwelling is supplied with a maximum of 4320 litres per day.

The water pressure delivered to the dwelling is dependent on the individual pump which is connected to the reticulated tank. Figure 1.1 below depicts a schematic diagram detailing how water is delivered from the reticulated water main into the residential dwelling.

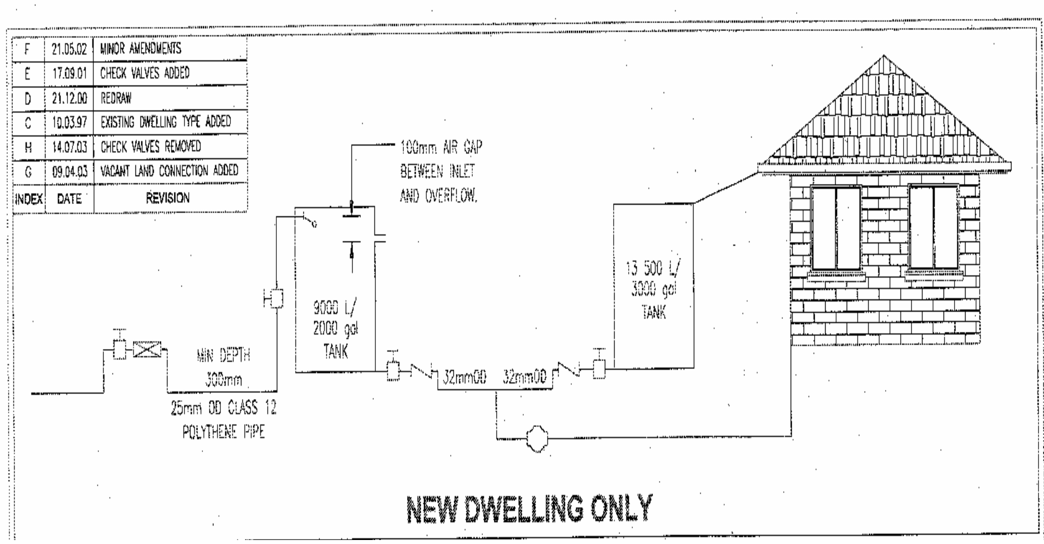

Figure 1.1 – Schematic diagram of constant flow water connection (LVRC, 2009)

The water supply arrangements for the newly formed Council need to be investigated to ensure the best outcomes for Council and the community are achieved. Due to the differences in supply agreements, and the need for a uniform approach across the local authority, an investigation into the costs of each option (both to Council and the environment) was required before Council can make an informed decision about a new combined policy. A cost benefit analysis of the two existing options has been sponsored by the Lockyer Valley Regional Council in order to regulate water supply infrastructure throughout the region.

The previous Laidley Shire Council water supply arrangement was decided by Council in 1989 due to the Council not possessing funds to supply the truck infrastructure required for full pressure water supply. This arrangement has continued due to the reduced trunk infrastructure requirements, pumping costs and perceived reduced water consumption rates.

Gatton Shire Council has supplied urban residential and rural residential developments with a full pressure water supply in accordance with their Planning Scheme Policies in and continues to supply full pressure water supply to all residential developments.

Water supply is a topical subject due to the current drought and extreme rapid population growth that South East Queensland is experiencing. The population of South East Queensland is expected to grow from 2.8 million to 4.4 million by 2031 with the number of dwellings doubling in the Lockyer Valley within the same time period (DSEQRP, 2009). The Draft South East Queensland Regional Plan is the statutory legislative framework that applies to the SEQ region in order to

> *"Manage regional growth and change in the most sustainable was to protect and enhance the quality of life in the region"*

The DSEQRP identifies three (3) land use zoning which are employed to ensure efficient provision of services and infrastructure, and limit further land fragmentation through land consolidation (DSEQRP, 2009 pp102). The three zoning are

- Urban Footprint
- Rural Living Area
- Regional Landscape and Rural Production Area

This report is focused on the Rural Living Area within the Lockyer Valley Regional Council jurisdiction, and more specifically described as the area north of the Warrego Highway including suburbs of Hatton Vale, Kensington Grove and Regency Downs. The location map below shown in Figure 1.2 depicts the study area.

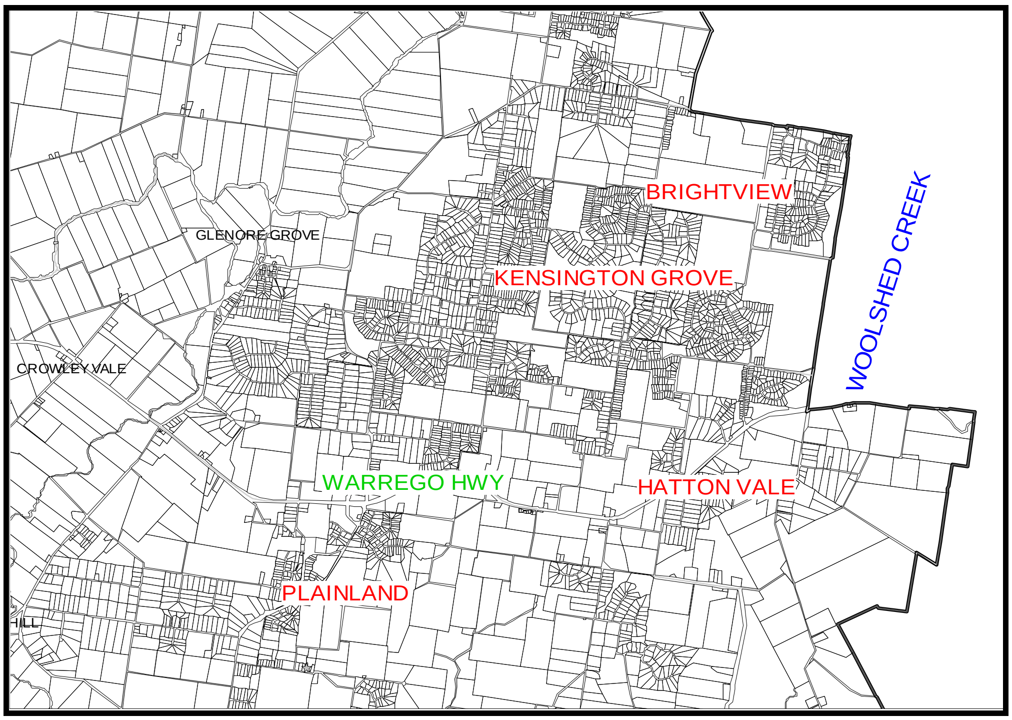

Figure 1.2 – Rural Residential Study Area

The abovementioned region is subject to the development requirements of the Laidley Shire Council Planning Scheme 2003. Under this planning scheme, rural residential development are required to have a minimum allotment size of 4000m^2 and be able to sustainably house an onsite effluent disposal system. Most of this development area is located within an area of protected vegetation (either under the Laidley Shire Council Planning Scheme or the Vegetation Management Act) and is generally flood free. Overland drainage paths drain easterly to the Woolshed Creek and wetlands which flows to the Lockyer Creek.

Due to the salinity which is currently present in the Woolshed Creek (Shaw, 2007) rural residential development has come under scrutiny for increasing the amount of water discharged into the groundwater table and acerbating the current land degradation. Vegetation removal to allow for residential dwellings and onsite sewerage facilities of households supplied with reticulated water supply are accused of causing increase salt loadings on the Woolshed and Lockyer Creek which supply irrigation water to the fertile Good Quality Agricultural Land (GQAL) of the Lockyer Valley.

Discussions indicating a change in water supply arrangements due to differing supply agreements throughout the Lockyer Valley Regional Council jurisdiction have instigated an investigation of the economic and environmental costs and benefits of constant flow and full pressure water supply. This is to ensure that any decisions in regard to water supply agreements is made on the premise that all applicable costs have been taken into account to ensure Council makes economically and environmentally sound decisions.

1.2 Research Objectives

The research paper will meet the following specific objectives:-

1. To collect data from current Laidley Rural Residential (constant flow) and compare with Gatton Rural Residential (full pressure) to conclude water consumption behaviour.

2. To research and investigate consumption behaviours due to physical and social attributes. Allotment size and, affluence of suburb will all be used to determine specific consumption behaviours.

3. To investigate the trunk infrastructure requirements for full pressure and trickle feed water supply and maintenance costs

4. To investigate and conclude the effect of Rural Residential development on salinity due to ground water table behaviour

5. To compare and contrast Cost Benefit Analysis (CBA) methodologies and applicable discount rates in order to develop a methodology to undertake a CBA for water supply. Limitations of the chosen method are to be fully explained and illustrated to ensure end consumer is aware of limitations of research project.

6. Provide a cost benefit analysis of two water supply options and provide recommendations which consider economic, social and environmental aspects in regard to trunk infrastructure supply, maintenance and environmental degradation due to salinity.

In conclusion, the research dissertation to undertake a cost benefit analysis of constant flow and full pressure water supply shall provide the Lockyer Valley Regional Council with the required information in order to make future decisions based on sound economic and environmental grounds.

Chapter Two

2.1 Literature Review

There is a significant amount of information in regard to water consumption behaviour in and around the home and the affect of water pricing on consumption, however a review of the available literature on the relationship between water availability and consumption has concluded that the topic has not been widely investigated.

The focus of this research topic is to investigate (through cost benefit analysis) the full pressure and constant flow water consumption behaviours of un-sewered rural residential developments and determine any associated environmental costs specifically in relation to dryland salinity. The following sections explore the available literature on consumption behaviours, dryland salinity and the technique of cost benefit analysis.

2.1.1 Consumption Behaviour

A review of the literature outlines that water consumption rates are associated with a range of independent factors based on socioeconomic elements and attitudes. This is important in order to compare consumption rates across the Lockyer Valley and determine whether factors other than water availability dictate consumption.

The Guidelines to Water and Sewerage Supply (DNR, 2005) states that outdoor water consumption is influenced by allotment size, location, rainfall, pricing and any applicable water restrictions. In contrast to these variables, Cary (2008) and Pigram (2006) state that socio demographics and consumer attitudes were the two largest and most important criteria which influence rates of water consumption with high water consumers generally being wealthier, older and living in larger, newer homes. Kenney et al (2008), Pigram (2006) and DNR (2000) consider that it is a combination of the aspects outlined by the Water and Sewerage Supply Guidelines and Cary with wealth, family size, age, water attitudes, type of dwelling, number of fixtures, age of household, and lot size determining the rate of consumption. These indicators for consumption were consistent throughout the literature available and are considered as accepted variables. Water consumption rates due to available pressure was briefly discussed by Pigram (2006) with comments that the Gold Coast City Council had reduced consumption through a reduction in main pressure however did not report on the percentage of reduction in consumption.

By using the allotment size and socio economic status of the suburb, consumption rates can be analysed to determine whether increase in consumption is due to water availability or external factors. Davies & Dandy (1994) presented a case that land valuation prices can be used as an indicator of consumer wealth. By using land valuations and ABS data for suburb wealth, the consumption rates of constant flow and full pressure can be evaluated to determine their influence. Land valuations are issued by the Department of Natural Resources and provide an unapproved land valuation. This can indicate affluence of suburb assuming that those who are wealthier possess properties with larger unapproved land valuations (NRW, 2009)

Rainfall, pricing and applicable water restrictions are a constant across the Lockyer Valley region, hence do not influence the applicable data set. There is limited information in regard to the number of people living within the dwelling, the age of the occupants and size of the dwelling, however will be used wherever possible to determine any evident trends. These values will be used to determine whether the study area has a comparative distribution of occupant number, age and dwelling size for the comparison between the constant flow and full pressure water supply areas.

Water consumption due to water availability has not been greatly investigated. From pipeline hydraulics, Chadwick et al (2004) explains that an increase in pressure head results in an increase in discharge. Therefore an increase in water pressure will result in additional discharge through existing sized pipes. Concluding from this information, it is reasonable to assume that an increase in pressure will result in additional consumption.

2.1.2 On-site Sewerage Systems and Dryland Salinity

The affect of water consumption in un-sewered rural residential developments is the hydraulic loading applied on the waste disposal system located on each allotment. Each allotment is supplied with an on-site sewerage disposal system which disposes of all waste water generated by the household through primary or secondary treatment. The principal of the septic systems is to treat the waste and dispose the effluent over a specified area where the water is either evaporated, stored in the soil or leaches through deep drainage to the ground water table (AS/NZ 1547:2000). Part of this investigation of this research project is whether on-site sewerage systems are greatly increasing the level of the ground water table and what will be the affect of an increase of water supply from constant flow to full pressure.

The Australian and New Zealand Standards (1547:2000) require that effluent leaves the dwelling to a septic tank or treatment facility where it is either irrigated over a land application area or discharged to a traditional disposal bed. The effluent is evaporated or absorbed by the soil, purified and then discharged into the ground water table. Depending on the size of the dwelling, the application areas are calculated in order to cater for the expected flows generated by the dwelling occupants. The Department of Natural Resources (2006) recommends that houses are sited away from areas experiencing high water tables as the house may be affected structurally as well as the on site disposal system acerbating the high water table.

The Department of Natural Resources (2006) states that deep drainage only occurs when the soil profile is saturated and water passes through to the ground water table. Deep drainage is the method of ground water recharge and is the reason for ground water tables to rise and one cause of complications with dryland salinity.

Gardner et al (1995) and Shaw (2007) agree that deep drainage is responsible for rises in groundwater table but contradicts the Australian Standard stating that on-site effluent systems should be adequately sized to ensure that deep drainage does not occur. Literature reviewed on on-site effluent systems states that deep drainage is a requirement for nutrient removal and disinfection prior to the effluent reaching the ground water table (Martens, 2001). It is assumed that all of the septic systems in the Lockyer Valley have been designed to the Australian Standard, therefore use of the water balance equations should be adequate in determining the volume of effluent discharged and the percentage disposed as deep drainage. This analysis of the literature shows that if deep drainage is required, a change in water consumption would result in an augmentation of the disposal area but would still result in deep drainage. Deep drainage cannot be avoided when designing and constructing on site sewerage systems in accordance with the Australian Standard.

To consider whether the deep drainage from septic systems adds a significant amount of groundwater recharge, it is imperative to consider the literature presented on water balance equations.

Gardner et al (1997) and Shaw (2007) consider that the natural water balance is disturbed when a rural residential subdivision is created as mature trees are removed, on-site effluent systems are installed and the hard surface runoff is discharged as point sources which increase the instance of deep drainage. They also present concern over suppling residences with mains reticulated water as it increases the ability to irrigate household gardens which is in addition to natural rainfall.

Shaw (2007) adds that the storage of rainwater and subsequent use on gardens also adds to the increased disposal of water to the ground water. This statement is not supported as the water collected from the residential roofs would have been disposed of on the ground surface in the first instance.

There is conflict in the work of Gardner et al (1997) and Shaw (2007) with the calculations presented in the Australian Standard. Gardner states approximately 750l/d of effluent is produced per household as Shaw indicates 160l/p/d with 4 persons per dwelling, corresponding to an additional 300mm/ha/year of rainfall. The Australian Standard states that designs should be based on 145l/p/day with the Laidley Shire Council Planning Scheme stating an average of 2.8persons per dwelling. This comparison shows

Gardner	750 l/d/dwelling
Shaw	640 l/d/dwelling
Australian standard	406 l/d/dwelling

From the above results, it indicates that the amount of effluent that is lost to deep drainage is dependant on the applicable water consumption rates, and no constant value can be assigned to discharge to ground water and associated potential threat to salinity.

From this review of literature, it is concluded that in order to determine whether there is an increase in salinity due to rural residential development, and the difference in threat depending on the reticulated water supply agreement, water consumption rates need to be obtained and analysed. From this information and the use of water balance equations, comparisons in the effect of reticulated water supply on salinity can be conducted.

2.1.3 Cost Benefit Analysis

A cost benefit analysis is universally agreed on throughout the literature as any critical method of determining costs and benefits of two or more alternative options in monetary terms, whether those terms are economic, social or environmental. Gilpin (1996) explains that CBA analysis is generally employed when there are social or environmental costs and benefits which cannot be identified in a financial evaluation. The cost benefit analysis within this research will be focused on two alternative options of providing constant flow or full pressure water supply to rural residential developments. Due to constraints, this research project will follow the CBA methodology, but will be limited to the environmental due to salinity and the physical infrastructure cost for the alternatives.

Gilpin (1996) and Smith (1986) describe the main concepts of CBA as, opportunity cost, willingness to pay, discount rates and the cost benefit rule. Through these aspects, an assessment of alternative projects is undertaken to ensure that monetary values are expressed for all social and environmental aspects of a project, not just the physical economic differences.

