University of Southern Queensland

Faculty of Health, Engineering and Sciences

VALUE RISK MATRIX FOR WATER SOURCE SELECTION FOR DALBY QLD

A dissertation submitted by

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Submitted to fulfil the requirements of

ENG4112 & ENG4112 Research Project

towards the degree of

Bachelor of Engineering (Honours) (Civil)

Submitted: 15th of October, 2023

Abstract

WDRC has expressed interest in the investigation of water source selection and operational cost analysis within the Dalby region. With the increasing costs throughout the industry, including increase in labour/operator hourly rates, increasing in costs for electricity, chemicals for appropriate treatment, and Council overheads, this project aims to optimise the strategy for water source development to achieve a reliable, cost effective potable water supply for Dalby QLD.

To achieve this aim, the key objectives of this report are to:

1. To develop an evaluation method by which the water source development can be optimised.
2. Access the current cost, and current/future risks of water supply for Dalby.
3. Make a recommendation for future planning upgrade considerations for Dalby's water supply.

The findings quantify water source selection through the use of creating an evaluation method built in the form of a value risk matrix. An operational cost analysis was completed on each available water source and incorporated into the value risk matrix.

This project has identified that the 'A' level alluvium bores present the most favoured water source from a value to risk consideration from the evaluation tool created. However the 'A' level bore source alone can't solely meet the average daily demand of 4.58 ML/day. In combination with another source, this source combination ultimately becomes the most favoured source combination due to the low value and risk scores associated with the 'A' level bore source. In lower turbidity conditions, from 20 NTU to 100 NTU the Loudoun Weir in combination with 'A' level bores becomes the most preferred option. However as the turbidity increases in the Loudoun Weir beyond the 100 NTU level, so does the value score associated with this source making 'B' level bores in combination with 'A' level bores the preferred source combination. Based on the results suggesting that Loudoun Weir should be more utilised in lower turbidity conditions (0-100 NTU range) and on current infrastructure conditions, an upgrade to Dalby's surface water treatment plant is recommended be undertaken.

Based on historic operation approach to Dalby's water source prioritisation generally supporting the results of the evaluation method created in the form of a value risk matrix, this evaluation tool would be beneficial to be as a guide in short to medium term water source selection (one to three months).

Overall, the research project has provided valuable insight to the Western Downs Regional Council providing evidence in assisting with signifying which water source should be prioritised and utilised available for Dalby's water supply. The project has provided an operation strategy based on value and risk. While this report does focus specifically on water treatment operations in the Western Downs area, similar results would be expected to be achieved in similar situations for other drinking water service providers.

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Dated: 15/10/2023

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Acknowledgements

I would like to thank my supervisor, Justine Baillie, for her guidance and support throughout the completion of this dissertation.

I would also like to extend a big thank you to Western Downs Regional Council for providing the information this analysis is based on. The assistance from staff has provided myself an invaluable sound board for ideas and direction for this research dissertation.

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Acronyms

Below are definitions of technical terms and abbreviations used in this report:

- CVM - Contingent Valuation Methodology
- DRDMW - Department of Regional Development, Manufacturing, and Water (DRDMW) which was previously known as the Department of Environmental and resource management
- DWQMP - Drinking Water Quality Management Plan
- E. coli - Escherichia coli
- EPA - Environmental Protection Agency
- GAB - Great Artesian Basin
- NTU - Nephelometric Turbidity Unit
- RO - Reverse Osmosis
- SCADA - Supervisory Control and Data Acquisition
- TDS - Total Dissolved Solids
- THMs - Trihalomethanes
- WDRC - Western Downs Regional Council
- WTP - Water Treatment Plant

1. Introduction

1.1. Context

Western Downs Regional Council (WDRC) manages numerous reticulated townships ranging in size over a widespread area. Fundamentally there are 2 main sources of water which WDRC utilise throughout the region being surface water and groundwater from bore of varying underground aquifers.

The Dalby town water supply has historically relied upon shallow groundwater resources from the upper Condamine 'A' level alluvium for most of the supply needs, with the Loudoun Weir on the Condamine River being used as a peak demand and backup/emergency supply.