In the application of CBA to the research objective, opportunity cost will not be explored. Opportunity cost is well defined by Atrill et al (2006) and Blocher et al (2002) as the difference of undertaking one action over another based on the rate of return. For example this research will not be extended into the determination of whether capital spent on water infrastructure would have created a greater or lesser benefit than money spent on road infrastructure. This aspect is required for a full in depth CBA analysis but is not required to meet the objectives of the research project.

Cost benefit analysis is reported throughout the literature as a holistic approach to project costing, however there are limitations that need to be outlined. The Department of Finance (1991) reports limitations in accurately costing benefits or costs of a project if it goes ahead or not. There are also intangibles that cannot be quantified in monetary terms or bias costs placed to make a project look more favourable then it is in reality. Smith (1986), Stiglitz (1994) and Haney & Spash (1993) all agree that the requirements of BCA can exceed the expertise of the majority of professionals conducting CBA analysis. Each professional can justify the CBA methodology and discount rates used as there is no rule within the literature of what is accepted. Smith (1986) further expresses concerns over the limitations of CBA stating the lack of consideration to the distribution of benefits and costs, does not take into account intangibles as they are left as 'unquantifiable' and requires large amounts of information in order to full express and quantify all actions and flow on effects of an action.

In order to overcome or reduce the limitations of the CBA methodology for the purposes of the research task, it is considered that outlining in detail all assumptions made as well as the limited scope of the research. By ensuring the project is described in detail, and intangibles highlighted, the project outcomes can be assessed and critiqued by the consumer.

Discount rates are agreed on from all literature that benefits and costs occur over time and a present value for each aspect is required. The basic analogy that one dollar today is not worth one dollar next year, or ten years in the future. Therefore all cost and benefits need to have a discount factor applied each year for the period being investigated. There is great controversy over discount rates throughout the literature. Sinden & Thampapillia (1995) state that a discount rate of 5% should be used as the Department of Finance (1991) believes that 8% should be employed for all public projects. Most literature depicts difficult and detailed investigations into capital markets is required to calculate an applicable discount rate. Smith (1986) contests this view, stating that access to perfect capital markets would be required when in reality market imperfections, taxes and lack of information can alter the rate applied. Alternatively, Ivan (1978) believes that the discount rate should be the rate of interest charged on the loan to conduct the project, or the interested earned if the expended money was in the bank. Contradicting the other reviewed literature, Stiglitz (1994) states that he does not believe there is any particular evidence that a discount rate should be calculated if a sensitivity analysis is undertaken and there is no change in result. This is confirmed by Walshe & Daffern (1990) who also write that if there is no change in result during a sensitivity test of discount rate and assumptions, then a detailed determination of the rate is not required.

From the literature reviewed, it is considered that the cost benefit analysis should be undertaken at the recommended values of 5% and 8% and determine whether a change in result occurs. If a change in result does occur, then review of the discount rate along with analysis of any assumptions would need to undertaken due to the relative impartial decision between the two alternatives. This process is identified in the CBA methodology.

To undertake a CBA, a chosen methodology is required. Limited literature was available for methodology processes as they greatly differ based on the reason for a CBA to be undertaken. Gilpin (1996 pp 37), Sinden & Thampapillai (1995 pp 178) and the Department of Finance (1991 pp 6) support a methodology flow chart described below

1. Determine scope and objectives
2. Identify constraints
3. Identify alternatives
4. Identify costs and benefits
5. Quantify/value costs and benefits
6. Calculate new present value
7. Undertake sensitivity testing
8. Consider equity issues and intangibles
9. Conclude report

As this methodology supports the literature reviewed and investigates the key components of CBA analysis, it is considered that this methodology is universally accepted.

From the review of the literature, a methodology to undertake the cost benefit analysis has been investigated, compared and concluded upon.

Chapter Three

3.1 Methodology

The following methodology for the investigation has been proposed in order to provide guidance for the extents of the project and to be able to complete the investigation within the specified timeframe.

A data audit from LVRC's Practical data system and Council's excel databases was undertaken to collect water consumption data of rural residential households supplied with full pressure and constant flow water supply. The information retrieved was supplied in form of a comma delimited CSV file which was able to be manipulated to provide lot and plan details, meter number, date of reading, meter reading, zoning and allotment size.

This information was then imported into a GIS system (MapInfo) and using this program, the information for the selected investigation areas (Rural Residential to the North of the Warrego Highway and all Rural Residential properties supplied with reticulated water in Gatton) was obtained. The information was then exported in the form of tables which could be opened as Comma Delimited CSV files in Microsoft Excel. This ensured that the information being analysed was from the investigation areas only, and not properties outside the scope of this research dissertation.

As there were approximately twenty thousand (20 000) readings for the Laidley Area between the years of 2002 and 2008, the analysis was confined to allotments up to 8000m^2 which resulted in approximately nine thousand (9000) data points over the selected time frame. From this, five thousand (5000) data points were analysed for the purposes of this research paper as they depicted the data set adequately. To ensure that the comparison between full pressure and constant flow could be conducted, the Gatton data was also limited to allotment sizes up to 8000m^2 which resulted in approximately seventeen hundred (1700) data entries. All of these data points were analysed in order to determine an average water consumption rated for each year.

As the information retrieved from Council's Practical system only provided meter readings and not annual consumption, the total of six thousand seven hundred (6700) data points selected above required to be sorted using Microsoft Excel and formulas used to determine the consumption from the data provided. This was required to be undertaken manually to ensure that the consumption calculated was accurate for each dwelling for each year as the data extracted was not sorted chronologically and each dwelling had a differing period of data dependent on when the property was created. Other factors including some 8000m^2 being subdivided into 4000m^2 also needed to be taken into account.

Once this analysis was complete, consumption data for each dwelling for each year was obtained and displayed in Microsoft Excel which allowed for conclusions based on pressure, and allotment size to be determined.

An audit of Australian Bureau of Statistics (ABS) data was undertaken to relate water consumption rates to affluence of suburbs and average household population rates. This was conducted through an online search of 2006 census data for the Laidley and Gatton localities. From the available information online, areas were selected which represented the study area most accurately. This information is required in order to determine whether increases in water consumption is due to pressure or affluence of the area and be cross referenced with the data in relation to allotment size to draw conclusions of whether pressure dictates water consumption.

Information from Council budgets (both Laidley and Gatton) was obtained for the last 5 years. Due to complications with Council's Practical system as a result of the merged Council information, only data for the last 5 years was extracted in relation to operation and maintenance costs of Council water infrastructure.

From the information gathered, it was possible to determine operational costs and some maintenance costs of the current constant flow areas. The information was related to a cost per connection, with the total number of constant flow connections used to calculate this dollar value. The same process was undertaken for the Gatton properties. This allowed for a comparable figure in order to determine which system is more economical to operate. The figures calculated will allow for a dollar value to be presented for the cost benefit analysis.

Ground water table behaviours were researched in order to determine the main factors contributing to increased salinity, in particular Woolshed Creek. Information was obtained from the Department of Environment and Resource Management (DERM) as well as South East Queensland Catchments (SEQ Catchments). Unfortunately past documented salinity Electric Conductivity (EC) levels which had been measured at Woolshed Creek has been misplaced by SEQ Catchments and only limited data could be obtained. This still allowed for some comparison of salinity levels, and through further research, allowed for conclusions to be drawn in regard to increased salinity and whether the creation of the rural residential developments have any impact on the salinity of Woolshed Creek.

Using Council created Microsoft Excel databases, the percentage of on-site treatment plants verses traditional trench systems was found. This information allowed for water balance equations to be undertaken specific to the two (2) main effluent disposal methods used and determine the total rate of deep drainage for the study area. This will allow for an approximate additional rainfall (mm/year) to be calculated due to the supply of reticulated water, and conclusions drawn in regard to the effect of reticulated water consumption, and on site effluent systems on potential increase in salinity.

From the above information, it was possible to conclude on total potential increase to salinity and determine the environmental cost of degradation. This puts the cost of the environment into monetary terms which can be entered into the CBA. Information from the Department of Natural Resources, reports commissioned by Laidley Shire Council and data from the Australian Government Natural Resource Atlas will be obtained in regard to the likely costs that salinity has on the Lockyer Valley. Estimates between the percentage increases in water entering the groundwater system shall provide a basis for the likely cost.

Lastly a cost benefit analysis (CBA) was undertaken for the two options taking into consideration infrastructure and environmental costs using the method justified from comparisons of discount rates undertaken in the literature review (Chapter Two). The cost benefit analysis will allow for all benefits and costs of each proposal to be compared in monetary values and recommendations made based on the overall cost of the proposal now and into the future.

The recommendations from the CBA will be presented to Lockyer Valley Regional Council for their internal use to provide an indication of the costs for the two alternative proposals and commission any required reports based on these initial findings.

Chapter Four

4.1 Discussion of Results

To meet the research objectives of this study, water consumption behaviour, water balance equations, the effects of on-site effluent systems on the ground water table and associated salinity, as well as the operation and maintenance costs of the constant flow and full pressure water reticulation systems needed to be analysed and reported on order to determine the primary factors which will influence the inputs of the cost benefit analysis.

These aspects have been calculated and concluded upon within this chapter in order to allow progression to complete the cost benefit analysis based on the aspects investigated above.

4.2 Water Consumption Behaviour

An investigation into the effect of water pressure on consumption is required in order to determine whether a change in water supply agreements will cause a change in consumption and possible have an increased economic and environmental cost. To determine whether pressure alone is the major influence in consumption, other factors such as demographics, affluence, and allotment size need to be taken into account and cross referenced in order to determine whether there are any other prevalent contributing factors.

4.2.1 Water Consumption

Rural residential water consumption data was obtained through scrutiny of Councils records retrieved from the Practical rating program from 2002 through to 2008. An example of the extracted raw data has been included in Appendix B. Within this timeframe approximately 5000 and 1700 water consumption readings were analysed from the Laidley and Gatton rural residential areas respectively. The readings were conducted for properties ranging from 2000 m^2 through to 8000 m^2. It is important to note that the current Laidley Shire Council Planning Scheme currently has a minimum allotment size of 4000 m^2, and the 2000 m^2 allotments which were included in the analysis were allotments approved prior to the 2003 Laidley Planning Scheme. The reason that these allotments were kept for analysis was due to two factors:-

1. The South East Queensland Regional Plan 2009-2031 has a minimum allotment size of 2000 m2 in the Rural living Area. Therefore any future planning scheme for the Lockyer Valley region can be approved by the State Government with allotment sized of 2000 m^2 or higher; and

2. The inclusion of the 2000 m^2 allotments provided a better distribution of data in order to determine whether allotment size influenced the rate of consumption.

From this analysis, conclusions could be drawn for the consumption behaviour for each year in the two study areas to determine whether the increase in pressure created an increase in consumption.

From the analysis of the consumption data for the rural residential areas the following graph (figure 4.1) was created.

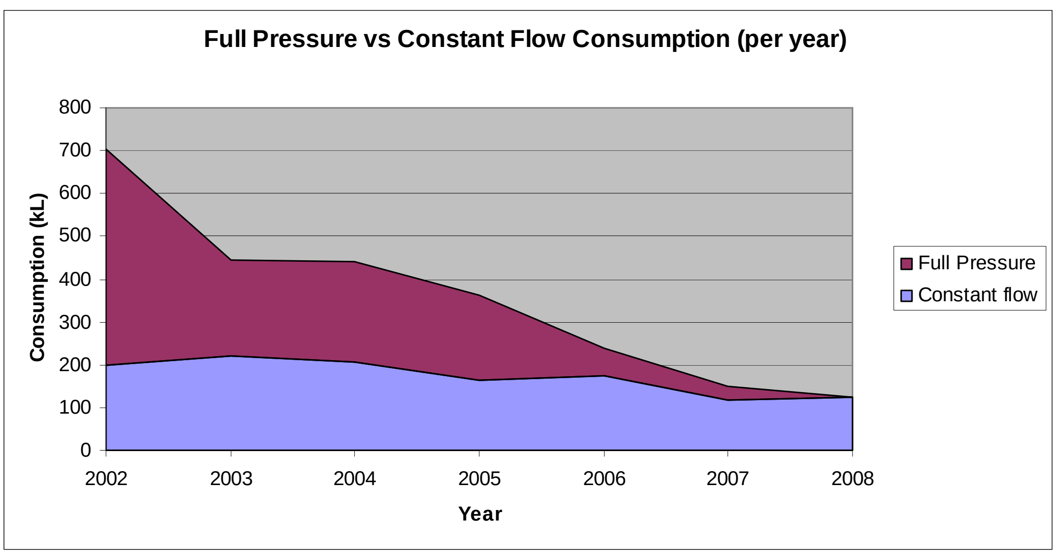

Figure 4.1 Average annual consumption for full pressure and constant flow per dwelling within the study area.

From the above graph it can be easily derived that the full pressure consumption is greatly higher than the constant flow, however a steady and sizable decline is evident in the full pressure consumption over the study period, with only 1.3kL difference in consumption for the 2008 year. The decline in consumption could be attributed to many changes in water supply regulation over the last decade, including:-

- Pressure reduction of the Gatton full pressure supply to reduce leaks;
- Water restrictions imposed by the Water Commission due to very low storage in Wivenhoe and Somerset Dams; and
- Introduction of mandatory rainwater tanks for all new dwellings.

The effect of these changes has been discussed in more detail below.

4.2.2 Pressure reduction

The Gatton Shire Council reduced the pressure of the reticulated full pressure mains in the Gatton township for a period of two (2) years from 2007 to January 2009. This was undertaken through an initiative with the Water Commission in order to reduce the loss of reticulated supply through leaks.

The northern section of the township to the north of the railway line was reduced from 600kPa to 430 kPa over a period of 6 months in 2007, while the town centre through to the west was reduced from 650 kPa to a range between 600 kPa to 300 kPa from a period of October 2008 through to January 2009. The southern and eastern section of the town mainly located around the Woodland Road region was not reduced due to the differences in elevation making it difficult to supply adequate pressure to all consumers.

Only a small portion of the rural residential area studied had pressure reduction applied, which indicates that the pressure reduction may not have had an impact on the consumption data analysed.

4.2.3 Water restrictions

The Water Commission introduced water restrictions for all properties within the South East Queensland region in order to kerb residential water consumption due to the extreme reduction in available water within the storage dams. The water restrictions commenced on the 13th of May 2005 and continued to increase until the 23rd of November 2007, with the first reduction in the level of water restrictions issued of the 31st July 2008. A summary of the restrictions imposed is outlined below (as supplied by the Water Commission):-

- High Level Restrictions commenced 31 July 2008
- Level 6 restrictions commenced 23 November 2007
- Level 5 restrictions commenced 10 April 2007
- Level 4 restrictions commenced 1 November 2006
- Level 3 restrictions commenced 13 June 2006
- Level 2 restrictions commenced 3 October 2005
- Level 1 restrictions commenced 13 May 2005

To determine the effect of the water restriction on the average annual consumption, figure 4.2 depicts the timing of the water restrictions and corresponding consumption in order to determine whether any effect is clearly shown.

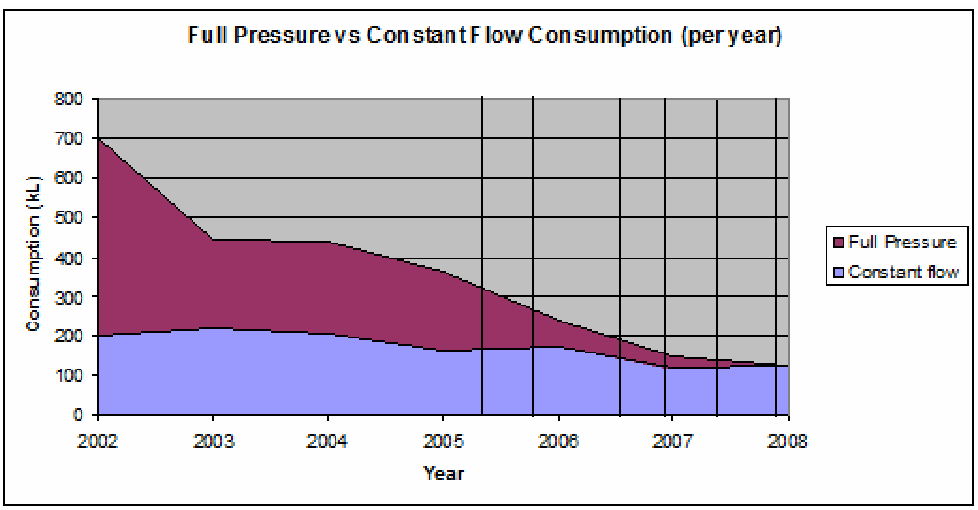

Figure 4.2 – Annual consumption per dwelling showing water restriction implementation periods.

Figure 4.2 shows that the reduction in full pressure water consumption was occurring prior to the implementation of water restrictions, however water consumption still drastically reduced over the period. Conversely, the constant flow area varied little over the study period and increased after the first two restrictions were imposed before reducing in the 2006-2007 period. The data analysed shown an increase in consumption by the end of the 2008 period which could be contributed to increase of rainfall over the 2008-2009 summer period which resulted in the relaxation of water restrictions on the 31st of July 2009.

To determine whether the water restrictions had any affect on the constant flow consumption, Table 4.1 was created and outlines the consumption per person and the target per person for each year due to water restrictions.

Year	Constant Flow Laidley (Litres/ per person)	Full Pressure Gatton (Litres/ per person)	Target per person consumption
2002	195.3	688.5	Nil
2003	217.2	434.7	Nil
2004	203.4	431.5	Nil
2005	158.7	356.1	230
2006	171.9	232.9	170
2007	115.0	146.7	140
2008	120.7	122.0	200

Table 4.1 – Daily per person consumption of reticulated water based on 2.8 persons per dwelling compared with target consumption.

From table 4.1 it can be easily shown that the constant flow properties were meeting, or slightly over the target. This is a contributing factor of the lack of steep descent in the constant flow consumption, as the residents were already using the recommended amount of water per person, and therefore may not have changed their habits as significant as those supplied with full pressure.

4.2.4 Water Tanks and Water Saving Devices

Another factor which changed how reticulated water supply was used in and around the dwelling was the announcement from the Building Codes Queensland (State Government) to make it mandatory for all new dwellings to install a rainwater tank connected to all sanitary flush systems and washing machines. This legislation was affective from the 1st of May 2005.

The affect of this legislation is uncertain as it would have only impacted on water consumption, as it applies to new residential dwellings only. For that reason the affect would be seen over time in contrast to water restrictions which apply to all households simultaneously. Therefore the affect is not considered to be easily determined, but it is considered that it contributes to the overall decline in consumption over the study period due to the large amount of residential growth within the study area.

4.2.5 Affect of Allotment Size on Water Consumption

As identified with the literature review (Chapter Two), it was recognized through other published works that the size of the allotment can influence the water consumption of the dwelling due to the proportional areas available for irrigated gardens and the alike. In order to investigate whether the allotment size affects the consumption, an analysis of the consumption data retrieved created figure 4.3 depicting consumption rates verses allotment area. The allotment areas were broken into ranges in order to clearly depict the relationships.

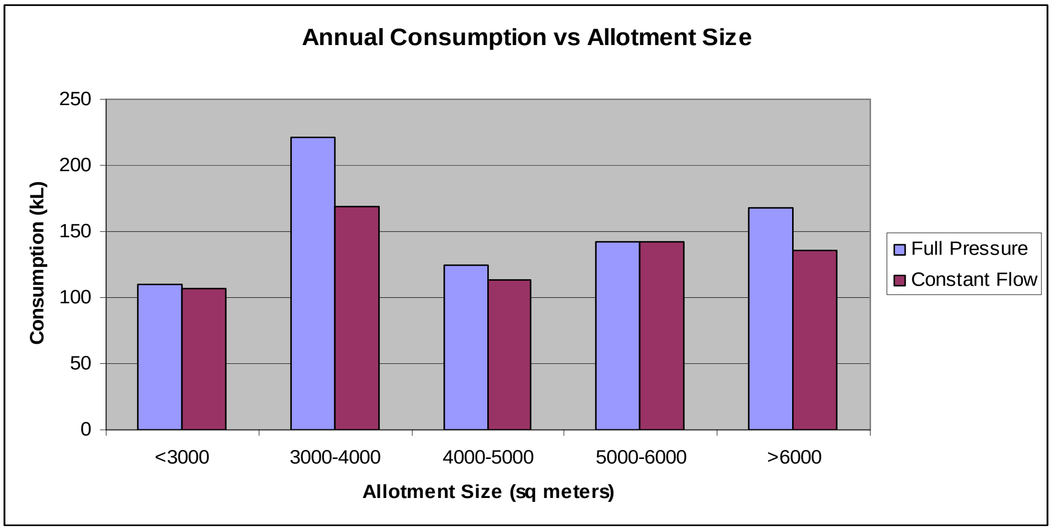

Figure 4.3 Annual consumption per dwelling verses allotment size.

Figure 4.3 and 4.4 depict that the allotment size does affect consumption with a clear linear relationship showing an increase of consumption with increase to allotment size, with exception to the 3000-4000m^2 allotments which have the highest average annual consumption. The reason for the increased consumption can be explained by the following points:-

1. The properties allocated full pressure are in close proximity to urban residential allotments and generally have highly landscaped gardens; and

2. There were only 5 properties in the constant flow are within this area allocation due to the Laidley Planning Scheme requiring a minimum allotment size of 4000m^2.

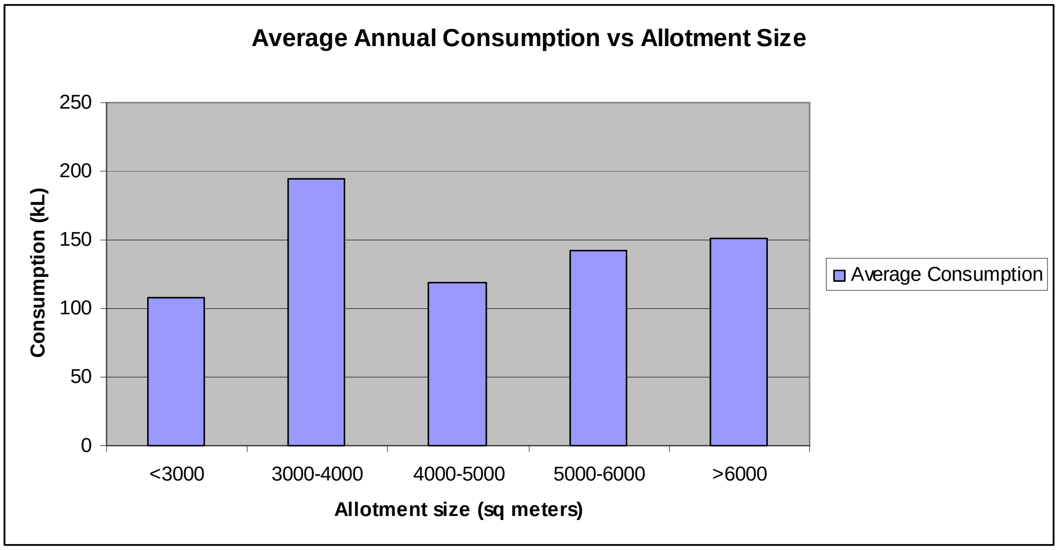

Figure 4.4 Average annual consumption per dwelling verses allotment size

The reason the allotment areas were grouped as shown in figures 4.3 and 4.4 is due to most of the full pressure rural residential properties fall into the 3000-4000 m^2 group and the constant flow rural residential is most prominent in the 4000-5000 m^2 group. This is fully explained as these figures are the minimum allotment size stated by the relevant planning schemes. Table 4.2 shows the number of consumption values in each classification in order to depict the distribution of data:-

Area (m^2)	Full Pressure (Gatton)	Constant Flow (Laidley)
<3000	68	212
3000-4000	1489	47
4000-5000	95	1425
5000-6000	44	929
>6000	42	2379

Table 4.2 – Number of consumption values per area group.

From Table 4.2 it shows that less confidence can be placed in the full pressure for the 4000-5000 m^2 and 5000-6000 m^2 groups, as well as the constant flow 3000-4000 m^2 group due to a lack of substantial data sets. The data set for the constant flow area is particularly suspect due to the 47 data points only depicting 5 individual properties. The full pressure data represents approximately 15 properties which makes the data more reliable.

In order to further investigate whether the increase in allotment size increases the consumption of water, further analysis was undertaken of the constant flow data for the 4000-5000 m^2 group and the greater than 6000 m^2 group due to the large number of data points available. Analysis of the 3000-4000 m^2 group was also undertaken. The results are shown below in figure 4.5:-

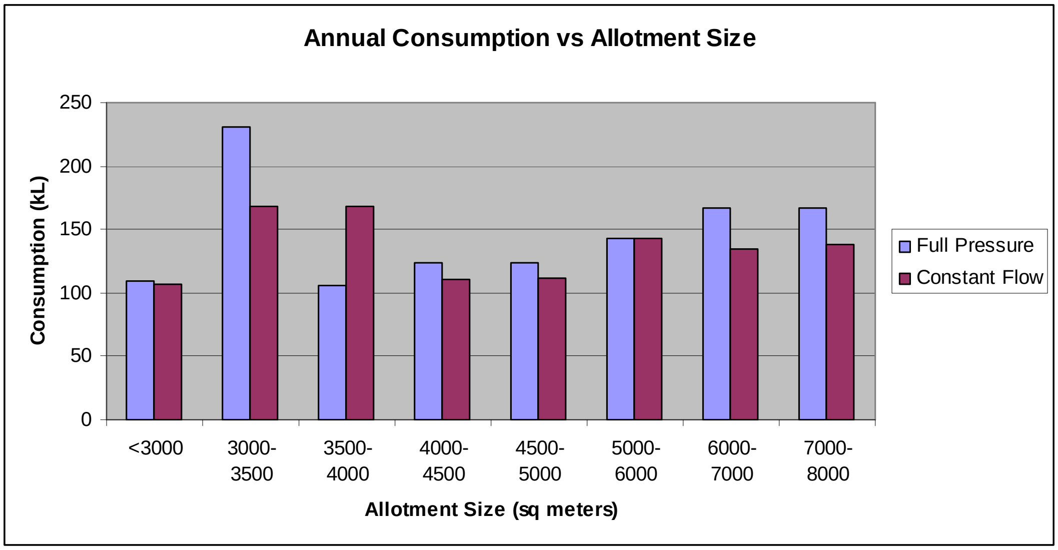

Figure 4.5 – Annual consumption per dwelling verses allotment size.

By further breaking down the allotment sizes where large data sets were available it can be seen that in the constant flow area the increase in allotment size did result in an increase in water consumption, however the overall trend of the constant flow water consumption does not show a strong increasing linear relationship. Conversely, the full pressure does depict a linear relationship with consumption increasing, however when the 3000-4000 m^2 group was broken into two parts, the 3500-4000m^2 had a lower consumption than that of the 3000-3500m^2.

From the above analysis, it is considered that there is an increase of consumption due to an increase of allotment size, but other factors such as social demographics, location and other external factors may have an affect which overrides any increase due to allotment size. This is evident due to the great increase in consumption for land areas which are the minimum under the respective planning schemes.

4.2.6 Affect of Affluence and Dwelling Population on Consumption

In order to determine whether household wealth and dwelling population could contribute to an increase or decrease in water consumption, the comparative study areas were analysed using 2006 Australian Bureau of Statistics Census data.

Affluence of Suburb

From the 2006 Census data analysed it was found that the study area in the previous Laidley Shire had a median weekly household income of $854.00 per week compared to Gatton which was $723.00 per week. This contradicts the information reviewed in Chapter Two, as it has been suggested that an increase in wealth corresponds with an increase in water consumption. As the Laidley constant flow area has a lower water consumption then Gatton, it can be concluded that the affluence of suburb is not causing a major impact on water consumption for the purposes of this research.

Dwelling Population

The Laidley Shire Council Planning Scheme and the Gatton Shire Council Planning Scheme both recommend a dwelling population of 2.8 persons. In order to determine whether the there was a difference in actual population characteristics of the dwelling which could contribute to the increased water consumption for the full pressure study area, 2006 Australian Bureau of Statistics Census data was consulted in regard to the household composition.

This analysis of data concluded that the Regency Downs study area had a composition of 78% families, 14.3% lone person households and 2.5% group households as the Gatton study area had 66% families, 25% lone person households and 4.3% group households. From this data it suggests that the Gatton study area has a greater proportion of lone person households which would account in a reduction to dwelling water consumption. As this is not the case, it is considered that the dwelling population does not greatly influence the consumption data for this research project, and does not account for the increase in consumption in full pressure reticulated areas.

4.2.7 Summary of Results – factors influencing consumption

From the above discussion it has been determined that the pressure of water supply greatly affects the household consumption of reticulated water. It is considered that an increase of water pressure allows for consumers to use a greater volume of water for each everyday task. It is important to note the follow outcomes of the water consumption analyses in order to fully explain and justify the conclusions reached.

1. The full pressure reticulation of the Gatton Area greatly decreased over the study period. From 2005 to 2008 this could be explained by the introduction of water restrictions, however the reductions from 2002 through to 2004 was not fully justified by this analysis.

2. The constant flow reticulation of the Laidley Area did not fluctuate greatly over time and increased for the 2007 year whilst strict water restriction were in place. This can be explained as the per person consumption of water was under the targets set by the Water Commission. It is possible that the consumers were not consciously reducing water consumption because of this.

3. It was considered that affluence and dwelling population did not create a reason for the increased/decreased water consumption within the two study areas.

4. Allotment size did seem to produce an increase in water consumption except for the 3000-4000 m^2 group which produced the highest water consumption. This is considered to be contributed by the location of the dwellings in proximity to the urban areas for the full pressure data set. The constant flow data did not show any strong relationship in comparison to the full pressure data, but still depicted some increase with allotment size. As the increase for the constant flow varied by less than 50 kL per year, it was considered that the relationship alone did not justify why the full pressure water supply consumed more than the constant flow.

4.3 Water Balance Equations and Salinity

To determine whether rural residential developments supplied with a reticulated water supply cause an increase in environmental degradation due to an increase in salinity, an understanding of water balance equations is necessary in order to calculate the additional water entering the ground water table due to on-site effluent systems. By using the results previously found in regard to water consumption behaviour, results can be obtained for full pressure and constant flow water consumption. This will allow for conclusions to be drawn in regard to whether an increase of water supply from constant flow to full pressure will have a large impact on the levels of salinity present in the Woolshed Creek.

4.3.1 Water Balance Equations

To determine the increase of deep drainage of effluent from on-site effluent systems into the ground water table, it is proposed to use the water balance equations outlined in AS/NZS 1547:2000 . To use the water balance equations, it is necessary to determine the proportion of traditional bed systems and land application (irrigation) systems in order to apply the correct equations and determine an accurate estimate of effluent being discharged into the water table.

Using Lockyer Valley Regional Councils records of approved on-site effluent systems, it was possible to calculate the percentage of each system within the study area. From this analysis it was determined that there were approximately 73% traditional bed systems and 27% land application systems. Figure 4.6 below diagrammatically represents the proportions found. The Laidley study area had a total of 2927 on-site effluent systems with 2136 being traditional bed systems and 790 being land application areas. It is considered that the proportion of land application systems will increase as they become more popular and allow for re-use of grey water for garden watering.

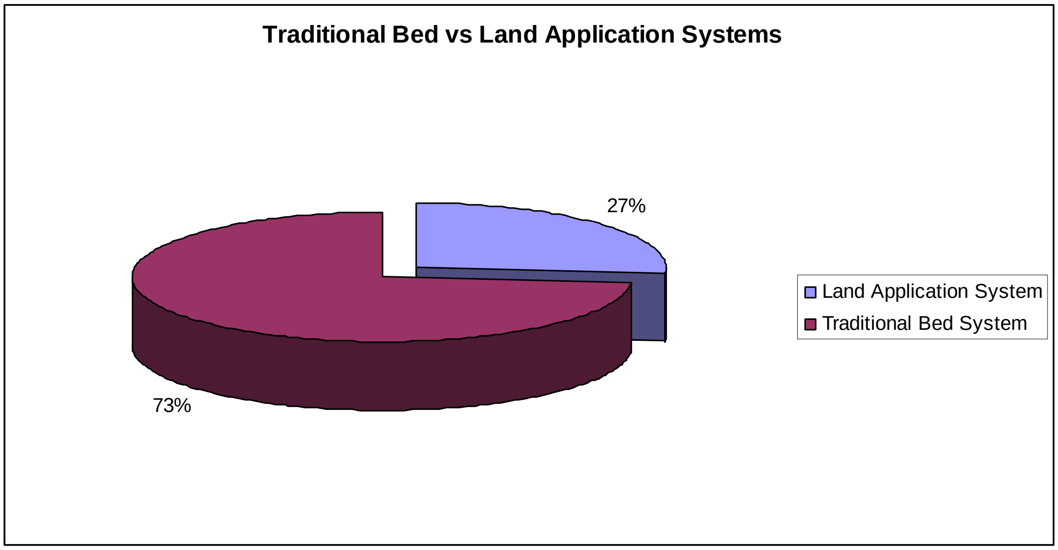

Figure 4.6 – Percentage of land application verses traditional bed on-site effluent systems for Lockyer Valley Regional Council.