WDRC has expressed interest in the investigation of surface water vs groundwater treatment cost analysis within the Dalby region. With the increasing costs throughout the industry, including increase in labour/operator hourly rates, increasing in costs for electricity, and chemicals for appropriate treatment, and Council overheads, this project aims to optimise the strategy for water source development to achieve a reliable, cost effective potable water supply for Dalby QLD.

1.2. Problem Statement

WDRC has expressed interest in the investigation of surface water vs groundwater treatment cost analysis within the Dalby region. With the increasing costs throughout the industry, including increase in labour/operator hourly rates, increasing in costs for electricity, and chemicals for appropriate treatment, and Council overheads, the following objectives are sought from this research project:

- Review the minimum standard of treatment for potable drinking water for a service provider;
- Review any prior/existing studies completed in this area;
- Review WDRC's treatment standard, to gain an understanding on the level of treatment/operation/service provided for cost;
- Operational cost analysis on the historic/current data available from WDRC;
- Review of results and recommendations.

WDRC has suggested that the cost of treating surface water compared to bore water has historically been considered to be similar value, however this has not been analysed in detail (Fagg, T 2023, pers. comm, 14 July). The surface water from the Loudoun Weir on the Condamine River has historically been used for treatment/supply to offset peak demand which usually occurs in times of above average consumption in the town of Dalby. The surface water has also been relied on as backup/emergency supply intime when there may be scheduled maintenance or breakdowns of the RO's (bore water supply). Therefore, the underground (bore) water has been relied on for average daily demand of Dalby in the last 20-30 years of operation. The underground (bore) water is noted to be more reliable source hence why in more recent times there has been a focus on any new capital infrastructure to be invested utilising underground aquifers. A review of this from an operational cost, flow, and water quality to risk analysis would be beneficial not only to WDRC but also to other drinking water service providers in similar operating conditions and similar available water sources.

1.3. Project Aim and Objectives

This project aims to optimise the strategy for water source development to achieve a reliable, cost effective potable water supply for Dalby QLD.

To achieve this aim, the key objectives of this report are to:

1. To develop an evaluation method by which the water source development can be optimised.
2. Access the current cost, and current/future risks of water supply for Dalby.
3. Make a recommendation for future planning upgrade considerations for Dalby's water supply

1.4. Overview of Dissertation

Overall, the dissertation investigates Dalby's water supply sources to optimise the water source development by investigating value and risk of the different source scenarios. Chapter two provides a background on Dalby's water supply including consumption, demand capacity, location and seasonal rainfall. Chapter three completes a literature review investigating existing studies and research in water resource management, decision making, different evaluation methods including decision value risk matrix. Chapter four investigates the methodology where a value risk matrix was selected as an evaluation method due to its ability to prioritise and visualise decisions, and its flexibility to adapt to the value/risks required to make an inform decision. Chapter 5 reviews the results comparing different demand scenarios and how sensitive the value risk matrix is based on user input. A discussion of result, conclusion, recommendations for further work were also presented.

2. Background

2.1. History of Dalby Water Supply

2.1.1. Dalby Water Supply Overview

Western Downs Regional Council (WDRC) manages numerous reticulated townships ranging in size over a widespread area. Fundamentally there are 2 main sources of water which WDRC utilise throughout the region:

- Surface Water
- Groundwater/ (Bore water)

The Dalby town water supply has historically relied upon shallow groundwater resources from the upper Condamine "A" level alluvium for most of the supply needs, with the Loudoun Weir on the Condamine River being used as a peak demand and backup/emergency supply.

The Dalby water supply system includes 13 alluvium "A"/"B" bores, 1 Great Artesian Basin (GAB) bore (treatment process for bore currently being designed), 1 weir (Loudoun Weir), a conventional water treatment plant, 3 desalination plants, 8.5km of rising main, 14.32km of bore lines, 144.675 kms of distribution mains, 2 low level reservoirs, and 2 elevated reservoirs (water towers).

The surface water treatment comprises flocculation, sedimentation, filtration, pH correction, fluoridation, and disinfection. The treatment process for "B" level sub artesian water comprises multimedia filtration, cartridge filtration, 2 stage reverse osmosis, aeration and pH correction. The "A" level alluvium bore water requires no treatment. All water is disinfected with chlorine and is normally fluoridated prior to pumping to the low-level reservoirs.