The equations outlined in AS 1547:2000 for land application and traditional bed systems are as follows:-

<u>Land Application Water Balance</u>

$$P + Effluent = Et + RO + IF + DI + \Delta S \qquad \text{(equation 4.1)}$$

Where P = rainfall

Effluent =volume of effluent entering system (litres/day)

Et = evapo-transpiration from the surface (mm/day)

RO = run off

IF = lateral downhill seepage on sloping sites

DI = deep drainage losses

ΔS = change in soil moisture content

Traditional Bed Water Balance

$$A \times (DLR) \leq IF + DI + Et \qquad \text{(equation 4.2)}$$

Where	A	= effective area of infiltration (m^2)
	DLR	=Design Loading Rate (L/unit area of A/day)
	IF	= lateral downhill seepage on sloping sites
	DI	= deep drainage losses
	Et	= evapo-transpiration from the surface (mm/day)

In order to use these equations to determine the amount of deep drainage for a land application and traditional bed system with constant flow and full pressure water supply, the following assumptions and calculations were performed.

Land Application Water Balance Equation Assumptions and Calculations

The following assumptions of variables within the equation were made.

P	From Bureau of Meteorology, average rainfall of 800mm/year was assumed.
Effluent	The volume of effluent is considered to be equal to the volume of reticulated water consumed. The determination of effluent has been further explained below.
Et	From Bureau of Meteorology, average evapo-transpiration of 600mm/year was assumed.
RO	Run off is considered to be equal to the rainfall as the irrigation area would be moderately wet due to irrigation of effluent.
IF	For the purposes of this assessment, it is considered the site for the effluent disposal system is not sloping.
DI	The unknown factor to be calculated.
ΔS	As per recommendations of the AS/NZS 1547:2000 this value is assumed to be zero for the long term operation of the system.

The determination of the value for effluent has been based on one hundred percent (100%) of the consumed reticulated water entering the on- site effluent system. This has been considered as accurate in the current climate of water restrictions. The reduction of water restrictions may cause additional outside watering, where the additional water consumption will not be entering the on-site effluent system. It is considered that this is a conservative measure.

The additional water which enters the on-site effluent system due to use of rainwater (toilets, washing machine) has not been included as rainwater is collected from the roof of the dwelling and (if the dwelling had not been there) would have fallen to the ground and taken part of the natural water balance. As the rainwater is being returned to the ground surface, it is considered to have no affect in increasing deep drainage. This is further emphasised as the irrigation area is approximately 200-300m^2 and the area of the average 3 bedroom home is also 200-300m^2. It is considered that the rainfall is not an applicable variable in determining the volume of deep drainage due to reticulated water supply.

The amount of effluent entering the system has been calculated on the average per person water consumption over the last 8 years. It is considered that these values are higher than the present consumption, but should be used as it is possible that water restriction may be eased in the future and consumption will increase. The following values represent the average consumption values per person based on 2.8 persons per household.

Year	Constant Flow (Litres/ per person/day)	Full Pressure (Litres/ per person/day)
2002	195.3	688.5
2003	217.2	434.7
2004	203.4	431.5
2005	158.7	356.1
2006	171.9	232.9
2007	115.0	146.7
2008	120.7	122.0
Average Consumption	168.9	344.6

Table 4.3- Average consumption per person based on 2.8 persons per household.

Currently, the Plumbing and Drainage Department of Lockyer Valley Regional Council uses consumption data under the Plumbing and Drainage Act to calculate the irrigation area on the following assumptions

- 1.5 persons per bedroom
- 145L/day per person

For an average 3 bedroom home, this equates to a consumption of 652.5L per dwelling per day. In order to compare the difference between the calculated consumption and the assumed consumption as well as the number of residents per dwelling, table 4.4 has been devised.

	Actual Daily Consumption Per Dwelling		Actual Daily Consumption per person @ 2.8 persons/dwelling		Actual Daily Consumption per person @ 4.5 persons/dwelling		Calculated Daily Consumption @ 4.5 persons/ dwelling
Year	Constant Flow (L/day)	Full Pressure (L/day)	Constant Flow (L/day)	Full Pressure (L/day)	Constant Flow (L/day)	Full Pressure (L/day)	All Situations (L/day)
2002	546.9	1927.9	195.3	688.5	121.5	428.4	652.5
2003	608.0	1217.2	217.2	434.7	135.1	270.5	652.5
2004	569.5	1208.2	203.4	431.5	126.6	268.5	652.5
2005	444.3	997.2	158.7	356.1	98.7	221.6	652.5
2006	481.2	652.1	171.9	232.9	106.9	144.9	652.5
2007	322.0	410.8	115.0	146.7	71.6	91.3	652.5
2008	337.9	341.7	120.7	122.0	75.1	75.9	652.5
Ave	472.8	965.0	168.9	344.7	105.1	214.5	652.5

Table 4.4 – Comparison of water consumption rates used in water balance equations.

Table 4.4 shows the differing consumption rates depending on the number of persons per dwelling. This analysis was undertaken to illustrate the differences between the actual and calculated reticulated water supply consumption figures. It can be determined from table 4.4 that the Australian Standard uses an estimated daily consumption of 652.5 litres per day, as the actual consumption based on 4.5 persons per dwelling is between 71.56 and 135.12 litres per day for constant flow and 75.94 and 428.42 litres per day for full pressure. This shows that the design of onsite effluent systems is based on a larger consumption then what exists which may reduce the amount of deep drainage for each of the disposal methods.

In the calculations for the effluent component of the water balance equation it is considered that the average actual consumption data for each dwelling per day be used as it will more accurately depict the level of deep drainage. For use in the water balance equations, the average consumption values have been determined for constant flow and full pressure as 172.645 m^3/ dwelling/ year and 344.64 m^3 dwelling/ year respectively.

To determine the millimetres per year of effluent entering the irrigation area, the following calculations were performed:-

Using the AS/NZS 1547:2000 to determine the area of irrigation for the system;

Irrigation Area = Litres/week / DIR (equation 4.3)

Using tables 2.4A4 of the AS/NZS 1547:2000 standard, it is considered that the soil in the study area has a Design Irrigation Rate of 20. Using this information and equation 4.3

Irrigation Area = Litres/week/dwelling / DIR

= (145L * 4.5 * 7) / 20

= 228.37 m^2

Please note that the 145 L per person and 4.5 persons per dwelling was used for this calculation as this is how all irrigation areas have been calculated for the study area. Therefore although the volume of effluent will be less than 145L per person, the irrigation area will remain constant.

To determine the equivalent depth of discharge of effluent in millimetres per year for constant flow, the following calculation is required:-

Volume = Area * Depth

172.645m^3 /year = 228.37 m^2 * Depth

Depth = 172.645m^3 year / 228.37 m^2

= 0.756 m ≈ 756mm

To determine the rate of deep drainage for the land application area, the equation must be re-arranged to find DI:-

$$DI = P + Effluent - Et - RO - IF - \Delta S \qquad \text{(equation 4.4)}$$

Substituting the assumed values stated for average rainfall (800mm/year) and average evapo-transpiration (600mm/year) from the Bureau of Meteorology:-

$$\begin{aligned} DI &= 800\ (mm/yr) + Effluent - (600mm/yr) - (800mm/yr) - 0 - 0 \\ &= 800\ (mm/yr) + 756\ (mm/yr) - (600mm/yr) - (800mm/yr) - 0 - 0 \\ &= 156\ mm/yr \end{aligned}$$

Hence for the constant flow water consumption using a land application area disposal method, it is estimated that an additional 156 mm/year of effluent will enter the ground water table.

Using the same method, deep drainage into the ground water table for the full pressure consumption average will be calculated in order to determine the rate of increase. The average annual consumption of full pressure water supply is 352.2 m^3/ year.

$$DI = P + Effluent - Et - RO - IF - \Delta S$$

Substituting the assumed values stated above:-

$$\begin{aligned} DI &= 800\ (mm/yr) + Effluent - (600mm/yr) - (800mm/yr) - 0 - 0 \\ &= 800\ (mm/yr) + 1542\ (mm/yr) - (600mm/yr) - (800mm/yr) - 0 - 0 \\ &= 942\ mm/yr \end{aligned}$$

From this result, it can be clearly determined that the increase in water consumption will greatly increase the amount of deep drainage into the water table.

Traditional Bed Water Balance Equation Assumptions and Calculations

The following assumptions of variables within the equation were made.

$A \times (DLR) \leq IF + DI + Et$ (equation 4.2)

A	The area will be determined by calculating the required disposal area as specified by AS/NZS 1547.
DLR	Design Loading Rate as specified by AS/NZS 1547 (5 mm/day)
IF	For the purposes of this assessment, it is considered the site for the effluent disposal system is not sloping.
DI	The unknown factor to be calculated.
Et	Evapo-transpiration is assumed to be zero

For purposes of determining the volume of deep drainage it is considered that the equation will be altered to allow for easier computation. This will result in the greater than - equal to being changed to an equal sign.

$A \times (DLR) = IF + DI + Et$ (equation 4.5)

Using the AS/NZS 1547:2000 to determine the area of irrigation for the system;

Disposal Area = Litres/day / DLR (equation 4.6)

Using tables 2.4A3 of the AS/NZS 1547:2000 standard, it is considered that the soil in the study area has a Design Loading Rate of 5 mm/day. Based on this information and equation 4.6

Disposal Area = Litres /person /day / DLR

= (145 * 4.5) / 5 mm/d

= 130.5 m^2

To determine the rate of deep drainage for the land application area, the equation must be re-arranged to find DI:-

A x (DLR) = IF + DI + Et

Substituting the assumed values stated above:-

A x (DLR)	= IF + DI + Et
130.5m2 * 5 mm/d	= 0 + DI + 0
652.5 L	= DI
DI	= 652.3 L/day

To determine the volume of effluent in millimetres per year for constant flow water consumption, the following calculation is required:-

Volume	= Area * Depth
238.162 m^3 year	= 130.5 m^2 * Depth
Depth	= 238.162 m^3 year / 130.5 m^2
	= 1.824 m ≈ 1824 mm/yr

Hence for the calculated water consumption using a traditional bed disposal method, it is estimated that an additional 1824 mm/year of effluent will enter the ground water table.

Traditional bed disposal methods primarily dispose of the effluent through deep drainage as can be seen through the calculations above. In order to comment using conservative measurements, it has been assumed that lateral flow is zero and all effluent has discharged directly downwards into the ground water. In practice, the effluent will seep into adjacent soil water and will not contribute as directly to ground water discharge.

Therefore it is reasonable to assume that all effluent disposed into the bed, is discharged into the ground water table. Therefore the following calculations depict the average annual constant flow and full pressure discharge values into the ground water table.

Constant Flow

Volume = Area * Depth

172.585 m^3 /year = 130.5 m^2 * Depth

Depth = 172.585 m^3 year / 130.5 m^2

= 1.322 m ≈ 1322 mm/yr

Full Pressure

Volume = Area * Depth

352.23 m^3 /yar = 130.5 m^2 * Depth

Depth = 352.23 m^3 year / 130.5 m^2

= 2.699 m ≈ 2699 mm/yr

Concluding the outcomes of this analysis using the water balance equations outlined in AS/NZS 1547:2000, Table 4.5 has been devised to summarise the results.

Treatment Type	Constant Flow (mm/year)	Full Pressure (mm/year)
Land Application	156	942
Traditional Bed	1322	2699

Table 4.5 – Summary of deep drainage results

These results strongly depict that the traditional bed disposal method discharges a greater volume of effluent into the ground water table.

As previously stated there are 776 land application disposal systems and 2151 traditional bed systems located within the study area. From this information it is possible to calculate the approximate additional effective rainfall that the locality is receiving due to the disposal of household effluent.

Constant Flow				
Treatment Type	Deep Drainage (mm/year/ system)	Volume of Deep Drainage (m3/year/ system)	Effective additional Rainfall (mm/year/ allotment)	Effective additional rainfall (mm/ha/year)
Land Application	156.00	35.63	6.60	6.60
Traditional Bed	942.00	122.93	39.88	39.88
27% Land Application & 73% Traditional Beds	729.78	95.24	17.66	17.66
Full Pressure				
	Deep Drainage (mm/year)	Deep Drainage (m3/year)	Effective additional Rainfall (mm/year/ allotment)	Effective additional rainfall (mm/ha/year)
Land Application	1322.00	301.91	55.97	55.97
Traditional Bed	2699.00	352.22	65.30	65.30
27% Land Application & 73% Traditional Beds	2327.21	303.70	56.30	56.30

Table 4.6 - Effective additional rainfall due to effluent disposal

To determine the deep drainage of 27% land application and 73% traditional bed system, the following calculation was performed based on 100 sites:-

$$\text{Deep Drainage} = (0.27*1322) + (0.73 * 2699)$$
$$= 2327.21 \text{ mm/year}$$

It is important to note that from Table 4.6 that currently there is approximately 17.66mm of additional rainfall falling on the study area due to the operation of on-site effluent systems. This effective rainfall is not subject to runoff or evaporation and is discharged into the soil water, thus contributing to deep drainage and groundwater discharge. If the study area was to be supplied with a full pressure water supply then there would be an increase of effective rainfall to 56.30mm. This is almost triple the amount of rainfall entering the soil water.

From the above analysis it can be concluded that land application and traditional bed disposal methods provide differing rates of infiltration into the ground water table. It has been determined that the traditional bed method almost triples the deep drainage into the ground water when compared with the land application method. Also it important to note that using the water balance equations and the information gathered, the actual deep drainage into the ground water table within the study area was determined which provides valuable information to calculate the current and possible future deep drainage. This provides a better estimate of the effect of on-site effluent systems on salinity levels within the Woolshed Creek Catchment.

4.3.2 Salinity and the Ground Water Table

To determine the potential for on-site effluent systems to cause land degradation through dryland salinity, the present salinity risk of the Woolshed Creek required investigation and conclusions draws to determine whether the current discharge of effluent into the Woolshed Creek is causing environmental harm. Once this has been investigated and determined, it is possible to determine what impact an increase of water consumption could have on the groundwater table.

The increase in saline ground water greatly affects the Lockyer Valley as the ground water is relied on heavily for irrigation of food crops. By irrigating with a slightly saline ground water, the salts within the soil profile become more concentrated through evaporation and plant use which can lead to deterioration of the soil structure and fertility complications (Singer & Munns, 2006). Irrigation salinity will not be addressed within this research project, however the environmental and social consequences due to lack a reduction in the profitability of Good Quality Agricultural Land will be considered.

Although it is important to have deep drainage in order to replenish ground water supplies and to cleanse the root zone of plants of excess salt, too much deep drainage can lead to the rising of the ground water table where vegetation roots are then exposed to water logging and additional salts within the ground water (Singer & Munns, 2006). Deep drainage should be kept in equilibrium with the natural water cycle. Naturally, in times of wet and dry, salinity increases and decreases, however if the use of the land is greatly dictating the natural water cycle and disposing a greater amount of water into the ground water table, then environmental harm can occur (Shaw, 2007).

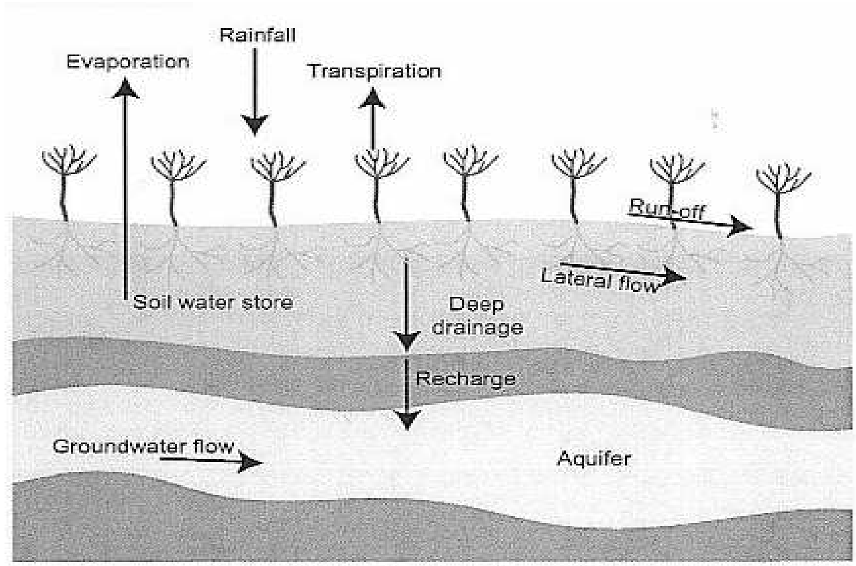

Figure 4.7 Water Balance diagram. Source: DERM (2006)

The Woolshed Creek catchment is particularly susceptible to salinity due to the geological formation of Winwill conglomerate as it greatly reduces the flow of ground water exiting the catchment (Shaw, 2008 pp 25). Figure 4.7 shows diagrammatically the geological restriction present in the Woolshed Creek catchment.

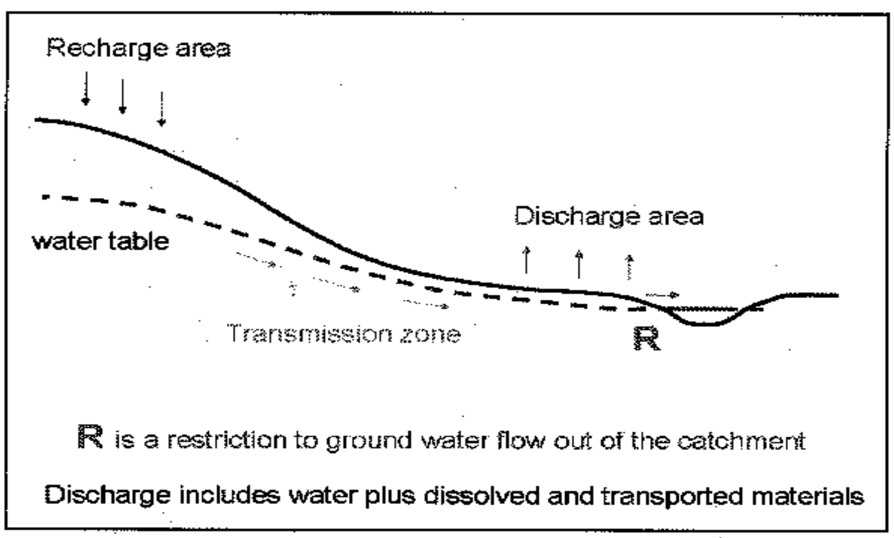

Figure 4.8 Diagram identifying the restriction to groundwater flow. Source: Shaw R 2007

Due to the Winwill conglomerate restricting the outflow of groundwater from the catchment, the groundwater table rises with the additional hydraulic loadings which are applied to the catchment (Shaw, 2007). Hydraulic loadings can comprise of any deep drainage inflows such as large rainfall events and the disposal of effluent from on-site systems. In times of large rainfall events, salinity is increased as a combination of deep drainage dissolving salts below the saturated zone, as well as the increase of ground water table as it fills due to the lack of high volume discharge from the catchment (Shaw, 2007).

The work conducted by Shaw (2008) on the Woolshed Creek has highlighted the requirements for salinity management actions to be undertaken due to the high susceptibility which the Woolshed Creek catchment has to further degradation. Using Shaw (2008) results for the estimated electric conductivity (EC) value of stream flow and tonnes per day of salt discharged by the catchment, it was possible to extrapolate data specific to Woolshed Creek based on the consumption rates found earlier in this chapter. The following results were found.

Constant Flow					
Treatment Type	Deep Drainage (mm/year)	Volume of Deep Drainage (m3/system/ year)	Volume of Deep Drainage for the catchment (ML/day)	EC of stream flow based of effluent discharge (dS/m)	Salt Leaving Catchment (tonnes/day)
27% Land Application & 73% Traditional Beds	729.78	95.24	0.76	16.00	6
Full Pressure					
	Deep Drainage (mm/year)	Volume of Deep Drainage (m3/system/ year)	Volume of Deep Drainage for the catchment (ML/day)	EC of stream flow based of effluent discharge (dS/m)	Salt Leaving Catchment (tonnes/day)
27% Land Application & 73% Traditional Beds	2327.21	303.70	2.44	11.20	11

Table 4.6 – Estimated EC and tonnage of salt discharged from the Woolshed Creek Catchment.

The increase from 6 tonnes per day of salt discharge to 11 tonnes per day is a 45% increase of salt loading on the Woolshed Creek and subsequent Lockyer Creek. It should also be noted that the increase of water consumption reduces the EC level of the water discharged. This is because there is a greater flow of water to dilute the water solution, however there is still an increase in the total tonnage of salt leaving the catchment which can greatly affect downstream catchments.

Assessment of the electric conductivity (EC) tests on the Woolshed Creek catchment over a long period of time would also allow parallels to be considered between residential growth of the region and patterns in EC levels. Unfortunately on retrieval of this information from the Department of Environment and Resource Management (DERM) it was advised that this historic information had been misplaced through the closure of the Lockyer Catchment Centre, and only limited data could be provided. This provided difficulties in determining the most prominent cause for increase in salinity levels for the Woolshed Creek and as a result Roger Shaw's previous investigation into the bio-physical options to prevent, minimise or manage salinity issues in the Lockyer Catchment was consulted. The processes outlined within this document allowed for an assessment to be carried out based on the researched and calculated volume of deep drainage discharged for the rural residential study area.

Shaw (2007) provided the following analysis of the Woolshed Creek Catchment in regard to potential for salinity risk:-

- Salinity is due to catchment restriction
- Present significance of salinity is small, however water quality is being affected and areas of bare patchy vegetation are evident
- Pressures on hydraulic loading are rainfall, non-sewered subdivisions, dams, roads across valleys and vegetation clearing.
- The increase in salinity is considered to impact of water quality, bridges, underground services, roads, landscape health, biodiversity and ecosystems, and enterprise viability.
- To remediate the effects of salinity will be difficult and expensive.

In ordered to assess the potential for each hydraulic load to impact on the ground water table, and determine whether on-site effluent systems are the major cause of discharge into the groundwater table, a table of indicative deep drainage values was devised.

To determine the hydraulic load from each factor, the following calculations were preformed. This method allowed for the research undertaken in earlier parts of Chapter Four to be combined with findings of Shaw (2008) and Gardner (1995) to create realistic results specific for the Woolshed Creek Catchment.

Rainfall

The rainfall value in millimetres per day was calculated through the average rainfall and evaporation data supplied by the Bureau of Meteorology (2009). Rainfall is estimated at 800mm per year and evaporation at 600 mm per year. Hence

Rate of Rainfall Deep Drainage = (Rainfall – Evaporation) /365

This is considered a conservative estimate as runoff is considered to be zero. This allows for the absolute maximum of deep drainage which could occur due to rainfall.

Onsite Effluent Systems

Daily deep drainage from onsite effluent systems was calculated using the millimetres per day value from previous calculations.

Deep Drainage (mm/day/ha) = 17.66/365
= 0.05 mm/day

Dams

Shaw (2007) provided evidence in his report on biophysical options to prevent, minimise or manage salinity issues in the Lockyer Catchment that dams provide deep drainage of 1mm per day. Using aerial photography it was determined that a greater proportion of properties with the study area had dams. It was considered that a rate of 1 dam per hectare would be used as the average allotment size was 0.5394 ha and approximately every second property had a dam.

Vegetation Clearing

Gardner (1995) reported on hydraulic implications of onsite effluent systems on the groundwater table, and through his analysis of using the daily water balance model PERFECT he determined that for each onsite disposal system, approximately two (2) hectares of deep rooted vegetation would be required to offset the deep drainage. Based on the deep drainage of the onsite effluent systems of 729.78 mm/year/system it can be determined that each hectare of vegetation removes 364.89mm/year (approximately 1mm/day) of deep drainage.

Hydraulic Load	Rate of deep drainage (mm/day/ha)	% contributed to deep drainage
Rainfall	0.54	20.8
on-site effluent system	0.05	1.9
dams	1	38.6
Vegetation clearing (per ha)	1	38.6
Total	2.59	100.0

Table 4.8– Contributing factors to additional hydraulic loading of the Woolshed Creek Catchment.

From this current assessment it is considered that the increase in hydraulic loading from on site effluent system is not the major factor which could cause significant environmental impacts. The major hydraulic loading is considered to be from combination of reduction of deep rooted vegetation and the establishment of dams. It can be determined from the above assessment that these factors present a higher hydraulic loading than the annual rainfall.

From the above discussion it is considered that rural residential developments have a large impact on the rate of deep drainage due to vegetation clearing and creation of dams. The effect of on-site effluent systems does not present a large threat as it only represents 1.9 percent of the hydraulic loading applicable to the development. It should be noted that the Laidley Shire Council Planning Scheme has the study area mapped as moderate to very high ecological significance which ensures that vegetation is maintained wherever possible.

4.4 Operation and Maintenance Costs

To establish the comparison of the costs for constant flow and full pressure water supply, an investigation into the operation and maintenance costs of the two systems is required. Ultimately this analysis would include all headworks infrastructure such as trunk mains, pump stations and reservoirs. This information was unavailable as Councils assets register did not provide the specific information in order to determine which properties were fed from which reservoir, pumping station or trunk main. In some cases this information was available for the study area, but due to the inconsistencies in comparing the two systems, there was insufficient information to provide an equal assessment of the two supply options. It was also difficult to determining the exact costs of each system due to the data being derived from the existing Gatton and Laidley Shire Council. Due to the separate financial reporting systems, costs were not grouped in a similar format which made the comparison of the two systems difficult.

Hence, due to the unavailability of all of required information, an analysis was undertaken on the following infrastructure aspects:-

- Salaries of water officers
- Electricity
- General expenses
- Meter maintenance expenses
- Mains maintenance expenses

The cost of purchasing the bulk water supply to users has not been included with this assessment due to two reasons:-

1. The financial system for Laidley did not supply this information explicitly, and therefore could not be determined; and

2. It is assumed that the cost of water is ultimately paid by the rate payers through water consumption rates. Therefore if additional water is consumed then the increase in water cost is met by the consumer.

As the constant flow and full pressure systems will be assessed the above information, it is considered that an even benchmark has been achieved and any disparity in cost will be illustrative of the cost difference of the two systems.

The comparison of the two supply options has been tabled below:-

	Financial Year					
	2002-2003		2003-2004		2004-2005	
Item	Constant Flow	Full Pressure	Constant Flow	Full Pressure	Constant Flow	Full Pressure
Water Officer salaries	n/a	$ 53,363	$ 62,362	$ 58,686	$ 61,914	$ 105,874
Electricity	n/a	$ 11,635	$ 2,917	$ 10,255	$ 2,599	$ 18,296
Meter maintenance expenses	n/a	$ 20,563	$ 31,419	$ 34,845	$ 49,410	$ 12,878
Mains maintenance expenses	n/a	$ 53,852	$ 23,424	$ 229,861	$ 40,125	$ 163,289
Total expense	$ -	$ 139,413	$ 120,122	$ 333,647	$ 154,048	$ 300,337
Expense per connection	$ -	$ 33	$ 41	$ 79	$ 52	$ 71

	Financial Year			
	2005-2006		2006-2007	
Item	Constant Flow	Full Pressure	Constant Flow	Full Pressure
Water Officer salaries	$ 53,679	$ 92,375	$ 103,804	$ 111,347
Electricity	$ 2,909	$ 11,552	$ 3,322	$ 11,491
Meter maintenance expenses	$ 40,641	$ 17,754	$ 17,399	$ 24,155
Mains maintenance expenses	$ 35,835	$ 405,325	$ 18,188	$ 223,361
Total expense	$133,064	$ 527,006	$ 142,713	$ 370,354
Expense per connection	$ 45	$ 124	$ 49	$ 87
Average constant flow price per meter	$ 47			
Average full pressure price per meter	$ 79			

Table 4.9 – Cost of operation and maintenance costs per year

The results of this analysis showed that suppling full pressure water has a greater cost per connection then constant flow water supply. This is mainly contributed to the increase in pumping costs and mains maintenance costs due to the additional pressure in the lines.

Through this analysis it has been determined that the costs of maintenance are dependent on the design lift of the pipes installed, hence maintenance figure vary greatly from year to year. The time period analysed was from 2002 through to 2008 due to availability of the data. Previous years either were not available or the information was not broken down in a manner which allowed determination of the alternative systems. Ideally further investigation into the costs of the two systems should be undertaken, however the results presented in this research study are adequate in determining the basic cost difference between the systems.

The results of the cost analysis are considered typical as it is considered that the full pressure water supply system comes at an additional cost due to the requirement to have a reservoir sized to hold three times the difference between peak day demand and mean day maximum month flows plus fire fighting storage (QPGWSS, 2008). This requires pumping to the gravity reservoir storage and distribution to the customer through a main sized to cater for the peak hour demand of the residential area serviced. The Queensland Planning Guidelines for Water Supply and Sewerage states that the peak hour demand is equivalent to the instantaneous demand of a residential dwelling for a period of two (2) hours at 15 litres per second. This is greater than the requirement for constant flow, where the residential property owner supplies a rainwater tank on site dedicated for storage of reticulated water which allows the mains to supply water at a rate of 3-5 litres per minute. Consequently the property owner pays for the additional reservoir capacity and pumping costs of supply reticulated water.

In conclusion, it is considered that the cost of full pressure water supply is 68% higher than the equivalent constant flow water supply agreement, with pipe maintenance and pumping costs the main contributors to the increase in cost.

4.5 Conclusion of Results

In conclusion to the analysis of household water consumption, water balance equations, the effect of onsite effluent systems on the groundwater table and salinity and the cost differentiation between full pressure and constant flow water supply for the selected study area, the following summary of results is provided.

Household water consumption

- The pressure reduction of the Gatton full pressure supply had no relationship with the reduction in consumption due to the localities affected by the decrease.

- Water restrictions reduced consumption for full pressure consumers, however did not impact on constant flow consumers as they were already meeting the targets set by the restrictions.

- Allotment size does affect water consumption as generally consumption increased with size. However other factors have a higher influence which is evident by the large increase in the 3000-4000 m^2 and 4000-5000 m^2 allotments.

- It was found in the case of the selected study area that affluence and dwelling population did not affect reticulated water consumption.

Water balance equations

- The use of water balance equation was effective in determining the volume of effluent entering the ground water table based on 27% and 73% of onsite effluent system being land application and traditional bed system respectively.

- The calculation produced the results in the table below which shows that traditional bed systems discharge almost three times as much effluent into the ground water table as land application systems.

Constant Flow				
Treatment Type	Deep Drainage (mm/year/ system)	Volume of Deep Drainage (m3/year/ system)	Effective additional Rainfall (mm/year/ allotment)	Effective additional rainfall (mm/ha/year)
Land Application	156.00	35.63	6.60	6.60
Traditional Bed	942.00	122.93	39.88	39.88
27% Land Application & 73% Traditional Beds	729.78	95.24	17.66	17.66
Full Pressure				
	Deep Drainage (mm/year)	Deep Drainage (m3/year)	Effective additional Rainfall (mm/year/ allotment)	Effective additional rainfall (mm/ha/year)
Land Application	1322.00	301.91	55.97	55.97
Traditional Bed	2699.00	352.22	65.30	65.30
27% Land Application & 73% Traditional Beds	2327.21	303.70	56.30	56.30

Table 4.6 – Effective additional rainfall due to effluent disposal.

<u>Groundwater table and salinity</u>

- Using methods created by Shaw (2008), the EC levels and tonnage of salt discharged from the catchment based on the deep drainage values determined by the water balance equations was calculated to be currently 16 dS/m and 6 tonnes per day respectively. It was also determined that if the rural residential area was supplied with full pressure the EC level would decrease to 11.2 dS/m however the tonnage of salt discharged would increase to 11 tonnes. This would have dire consequences to the Woolshed Creek and downstream catchments.

- Vegetation clearing and creation of dams were determined to the largest contributors to hydraulic loading with a contribution of 38.6% each to the total loading. It was determined that the creation of on-site effluent systems contributed 1.9% to the total hydraulic loading, thus do not present the highest risk to increased groundwater table levels. These result are depicted in Table 4.8 below.

Hydraulic Load	Rate of deep drainage (mm/day/ha)	% contributed to deep drainage
Rainfall	0.54	20.8
on-site effluent system	0.05	1.9
dams	1	38.6
Vegetation clearing (per ha)	1	38.6
Total	2.59	100.0

Table 4.8 – Contributing factors to additional hydraulic loading of the Woolshed Creek catchment.

Operation and maintenance costs of full pressure and constant flow water supply.

- From the analysis of the data available to determine the cost differences between full pressure and constant flow water supply, it was determined that full pressure was 68% higher than constant flow with an average cost of $47.00 and $79.00 per connection respectively.

Chapter Five

5.1 Cost Benefit Analysis

A cost benefit analysis (CBA) is a method of determining the costs and benefits of two or more alterative options where the inputs can be economic, environmental and/or social. As this research project is concerned with the economic and environmental costs of two water supply options, it is considered that the method of CBA is an apt method for the research objectives. From review of the literature on CBA contained within Chapter Two, it is considered that the methodology outlined by the Department of Finance in the Handbook of Cost Benefit Analysis be used. The chosen methodology consists of:-

1. Determine scope and objectives
2. Identify constraints
3. Identify alternatives
4. Identify costs and benefits
5. Quantify/value costs and benefits
6. Calculate new present value
7. Undertake sensitivity testing
8. Consider equity issues and intangibles
9. Conclude report

The following section discusses each step of the methodology and provides a recommendation in regard to whether the study area should continue to be provided with constant flow water supply, or whether the water supply should be increased to full pressure. It should be noted that due to the results of Chapter Four, both systems have economic and environmental costs, hence there will be a greater emphasis on the cost difference between the systems which will dictate the conclusion and associated recommendations.

5.2 Determine Scope and Objectives

The scope of the cost benefit analysis (CBA) is to evaluate the constant flow water supply and full pressure water supply options applicable to the rural residential developments west of the Woolshed Creek based on the results presented in Chapter Four.

The objectives of the CBA analysis is to:-

1. To determine the costs of the two alternative water supply options in regard to impacts on the groundwater and possible increase in salinity; and

2. Use the costs of the two alternative water supply agreements to provide a recommendation to the Lockyer Valley Regional Council in regard to sustaining or increasing the current supply agreements.

5.3 Identify Constraints

The constraints of the CBA analysis are the restricted issues investigated within Chapter Four. Due to the time constraints of this research paper, the following constraints and/or limitations imposed:-

- The effect of increasing water supply to rural residential customers has been limited to dryland salinity and how this affects agriculture. Realistically there are many other environmental concerns that would need to be investigated for a complete and holistic CBA analysis. These environmental issues include but are not limited to:-
    - The overall effect on the environment and air quality due to each dwelling pumping water from the on-site tank to the home in the constant flow area, and how this compares to the emissions created from pumping full pressure water supply;

    - The environmental degradation caused from the manufacture and distribution of additional rainwater tanks and pumps required for each property. Manufacturing and transport processes cause additional usage of natural resources which comes at a cost to the environment;

    - Additional water provided may result in larger amounts of energy used within the home due to excess use of hot water systems, dishwashers etc;

    - The nutrient loading of effluent on ground water quality. This may have additional impacts on salinity due to large levels of sodium present as well as concerns due to concentrations of phosphorous and nitrogen;

    - Environmental implications further downstream due to the effects of salt and nutrient loadings on Morton Bay;

    - The reduction of vegetation cover on carbon emissions within the atmosphere;

    - Effects of erosion of creeks and rivers due to exposed soil at great risk of water erosion.

- Social factors such health concerns over reticulated water being stored within a storage device where chorine levels may reduce to levels below health standards and/or effect of community possibly consuming more captured rainwater due to lower town supply;

- The cost of supplying, maintaining and operating the alternative forms of water supply. A basic cost analysis has been undertaken, however additional studies into the cost of upgrading each pipe within the reticulated constant flow water supply area as well as a whole life cost analysis of approximately 30-50 years would offer an in depth consideration of the true costs for each system.

These impacts were outside the scope of the research project and therefore are considered as a constraint or limitation of the CBA analysis.

5.4 Identify Alternatives

For this CBA analysis it is considered that the two alternatives chosen will be a 'do nothing' and 'proposed' case. The Department of Finance (1991) suggests that a 'do nothing' alternative should always be involved in the CBA analysis process as it identifies the cost of the present situation, which may identify additional requirements for future CBA analysis. Therefore the following alternatives will be considered:-

1. Do Nothing Alternative – continue to supply rural residential developments with a constant flow water supply

    - No additional infrastructure or resources is required

2. Proposed Alternative – supply all rural residential developments with a full pressure water supply.

    - All reticulation mains servicing the rural residential area would need to be increased from the current main diameter to convey the increase of 3-5 litres per minute to 15 litres per second in order to convey the required peak hour demand.

- Additional reservoir(s) constructed to contain the MDMM plus fire fighting storage.

- Additional pumping stations and flow restrictors in order to provide water within the allowable pressure heads between 300-600 kPa.

- Purchase of land to place an additional reservoir within the Regency Downs area to supply the rural residential development.

The above infrastructure requirements will be used to assess the costs of each alternative. The cost of upgrading all reticulated delivery water pipes and the associated supply infrastructure (pumping stations, flow restrictors) within the rural residential area will not be costed, as it is subject to a detailed assessment and subsequent design for the 2940 properties connections that would be affected. This costing was outside the scope of the research project which only included headworks infrastructure such as additional reservoir(s) and trunk mains.

5.5 Identify Costs and Benefits

To identify the costs and benefits of each alternative, a table of costs has been devised outlining each elements cost per year, based on the outcomes of Chapter Four. The overall assessment will be the cost of each proposal for the next 20 years.

As a result of the outcomes of Chapter Four, it can be determined that the present situation of providing constant flow water supply is at a cost to the environment and the economy. The increase of water supply to a full pressure supply acerbates the current costs, therefore it is considered that there are limited benefits with either system. This result is based on the items which were included in the scope of this research project. If further CBA analysis is undertaken including the items outlined in section 5.2, then the result may be altered.

It should be noted that due to the nature the results of Chapter Four and the incentive for this research to be undertaken, the CBA analysis is considered to be mainly cost analysis of the two options. CBA analysis was still considered as an accurate tool to undertake this research, as it provides the basis of putting a dollar value to the cost to the environment, which under normal economic analysis is not considered.

Do Nothing Alternative – continue constant pressure supply

Costs

- Cost of increase in salinity on agriculture due to current excess deep drainage into the ground water table from rural residential developments;

- Reduction in aesthetics of the environment due to degradation of environment; and

- Additional costs to consumer for power and rainwater tank in order to have own storage;

Benefits

- Reduction in water base charge;

- Less headworks infrastructure (reservoirs) required to provide an adequate reticulated supply;

- Reduction in maintenance and operation costs on a per connection basis;

- Reduction in consumer water consumption; and

- Maintains current salinity increase

Proposed Alternative – Increase supply to full pressure.

Costs

- Cost to agriculture due to impact of additional salinity and saline ground water;
- Higher than expected salinity increase. Water consumption may be greater than the estimated full pressure consumption due to reduced 'water wise' behaviours as residents did not have to alter their water consumption in the constant flow area to meet water restriction targets;
- Increased environmental degradation (reduction in aesthetics) due to salt scalding/ waterlogging of the environment;
- Increased costs to residential water consumption and rates notice;
- Increase of all water infrastructure to cater for increase of demand including upgrading of pipes, additional pumping stations, flow restrictor devices;
- Cost of construction for additional reservoir to cater for increase in demand;
- Cost to acquire land to construct reservoir

Benefits

- Perceived infrastructure improvement by consumer.

A summary of the items to be costed in this assessment to be conducted over a period of ten (20) years follows:-

- Benefit/cost of increased infrastructure supply for full pressure;
- Cost of salinity on agriculture for constant flow and full pressure water supply;
- Cost of reduction in aesthetics due to salinity;
- Cost of reservoir and trunk main.
- Cost of additional rainwater tank and pump for constant flow water supply;
- Cost of pump energy used for constant flow and full pressure; and
- Cost of rates for both constant flow and full pressure

These values will be calculated in the preceding section 5.5. It is considered that an assessment of these aspects will fulfil the scope of the study.

5.6 Quantify Costs and Benefits

To quantify the items contained within the section 5.4, the following information is provided to descript how each value was attained. Using these methodologies, the results of the costs can be provided.

Benefit/cost due to increased infrastructure supply

The increase of water supply infrastructure may be welcomed or dismissed by the community for the following reasons.

The increase of supply may be welcomed as ratepayers may believe they are receiving more infrastructure for their rates, however they may be exasperated due to the increase of base water charge and (due to additional consumption) a greater water charge. Also their may be additional disapproval as addition water tanks and pumps which needed to be purchased will be redundant. Ultimately if Council decides to increase water supply based on the recommendations of the cost benefit analysis, then residential surveys should be conducted to obtain whether this aspect is a social cost or benefit.

Cost of reduction is aesthetics due to salinity

Due to the increase in salinity from supplying properties with a full pressure water supply, waterlogging, vegetation cover decline and salt scalds are all salinity related factors which can reduce aesthetics within the Woolshed Creek catchment. Due to the location of the catchment, much of the rural residential development overlooks the Woolshed Creek, as well as motorists passing along the Warrego Highway between Brisbane and Toowoomba all have high exposure to the landscape.

Although this aspect is difficult to determine, it is considered this adds weight to the overall net present cost value and should be taken into consideration when the recommendation is provided to the Lockyer Valley Regional Council.

Agricultural costs of salinity

To determine the agricultural cost of salinity the Australian Government Natural Resource Atlas was consulted, which provided an agricultural cost per EC of increase in ground water for the Murray Darling Basin. Of all the information considered in determining the effect that traditional bed and land application effluent disposal methods, this was considered the most accurate as EC readings of the Lockyer Creek in 1984 and 1994 could be used.

In order to calculate the dollar value of increase for each year, the following methodology was carried out:-

The EC readings for the Lockyer Creek in the region of the intersection with Woolshed Creek for 1984 and 1994 were used to calculate the average EC (dS/m) for 1984 and 1994. These values were obtained from the Salinity Management Scoping Study written by Matt Kunde in July 2001. Using these average values, it was determined that there was an average increase of 0.054 (dS/m) every year for the last ten (10) years. Further data for the last 10 years was not available as advised by the Department of Environmental Resource Management (DERM) as data had been lost through the closure of the Lockyer Catchment Centre. This value is considered to be representative of the current constant flow water supply situation.

Chapter Four concluded that if the existing rural residential developments were converted to full pressure water supply, then there would be a 3.1 times increase in deep drainage to the groundwater table. Therefore it is considered that a conservative estimate of determining the increase in EC levels would be conducted by multiplying the average annual increase in EC levels by 3.1. This resulted in an EC increase to 0.167 dS/m per year. It is acknowledged that this increase in EC is based on assuming that the current increase in EC levels is solely due to rural residential developments, however with the information available, it is considered to be the best information to draw assumptions upon.

From the Australian Government Natural Resource Atlas (2009), it was reported that downstream effects of EC level increase resulted in between $87,000 and $124,000 decline of agricultural profit each year. Considering that this information is based on the Murray Darling Basin which creates a total income of $302 864 for each land holder and the Lockyer/Brisbane River creates a total income of $191824 for each land holder, the dollar value needed to reduced by a multiple of 0.633 in order to reflect the reduction in profit for the Lockyer Valley. Again this was considered to be a conservative estimate and a value of $66 837 was adopted for each rise in EC (1 dS/m) estimated. This resulted in the following approximations

Constant Flow – reduction in agricultural profit per year

$$\$66\,837 * 0.054 = \$\,3475.50 \text{ farm/ year}$$

Full Pressure – reduction in agricultural profit per year

$66837 * 0.145 = $ 11 161.77 farm/ year

Therefore using this methodology, net present value loss in agricultural production over the next twenty years is valued at -$30 979.00 for constant flow water and -$86 396 for full pressure water supply.

Cost of land acquisition

The cost of land acquisition was based on the purchase of a $4000m^2$ allotment in the Regency Downs area. Research of land prices was conducted using Realestate.com where land prices within the locality ranged from $100,00 to $150 000. It is considered that possibly Council could purchase a portion of an existing property, however this option is dependant on owner consent and reconfigure a lot approval through the Laidley Shire Council Planning Scheme. Therefore a price of $110,000 is considered reasonable.

Cost of reservoir an trunk main

To determine the cost of a reservoir and assumed upgrade to a portion of the trunk main to the reservoir in order to store the required quantity of water needed for full pressure water supply, the size of the reservoir needed to be calculated.

Size of reservoir

According to the Queensland Planning Guidelines for Water Supply and Sewerage (QPGWSS), a reservoir needs to accommodate three times the difference between peak day and mean day maximum month flows, plus one peak day demand for break down storage and fire fighting storage. Fire fighting storage for residential areas should be equal to a fire-flow of 15 litres per second for duration of two (2) hours. This can be illustrated by the following equations:-

Operating Storage	= 3 (PD – MDMM)	Equation 5.1
Break Down Storage	= 1 PD	Equation 5.2
Fire fighting Storage	= (15 L/s * 2 hr * 3600) / 1000 kL = 108 kL	Equation 5.3
Total Capacity	= Operating + Breakdown + Fire fighting storage	Equation 5.4

Using the result for consumption in Chapter Four, the full pressure average day (AD) demand was calculated at 344.64 litres per person per day. As there are 2940 water connections at 2.8 persons per connection, there is an assumed average day (AD) consumption of 2.837 ML/day for the study area.

The QPGWSS states that the peak day (PD) demand is calculated at a rate of 1.5 times the AD demand if the population is greater than 5000 persons. Therefore the PD demand is calculated as:-

PD	= 1.5 * AD = 4.255 ML/day	Equation 5.5

The maximum day mean month consumption is calculated at a rate of 1.4 times the AD demand as advised by QPGWSS, hence

MMDM	= 1.4 * AD = 3.971 ML/day

Therefore by using equations 5.1 to 5.4, the total storage required for the current rural residential development can be calculated.

Operating Storage	= 3 (PD – MDMM) = 3 * (4.255 ML – 3.971 ML) = 0.855 ML

Break Down Storage = 1 PD

= 4.255 ML

Fire fighting Storage = (15 L/s * 2 hr * 3600) / 1000 kL

= 108 kL

Total Capacity = Operating + Breakdown + Fire fighting storage

= 0.855 + 4.255 + 0.108

= 5.218 ML

Therefore it is considered that a 5.218ML reservoir would be required.

Reservoir Cost

In 1995, Council commissioned a report through John Wilson and Partners to provide a cost for an additional 5 Megalitre reservoir for the Laidley and Forest Hill Township full pressure water supplies. It is considered that a CPI adjusted estimate for this reservoir provides a good estimate to the cost of a reservoir for the purposes of the CBA analysis. The CPI figures used were obtained from Australian Bureau of Statistics (2009). Based on the estimate completed in 1995, the following estimate is provided:-

Item	Year	
	1995	2008
Establishment	$15,000	$21,217
Site Earthworks	$50,000	$72,256
Foundation preparation	$20,000	$28,902
Supply and place concrete	$220,000	$317,927
Supply and place reinforcement	$85,000	$122,835
Flood joints, bearing strips, water stops and sponge rubber	$25,000	$36,128
Steel roof complete including ladders	$130,000	$187,866
Cast iron and drainage pipe work	$30,000	$43,354
Altitude valve, wiring	$20,000	$28,902
Painting	$13,000	$18,787
Access road	$35,000	$50,579
Landscaping, commissioning,	$10,000	$14,451
300mm diameter inlet main	$63,000	$91,043
375mm outlet main	$83,000	$119,945
sub-total	$799,000	$1,154,653
contingencies	$160,000	$231,220
Preliminary estimate	**$959,000**	**$1,385,873**

Table 5.1 – Updated estimate for 5 ML reservoir completed by John Wilson and Partners using CPI adjustment.

It is considered that this estimate would be applicable to creation of a reservoir in the Regency Downs area as this reservoir was also constructed on the 4000m^2 rural residential allotment of similar elevation and access opportunities. This estimate provided an estimate for a new inlet and outlet main of 300m length. Due to the location of the trunk main providing bulk water supply and the elevations within this area, it is considered that a property along the main would be the best location, and therefore this estimate is considered acceptable.

Cost of pump

To determine the approximate cost of a household pump, an online search resulted in a Davey HP 45-05 pump being selected due to its suitability for residential potable water supply. This pump had a recommended retail price of $ 995.00 (Davey, 2009). Therefore this price was used in the CBA analysis.

Cost of pump energy

To determine the cost of energy which the pump would consume when used in constant flow situations, the following methodology was used.

Using the technical specifications for the Davey HP 45-05 pump, it was determined that the pump input power was 0.77kW. Assuming that the pump would be running for approximately 15 hours a day as a conservative figure, then the pump would have a power input of 11.55 kWh.

Researching the cost of residential power through ORIGIN power (2009) it was considered that the current kilowatt power consumption rate is 0.2112 dollars per kilowatt hour.

Therefore it was determined that the yearly consumption of power from the pump used to supply constant flow water would be $890.36 per year.

Cost of rainwater tank

To determine the cost of a 9000 litre rainwater tank, an online search of Duraplas rainwater tanks determined that an average cost was $1550 (Duraplas, 2009). Therefore this cost was used in the CBA analysis.

Cost of water rates

By evaluating the Practical rates system used by the Lockyer Valley Regional Council, it was found that a property supplied with constant flow water supply has a based charge of $300.00 per year, as a property with full pressure water supply was charged $405.00 per year. These figures were input into the CBA analysis.

Cost of water based on average consumption

Using the average water consumption figures determined in Chapter Four, the average cost of water for constant flow and full pressure water properties were determined at the present rate of $1.30 per kilolitre.

Hence, constant flow water supply was calculated at $224.36 per year and the full pressure water supply at $457.89 per year based on a yearly consumption of 172.585 kL and 352.23 kL per year respectively.

Total Annual Net Costs

Using the above itemised costs, table B1, B2, and B3 in Appendix B depicts the annual net costs to Council, agriculture and the community respectively for the next twenty (20) years. A summary of the result are shown below in table 5.2

Year	Annual Net Costs (Council)		Annual Net Costs (to Agriculture per Farm)		Annual Net Costs (per Dwelling)	
	C/F	F/P	C/F	F/P	C/F	F/P
0	-138,180	-1,728,133	-3,475	-11,161	-3959.72	-862.92
1	-138,180	-232,260	-3,475	-11,161	-1414.72	-862.92
2	-138,180	-232,260	-3,475	-11,161	-1414.72	-862.92
3	-138,180	-232,260	-3,475	-11,161	-1414.72	-862.92
4	-138,180	-232,260	-3,475	-11,161	-1414.72	-862.92
5	-138,180	-232,260	-3,475	-11,161	-1414.72	-862.92
6	-138,180	-232,260	-3,475	-11,161	-1414.72	-862.92
7	-138,180	-232,260	-3,475	-11,161	-1414.72	-862.92
8	-138,180	-232,260	-3,475	-11,161	-1414.72	-862.92
9	-138,180	-232,260	-3,475	-11,161	-1414.72	-862.92
10	-138,180	-232,260	-3,475	-11,161	-1414.72	-862.92
11	-138,180	-232,260	-3,475	-11,161	-1414.72	-862.92
12	-138,180	-232,260	-3,475	-11,161	-1414.72	-862.92
13	-138,180	-232,260	-3,475	-11,161	-1414.72	-862.92
14	-138,180	-232,260	-3,475	-11,161	-1414.72	-862.92
15	-138,180	-232,260	-3,475	-11,161	-1414.72	-862.92
16	-138,180	-232,260	-3,475	-11,161	-1414.72	-862.92
17	-138,180	-232,260	-3,475	-11,161	-1414.72	-862.92
18	-138,180	-232,260	-3,475	-11,161	-1414.72	-862.92
19	-138,180	-232,260	-3,475	-11,161	-1414.72	-862.92
20	-138,180	-232,260	-3,475	-11,161	-1414.72	-862.92

Table 5.2 – Summary of results of cost benefit analysis for the two options over a 20 year period

From the above table of costs, it can be determined that constant flow and full pressure water supply comes at a cost to Council, the environment (with the effect measured by reduction in agriculture) and to the householder. There are no benefits with this assessment as determined by the results of Chapter Four.

5.7 Net Present Value

The net present value is the value which would be applicable if the cost was incurred today, albeit a cost 20 years in the future. This also allows for the alternate project to be assessed equally, as all costs are put in a 'today' cost which allows for easier comparison.

Within the literature review (Chapter Two) discount rates in order to calculate the present net value were discussed. It was recommended that the CBA analysis be undertaken using the methodology set out by the Department of Finance (1991) and the recommended discount rate of 5% be used.

The Department of Finance (1991 pp. 42) describes the discount rate as the exchange rate between the value today and the value in the future. The present value can be calculated using the following equation:-

$$PV = \frac{f}{(1+r)^n} \qquad \text{Equation 5.6}$$

Where

f = actual value of the cost or benefit
r = discount rate
n = number of periods under consideration

Using this formula, the present value of the costs calculated within section 5.5 can be compared. The complete results shown in tables C1, C2 and C3 of Appendix C, with a summary of the results shown below in table 5.3 below.

Flow	Net Present Value		
	Cost to Council	Cost to Agriculture (Salinity)	Cost to the Community
Constant Flow	-$1,231,830.00	-$30,979.00	-$15,156.80
Full Pressure	-$3,566,396.00	-$86,396.00	-$7,692.70

Table5.3 – Summary of net present values for items analysed in CBA.

The principal of CBA is to determine a project based on the net present value of the costs and of the benefits and if the net present value ratio is positive (i.e. the net present value of the benefits outweighs the net present value of the costs) then the project is considered acceptable to proceed.

In the case of this research project, the objectives of determining the costs and benefits of the existing and possible future water supply options were set prior to results of the investigation being set. Once an assessment of the water supply options was undertaken, it was determined that both options are at a cost to council, the environment and the consumer, however one is greater than another. Therefore based on CBA principals and methodologies, neither of the options are considered positive. As the existing water supply option cannot be changed, then an assessment will be based on the less costly of the two options.

From the assessment it can be determined that cost of increasing the water supply of rural residential developments to full pressure comes at a significant cost to Council with an increased cost of $2,334,566.00 over a twenty year period. In addition, the increased water supply will also cost each agricultural farm approximately $68,518.00 over the twenty years in reduced yield due to salinity. The only cost saving is to the consumer (household) who will save approximately $7464.10 over the twenty years due to reduced power consumption and less capital outlay.

To ensure that the results that are obtained are not sensitive to the discount rate, a sensitivity analysis needs to be undertaken to ensure the same results are achieved for an increase discount rate.

5.8 Sensitivity Testing

To determine whether the results are sensitive to a change in discount rate, the Department of Finance (1991) suggests to re-calculate the net present value at 8% to determine whether there is a change in result. Accordingly, the met present value was re calculated and the results follow.

Flow	Net Present Value		
	Cost to Council	Cost to Agriculture (Salinity)	Cost to the Community
Constant Flow	-$778,539.00	-$19,579.00	-$10,515.91
Full Pressure	-$2,804,482.00	-$62,884	-$4861.93

Table 5.4 - Net present value re-calculated using an 8% discount rate.

From the results in table 5.4 it can be determined that the results are not sensitive to the discount rate and the constant flow reticulated water supply still comes at a lower cost to Council and the environment, with a saving still evident to the consumer. Therefore it is considered that the results are still correct.

5.9 Intangibles

It is considered that the impacts of altering the water supply to full pressure on the community as well as the reduction in aesthetics due to the increase of salinity are intangibles within the CBA process. However, due to the outcomes of the cost analysis it is considered that these factors would not alter the outcome, and possibly would further reinforce the outcome.

If the community highly regarded the increase of water supply as a social benefit, it is unlikely that it would be valued greater than the $2,334,566.00 cost difference currently calculated, and therefore would not change the outcome. Therefore it is considered that the intangibles will not have any impact on the outcome of the cost benefit analysis.

5.10 Conclusion

It is considered that during the process of the cost benefit analysis that the most cost effective option is to continue to provide the rural residential developments with a constant flow water supply. The supply of full pressure water supply would come at an additional cost of $2,334,566.00 for Council, and $68518.00 to agricultural yield per farm. Although the constant flow water supply comes at a higher cost to the consumer (ratepayer), it is considered that the consumer has the choice to purchase land with either a full pressure or constant flow supply, and therefore accepts in increase in capital cost. This additional cost only comes to those who build on vacant land, as purchasing an existing dwelling would already have this capital cost accounted for.

Chapter Six

6.0 Conclusions and Recommendations

From the research objectives set out in Chapter One, this research dissertation has concluded upon household water consumption rates for constant flow and full pressure water supply, used the calculated consumption rates and water balance equations to determine the difference in deep drainage for traditional bed and land application effluent disposal systems, related the volume of deep drainage to an increase of dryland salinity evident in ground water supplies and finally determined the cost per water connection of properties dependant on whether they are supplied with full pressure or constant flow water supply.

This information was then used to determine the costs for each system to the Council, environment and the community through a cost benefit analysis. From this assessment it was considered that the most cost effective option is to continue to provide the rural residential developments with a constant flow water supply. The supply of full pressure water supply would come at an additional cost of $2,334,566.00 for Council, and $68518.00 to agricultural yield per farm.

Although the constant flow water supply comes at a higher cost to the consumer (ratepayer), it is considered that the consumer has the choice to purchase land with either a full pressure or constant flow supply, and therefore accepts in increase in capital cost. This additional cost only comes to those who build on vacant land, as purchasing an existing dwelling would already have this capital cost accounted for.

From these conclusions, it is recommended to Council that they continue to supply rural residential developments within the study area with constant flow water supply due to the costs to Council and the environment if full pressure reticulated water is supplied. Also, it is considered that if Council can offset the cost of trunk infrastructure through developer contributions, the cost to the environment and agriculture alone warrants that rural residential developments should not be supplied with additional reticulated water supply.

It is also recommended that due to the outcomes of this research project, that supply of full pressure reticulated water to Gatton's rural residential developments should be re-evaluated and a constant flow supply provided.

Chapter Seven

7.1 Further Research

When undertaking a cost benefit analysis, the cost of undertaking the analysis also needs to be taken into account, and constraints put in place dependant on the time and budget available. For the purposes of advising the Lockyer Valley Council of the costs to Council and the environment of two water supply options, the analysis was constrained to meet the project objectives. Therefore, the following further research opportunities have been devised to further investigate all facets of the cost benefit analysis:-

- Experimentation could occur on both traditional bed systems and land application effluent disposal systems to validate the deep drainage values obtained from the water balance equations;

- An investigation could be undertaken to determine cost of increase in salinity on infrastructure such as roads, bridges, underground services and dwelling constructions;

- A complete re-design and cost estimate of all water reticulation delivery mains within the study area if peak demands of full pressure are to be supplied;

- A cost analysis of converting each existing residential dwelling to full pressure;

- The overall effect on the environment and air quality due to each dwelling pumping water from the on-site tank to the home in the constant flow area, and how this compares to the emissions created from pumping full pressure water supply;

- The environmental degradation caused from the manufacture and distribution of additional rainwater tanks and pumps required for each property. Manufacturing and transport processes cause additional usage of natural resources which comes at a cost to the environment;

- Additional water provided may result in larger amounts of energy used within the home due to excess use of hot water systems, dishwashers etc;

- The nutrient loading of effluent on ground water quality. This may have additional impacts on salinity due to large levels of sodium present as well as concerns due to concentrations of phosphorous and nitrogen;

- Environmental implications further downstream due to the effects of salt and nutrient loadings on Morton Bay;

- The reduction of vegetation cover on carbon emissions within the atmosphere;

- Effects of erosion of creeks and rivers due to exposed soil at great risk of water erosion;

- Social factors such health concerns over reticulated water being stored within a storage device were chorine levels may reduce to levels below health standards and/or effect of community possibly consuming more captured rainwater due to lower town supply;

- Undertake community surveys to determine the community's opinion in regard to their current water supply, and the possibility of having it increased to full pressure at a cost to them. This would provide a 'willingness to pay' aspect of the cost benefit analysis.

- Complete a new headworks infrastructure development charge based on the findings of the additional infrastructure requirements and costs. Developers would need to pay this contribution for each additional equivalent person (EP) created through developments such as reconfigure a lot and material change of use applications. This would be considered a benefit under the cost benefit analysis due to revenue being received which could offset some costs associated with the infrastructure upgrade specific to rural residential areas.

It is considered that the above items are all aspects which could be investigated and supplemented to the cost benefit analysis undertaken in Chapter Five. This would explore further items which make part of a holistic cost benefit analysis, and provided a closer estimate to the ‘true’ cost and benefit of each proposal.

References

1. Atrill, McLaney, Harvey and Jenner, 2006, '*Accounting: An introduction'*, Pearson Education Australia, Australia.

2. Australian Bureau of Statistics, 2006, *'2006 Census QuickStats: Gatton (Urban Centre Locality'*, 8th September 2009, http://www.censusdata.abs.gov.au/ABSNavigation/prenav/ProductSelect?newproducttype=QuickStats&btnSelectProduct=View+QuickStats+%3E&collection=Census&period=2006&areacode=UCL321800&geography=&method=&productlabel=&producttype=&topic=&navmapdisplayed=true&javascript=true&breadcrumb=LP&topholder=0&leftholder=0&currentaction=201&action=401&textversion=false

3. Australian Bureau of Statistics, 2006, *'2006 Census QuickStats: Regency Downs (Laidley Shire)(state Suburb)'*, 8th September 2009, http://www.censusdata.abs.gov.au/ABSNavigation/prenav/ProductSelect?newproducttype=QuickStats&btnSelectProduct=View+QuickStats+%3E&collection=Census&period=2006&areacode=SSC37289&geography=&method=&productlabel=&producttype=&topic=&navmapdisplayed=true&javascript=true&breadcrumb=LP&topholder=0&leftholder=0&currentaction=201&action=401&textversion=false

4. Australian Bureau of Statistics, 2006, *'Consumer Price Index'*, 8th October 2009, http://www.abs.gov.au/AUSSTATS/abs@.nsf/Latestproducts/6401.0Main%20Features6Sep%202009?opendocument&tabname=Summary&prodno=6401.0&issue=Sep%202009&num=&view=

5. Bureau of Meteorology, 2009, '*Average annual, monthly and seasonal evaporation'*, viewed 20th October 2009, http://www.bom.gov.au/jsp/ncc/climate_averages/evaporation/index.jsp

6. Bureau of Meteorology, 2009, *'Average annual, seasonal and monthly rainfall'*, viewed 20th October 2009, http://www.bom.gov.au/jsp/ncc/climate_averages/rainfall/index.jsp

7. Biggs A, Tolmie P & Silbum D, 2006, 'Facts: Land Series: Deep Drainage – a problem or an asset?', viewed 11th May 2009 <http://www.nrw.qld.gov.au/factsheets/pdf/land/l109.pdf>

8. Blocher, Chen & Lin, 2002, '*Cost Management 2e: A Stategic Emphasis*', McGraw Hill, New York.

9. Building Commission Australia, 2009, 'BCA Legislation', viewed 8th September 2009, http://www.buildingcommission.com.au/www/html/725-bca-2005.asp

10. Cary, J, 2008 *'influencing attitudes and changing consumers household water consumption behaviour'*, Vol 8 No 3, pp 325-330.

11. Chadwick A, Morfett J, and Borthwick M, 2004, '*Hydraulics in civil and environmental engineering*', Fourth edition, Spon Press, London.

12. Davey Australia, 2009, *'Davey Water Products'*, viewed 15th September 2009, http://www.davey.com.au/site/DefaultSite/filesystem/documents/datasheets/D944-2%20HP45-05.pdf

13. Department of Finance, 1991, '*Handbook of Cost Benefit Analysis'*, Commonwealth Government Printer, Canberra.

14. Department of Natural Resources and Mines, 2005, 'Planning Guidelines for Water Supply and Sewerage, Department of Natural Resources and Mines, Queensland

15. Davies CM & Dandy GC, 1994, '*A study of residential water demand in Adelaide*', reprint of papers presented to Water Down Under 94, Adelaide Convention Centre, Adelaide 21-25 November 1994 Vol 1.

16. Department of Natural Resources and Water, 2009, '*Annual land valuations*', viewed 11th May 2009, http://www.nrw.qld.gov.au/factsheets/pdf/land/l14.pdf

17. Gardner T, Littleboy M and Beavers P, 1995, *'Using water balance model to assess the hydrological implications of on-site effluent disposal'*, paper presented to 16th AWWA federal Convention, Sydney, April 1995.

18. Gardner T, Geary P, and Gordon I, 1997, *'Ecological sustainability and on-site effluent treatment systems'*, Australian Journal of Environmental Management, Vol 4 pp144-156.

19. Gilpin A, 1996, '*Environmental Impact Assessment'*, Government Printer, Melbourne, pp 35-62.

20. Gordon I, 2006, '*Facts: Land Series: Salinity in Queensland*, viewed 11th May 2009 http://www.nrw.qld.gov.au/factsheets/pdf/land/l51.pdf

21. Gordon I, 2006, '*Facts: Land Series: Impacts and costs of Dryland Salinity*, viewed 11th May 2009 http://www.nrw.qld.gov.au/factsheets/pdf/land/l59.pdf

22. Irvin G, 1978, '*Modern Cost-Benefit Methods – an introduction to financial, economic and social appraisal of development projects*', Macmillian Press Ltd, London

23. Johnson, M & Rix S, 1993,' *Water in Australia: managing economic, environmental and community reform*', Pluto Press Australia, NSW.

24. Kenney S, Goemans C, Klein R, Lowrey J, and Reidy K, 2008, *'Residential Water Demand Management: Lessons From Aurora Colorado'* Vol 44 No. 1 pp 192 – 207.

25. Kunde M, 2001, '*Salinity management Scoping Study – Laidley and Sandy Creek in the Lockyer Catchment under the National Action Plan for Salinity and Water Quality'*, Lockyer catchment Coordinating Committee, Forest Hill.

26. Martens D, 2001, 'Enhancing Nutrient Removal from existing on-site systems', paper presented at the On-site '01 Conference, Armidale, NSW, Australia, 2001

27. Montgomery Watson, 2000, *'Improving water use efficiency in Queensland's urban communities- demand analysis'*, Queensland Department of Natural Resources, Queensland.

28. Pearce, DW, 1983, *'Cost Benefit Analysis'*, second edition, Macmilliam Press Ltd, London.

29. Pigram J, 2006, '*Australia's Water Resources – from use to management'*, CSIRO Publishing, Victoria.

30. Queensland Government, 2009, 'Draft South East Queensland Regional Plan', Department of Infrastructure and Planning, Brisbane

31. Sinden JA & Thampapillai DJ, 1995 *'Introduction to benefit-cost analysis'*, Logman, Melbourne pp178-99.

32. Singer M & Munns D, 2006, *'Soils – An Introduction'*, sixth edition, Pearson Prentice Hall, New Jersey.

33. Shaw, R 2007,'Strategic approach to determining salinity mitigation investment for Woolshed & Plain creek catchments 2007-2012, South East Queensland Catchments, Australia

34. Smith, K 1986, 'A conceptual overview of the foundations of benefit-cost analysis', in JD Bentkover, V Covello & J Mumpower (eds), *Benefits Assessment: the state of the art*, D Reidel Publishing Company, Holland pp 13-34.

35. Standards Australia, 2000, *'Australian and New Zealand Standard 1547:2000 - On-site domestic wastewater management'* Standards Australia, Australia

36. Walshe G & Daffern P, 1990, *'Managing Cost-Benefit Analysis'*, Macmillian Education, London.

37. Water Commission, 2009, '*Water Restrictions'*, viewed 3rd September 2009, http://www.qwc.qld.gov.au/water+restrictions

Appendix A – Project Specification

another copy exists

Appendix A

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project
PROJECT SPECIFICATION

FOR: Nicole Amy Dakers (0050025840)

TOPIC: Cost benefit Analysis for Rural Residential Water Supply – Trickle Feed vs Full Pressure

SUPERVISORS: Mark Porter (USQ)
Jim Barton (LVRC -B.Eng (Civil))
David Kay (LVRC - B.Eng (Civil), GDip Urban & Regional Planning)

ENROLMENT: ENG 4111/2

SPONSORSHIP: Lockyer Valley Regional Council

PROGRAMME: Issue A, 19th March 2009

PROJECT AIM: This project seeks to investigate the true costs and benefits of full pressure water supply and trickle feed water supply on Rural Residential communities and the Environment.

METHODOLOGY/PROJECT TASKS:

1. Research water consumption rates for Rural Residential (i.e. Gatton Rural Residential and Laidley Rural Residential)
2. Research affect of increased water availability on demand.
3. Compare environmental impacts of trickle feed vs full pressure.
4. Collect data in regard to water consumption rates and operational costs
5. Compare headworks infrastructure requirements for trickle feed and full pressure water supply.
6. Undertake a Cost Benefit Analysis of the two proposed options and provide a report to the Lockyer Valley Regional Council

AGREED ____________ (N Dakers) ____________ (Mark Porter)

Date: 9 / 4 / 2009 Date: 9 / 4 / 2009

Assistant Examiner: ____________

21/4/2009 20/04/09

Appendix B – Example of raw data

Laidley Data

ASSESSMENT	Lot_plan	METER	STATUS	READING	CONSUMPTION	Date	Zoning	Area (SQ M)
12335-10000-000	33RP810696	05W800795	Active	0	0	2005	Rural Residential	1073.59
12335-10000-000	33RP810696	05W800795	Active	96	96	2006	Rural Residential	1073.59
12335-10000-000	33RP810696	05W800795	Active	131	35	2007	Rural Residential	1073.59
12335-10000-000	33RP810696	05W800795	Active	134	24	2008	Rural Residential	1073.59
12375-54100-000	43RP845063	02W494887	Active	0	0	2003	Rural Residential	1804.23
12375-54100-000	43RP845063	02W494887	Active	303	303	2004	Rural Residential	1804.23
12375-54100-000	43RP845063	02W494887	Active	58	0	2005	Rural Residential	1804.23
12375-54100-000	43RP845063	02W494887	Active	499	441	2006	Rural Residential	1804.23
12375-54100-000	43RP845063	02W494887	Active	671	172	2007	Rural Residential	1804.23
12375-54100-000	43RP845063	02W494887	Active	719	48	2008	Rural Residential	1804.23
12375-54200-000	42RP845063	01W306698	Active	77	0	2003	Rural Residential	1804.29
12375-54200-000	42RP845063	01W306698	Active	162	85	2004	Rural Residential	1804.29
12375-54200-000	42RP845063	01W306698	Active	115	0	2005	Rural Residential	1804.29
12375-54200-000	42RP845063	01W306698	Active	215	100	2006	Rural Residential	1804.29
12375-54200-000	42RP845063	01W306698	Active	215	0	2007	Rural Residential	1804.29
12375-54200-000	42RP845063	01W306698	Active	215	0	2008	Rural Residential	1804.29
12375-54700-000	37RP845064	05W828250	Active	0	0	2005	Rural Residential	1843.43
12375-54700-000	37RP845064	05W828250	Active	0	0	2006	Rural Residential	1843.43
12375-54700-000	37RP845064	05W828250	Active	30	30	2007	Rural Residential	1843.43
12375-54700-000	37RP845064	05W828250	Active	61	31	2008	Rural Residential	1843.43
13212-50000-000	999RP197707	06W969849	Active	0	0	2007	Rural Residential	1904.54
13212-50000-000	999RP197707	06W969849	Active	0	0	2008	Rural Residential	1904.54
12375-57500-000	12RP838873	05W911347	Active	0	0	2006	Rural Residential	1968.98
12375-57500-000	12RP838873	05W911347	Active	8	8	2007	Rural Residential	1968.98
12375-57500-000	12RP838873	05W911347	Active	39	31	2008	Rural Residential	1968.98
12375-51700-000	45RP845064	03W642859	Active	0	0	2004	Rural Residential	1998.96
12375-51700-000	45RP845064	03W642859	Active	88	88	2005	Rural Residential	1998.96

Gatton Data

23169-04100-000	61SP182255	06W986448	Active	0	2006	0Park Residential	2966.12GSC
23169-04100-000	61SP182255	06W986448	Active	0	2006	0Park Residential	2966.12GSC
23169-04100-000	61SP182255	06W986448	Active	62	2007	62Park Residential	2966.12GSC
23169-04100-000	61SP182255	06W986448	Active	147	2007	85Park Residential	2966.12GSC
23169-04100-000	61SP182255	06W986448	Active	265	2008	118Park Residential	2966.12GSC
23169-04100-000	61SP182255	06W986448	Active	357	2008	92Park Residential	2966.12GSC
23169-04100-000	61SP182255	06W986448	Active	455	2009	98Park Residential	2966.12GSC
22969-09000-000	47SP167572	05W887963	Active	0	2005	0Park Residential	2986.77GSC
22969-09000-000	47SP167572	05W887963	Active	59	2006	58Park Residential	2986.77GSC
22969-09000-000	47SP167572	05W887963	Active	1	2006	1Park Residential	2986.77GSC
22969-09000-000	47SP167572	05W887963	Active	91	2007	32Park Residential	2986.77GSC
22969-09000-000	47SP167572	05W887963	Active	105	2007	14Park Residential	2986.77GSC
22969-09000-000	47SP167572	05W887963	Active	118	2008	13Park Residential	2986.77GSC
22969-09000-000	47SP167572	05W887963	Active	139	2008	21Park Residential	2986.77GSC
22969-09000-000	47SP167572	05W887963	Active	152	2009	13Park Residential	2986.77GSC
22969-80700-000	64SP172581	05W840325	Active	0	2005	0Park Residential	2987.08GSC
22969-80700-000	64SP172581	05W840325	Active	241	2006	228Park Residential	2987.08GSC
22969-80700-000	64SP172581	05W840325	Active	12	2006	12Park Residential	2987.08GSC
22969-80700-000	64SP172581	05W840325	Active	378	2007	137Park Residential	2987.08GSC
22969-80700-000	64SP172581	05W840325	Active	401	2007	23Park Residential	2987.08GSC
22969-80700-000	64SP172581	05W840325	Active	421	2008	20Park Residential	2987.08GSC
22969-80700-000	64SP172581	05W840325	Active	467	2008	46Park Residential	2987.08GSC
22969-80700-000	64SP172581	05W840325	Active	535	2009	68Park Residential	2987.08GSC
22969-81200-000	69SP172581	05W908025	Active	0	2006	0Park Residential	2987.74GSC
22969-81200-000	69SP172581	05W908025	Active	40	2006	40Park Residential	2987.74GSC
22969-81200-000	69SP172581	05W908025	Active	171	2007	131Park Residential	2987.74GSC
22969-81200-000	69SP172581	05W908025	Active	294	2007	123Park Residential	2987.74GSC
22969-81200-000	69SP172581	05W908025	Active	419	2008	125Park Residential	2987.74GSC

Appendix C – Annual Net Cost Tables

- Table B1 – Annual net costs to Council
- Table B2 – Annual net costs to Agriculture
- Table B3 – Annual net costs to Community

Costs to Council										
Year	Cost of Reservoir and trunk main		Cost of land Acquisition		Social cost of reduction in aesthetics		General Operating and Maintenance Cost		Annual Net Benefits	
	C/F	F/P	C/F	F/P	C/F	F/P	C/F	F/P	C/F	F/P
0	n/a	1,385,873	n/a	110,000	u/d	u/d	138,180	232,260	-138,180	-1,728,133
1	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260
2	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260
3	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260
4	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260
5	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260
6	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260
7	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260
8	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260
9	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260
10	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260
11	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260
12	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260
13	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260
14	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260
15	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260
16	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260
17	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260
18	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260
19	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260
20	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260

Table B1 – Annual net costs to Council

Costs to Agriculture due to Salinity (per farm)				
Year	Agricultural Costs from Salinity		Annual Net Benefits	
	C/F	F/P	C/F	F/P
0	3,475	11,161	-3,475	-11,161
1	3,475	11,161	-3,475	-11,161
2	3,475	11,161	-3,475	-11,161
3	3,475	11,161	-3,475	-11,161
4	3,475	11,161	-3,475	-11,161
5	3,475	11,161	-3,475	-11,161
6	3,475	11,161	-3,475	-11,161
7	3,475	11,161	-3,475	-11,161
8	3,475	11,161	-3,475	-11,161
9	3,475	11,161	-3,475	-11,161
10	3,475	11,161	-3,475	-11,161
11	3,475	11,161	-3,475	-11,161
12	3,475	11,161	-3,475	-11,161
13	3,475	11,161	-3,475	-11,161
14	3,475	11,161	-3,475	-11,161
15	3,475	11,161	-3,475	-11,161
16	3,475	11,161	-3,475	-11,161
17	3,475	11,161	-3,475	-11,161
18	3,475	11,161	-3,475	-11,161
19	3,475	11,161	-3,475	-11,161
20	3,475	11,161	-3,475	-11,161

Table B2 – Annual net cost to agriculture

Costs to Community (per Household)													
Year	Cost of Pump		Cost of Pump Energy		Cost of rainwater tank		Cost of water rates		Cost of water consumption based on average consumption per year		Annual Net Benefits	
	C/F	F/P	C/F	F/P	C/F	F/P	C/F	F/P	C/F	F/P	C/F	F/P
0	995	0	890.3664	0	1550	0	300	405	224.3605	457.925	-3959.7269	-862.925
1	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925
2	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925
3	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925
4	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925
5	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925
6	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925
7	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925
8	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925
9	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925
10	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925
11	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925
12	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925
13	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925
14	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925
15	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925
16	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925
17	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925
18	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925
19	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925
20	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925

Table B3 – Annual net costs to community

Appendix D – Net Present Value Tables

- Table B1 – Net present value to Council
- Table B2 – Net present value to Agriculture
- Table B3 – Net present value to Community

Costs to Council														
Year	Cost of Reservoir and trunk main		Cost of land Acquisition		Social cost of reduction in aesthetics		General Operating and Maintenance Cost		Annual Net Benefits		Present Net Value (5%)		Present Net Value (8%)	
	C/F	F/P	C/F	F/P	C/F	F/P	C/F	F/P	C/F	F/P	C/F	F/P	C/F	F/P
0	n/a	1,385,873	n/a	110,000	u/d	u/d	138,180	232,260	-138,180	-1,728,133				
1	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260				
2	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260				
3	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260				
4	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260				
5	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260				
6	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260				
7	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260				
8	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260				
9	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260				
10	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260	-$1,231,830	-$3,566,396	-$778,539	-$2,804,482
11	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260				
12	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260				
13	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260				
14	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260				
15	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260				
16	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260				
17	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260				
18	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260				
19	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260				
20	0	0	0	0	u/d	u/d	138,180	232,260	-138,180	-232,260				

Table C1 – Net present value of costs to Council

Costs to Agriculture due to Salinity (per farm)								
Year	Agricultural Costs from Salinity		Annual Net Benefits		Present Net Value (5%)		Present Net Value (8%)	
	C/F	F/P	C/F	F/P	C/F	F/P	C/F	F/P
0	3,475	9,691	-3,475	-11,161				
1	3,475	9,691	-3,475	-11,161				
2	3,475	9,691	-3,475	-11,161				
3	3,475	9,691	-3,475	-11,161				
4	3,475	9,691	-3,475	-11,161				
5	3,475	9,691	-3,475	-11,161				
6	3,475	9,691	-3,475	-11,161				
7	3,475	9,691	-3,475	-11,161				
8	3,475	9,691	-3,475	-11,161				
9	3,475	9,691	-3,475	-11,161				
10	3,475	9,691	-3,475	-11,161	-30,979	-86,396	-19,579	-62,884
11	3,475	9,691	-3,475	-11,161				
12	3,475	9,691	-3,475	-11,161				
13	3,475	9,691	-3,475	-11,161				
14	3,475	9,691	-3,475	-11,161				
15	3,475	9,691	-3,475	-11,161				
16	3,475	9,691	-3,475	-11,161				
17	3,475	9,691	-3,475	-11,161				
18	3,475	9,691	-3,475	-11,161				
19	3,475	9,691	-3,475	-11,161				
20	3,475	9,691	-3,475	-11,161				

Table C2 – Net present value of costs to agriculture

Costs to Community (per Household)																
Year	Cost of Pump		Cost of Pump Energy		Cost of rainwater tank		Cost of water rates		Cost of water consumption based on average consumption per year		Annual Net Benefits		Present Net Value (5%)		Present Net Value (8%)	
	C/F	F/P	C/F	F/P	C/F	F/P	C/F	F/P	C/F	F/P	C/F	F/P	C/F	F/P	C/F	F/P
0	995	0	890.3664	0	1550	0	300	405	224.3605	457.925	-3959.7269	-862.925				
1	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925				
2	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925				
3	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925				
4	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925				
5	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925				
6	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925				
7	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925				
8	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925				
9	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925				
10	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925	-15156.84	-7692.70	-10515.91	-4861.93
11	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925				
12	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925				
13	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925				
14	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925				
15	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925				
16	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925				
17	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925				
18	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925				
19	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925				
20	0	0	890.3664	0	0	0	300	405	224.3605	457.925	-1414.7269	-862.925				

Table C3 – Net present value of costs to the community.