2.1.2. Consumption and Capacity

The Loudoun Weir has the capacity to extract up to 6ML/day. The "A" alluvium bores can supply up to a total of approximately 2ML/day, "B" alluvium bores can produce up to approximately 4ML/day, which is 2ML/day through both RO1 and RO2. RO3 can produce up to 0.5ML/day treating the concentrate water from both RO1 and RO2.

Council has an annual allocation of 650ML from the Condamine River as well as an annual allocation of 2,700ML form groundwater. The scheme services a population of about 10,000 residents. The average daily consumption is approximately 4.58ML/day (PPK, 1999/2000).

2.1.3. Location and Rainfall

The town of Dalby situated approximately 180km west of the South Pacific Ocean within Queensland. It has a population of 12,758 (ABS, 2021) from 2021 census and is approximately 347m above the mean sea level. The topography of the town and it's surrounds I extremely flat. The edge of its catchment is the Great Dividing Range at 650m. The plains which surround Dalby slope approximately 0.5m per kilometre to the North-west direction as indicated by the flow of the Condamine River. Dalby typical climatic zone based on temperature and humidity is considered a hot dry summers, with cold winters (Commonwealth of Australia 2022).

Dalby's rainfall is typically bears a wetter summer with thunderstorms being a high source of rainfall. Winter typically provides low rainfall within the region/catchment area. The below figure from the Bureau of Meteorology demonstrates the Australian seasonal rainfall average as represented in the below zones:

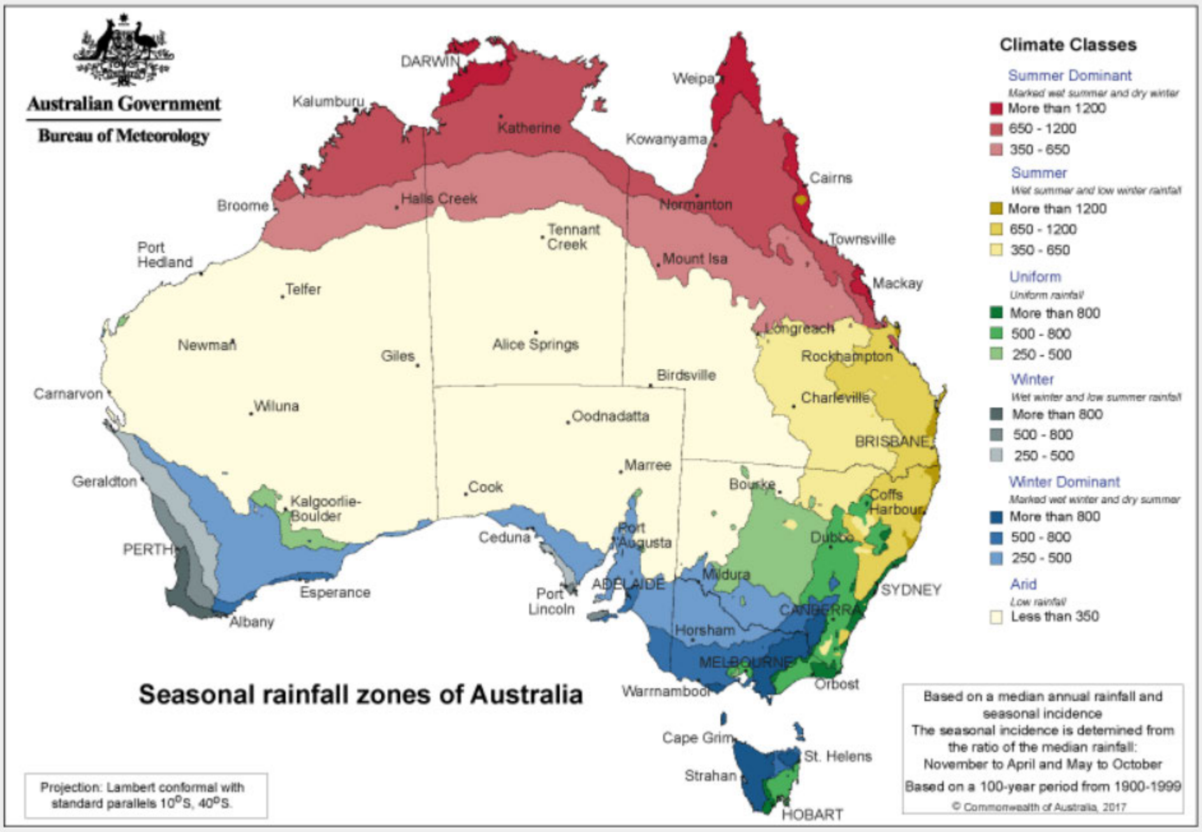

Figure 2.1: *Seasonal Rainfall Zones of Australia (Seasonal Rainfall - all zones, Climate Classification Maps, Australian Government Bureau of Meteorology).*

2.1.4. Identification and Assessment of Options

Previously there has been a requirement to investigate new sources of raw water to replace the existing bore water supply and meet increasing demands. In 1999/2000 PPK reviewed possible supply options for Dalby and detailed these in the report "Dalby Raw Water Source Options Study-Part B Options Report" April 2000. This report identified the following 15 potential raw water sources:

1. Increase usage of existing Loudoun Weir;
2. Raise the existing Loudoun Weir;
3. Construct a new weir on the Condamine River;
4. Carry out flood harvesting from the Condamine River;
5. Construct additional bores into shallow (Layer A) Condamine Alluvium;

6. Construct additional bores into lower-level Condamine Alluvium (Layers B and C);
7. Construct Hutton Sandstone bores;
8. Construct Precipice Sandstone bores;
9. Construct a new storage on Myall Creek North Branch;
10. Carry out flood harvesting from Myall Creek;
11. Carry out overland flow harvesting;
12. Carry out stormwater recycling;
13. Carry out effluent recycling;
14. Construct a potable water pipeline from Oakey; and
15. Install rainwater tanks.

2.1.5. Demand Management Strategies

A Water Wise program was developed in 2001-2002 between council and the WaterWise Unit of Environmental Protection Agency (EPA) - Sustainable industries Division. From this program Council implemented a number of measures to attempt to reduce water demand within Dalby. A study by Montgomery Watson (Improving Water Efficiency in Queensland's Urban Community Nov,2000) indicates that due to the implementation of user pays metering programs and demand management strategies there is difficulty in separating the decreases in demand. The report suggested that demand management strategies could account for approximately 10 percent of the decreases in demands observed.

2.1.6. Dalby's Current Water Supply Strategy

It is Dalby's current strategy of investigating Hutton bores and continued development of Dalby's GAB bore system. WDRC is also in the process of replacing the single rising main from the existing Dalby WTP into Dalby. To provide some redundancy in times floods, etc it is planned that any Gab and Hutton Bores constructed be flows are transferred and treated at new proposed WTP at a separate flood proof position closer to Dalby. The proposed WTP will require additional evaporation ponds, additional low level treated storage capacity and additional pipelines installed to link to the existing potable water network and existing low level reservoirs and high service pumpstation.

2.1.7. Legislation/ Statutory Obligations

Under the Water Supply (Safety and Reliability) Act 2008, a water service includes but no limited to the following:

- Water collection or harvesting, which includes bores, dams, weirs, and/or direct extraction from watercourses);
- The Water Treatment and recycling.

To gain an understanding on the minimum level of service required in Queensland, the following legislative standards has been identified to assist service providers:

- Water Act 2000
- Water Supply (Safety and reliability Act 2008
- South-East Queensland water (Restructuring) Act 2007

2.2. Australian Drinking Water Quality Guidelines

The National Health and Medical Research Council Australian Drinking Water Quality Guidelines (ADWG) are concerned with aesthetic quality and safety of drinking water consumers in Australia. Drinking water is required to be safe to drink for people and contain no harmful concentrations of chemicals or pathogenic microorganisms. Aesthetics is also a consideration as water should be pleasing regarding appearance, odour, and taste.

There are mainly 2 different types of guideline values used in the ADWG (NHMRC, NRMMC 2011):

- Health related guideline value;
- Aesthetic guideline value;

Page 176 provides a summary of the guideline values for microbial, chemical, and physical and characteristics table 10.6, extract below of some common characteristics:

Table 2.1: *Extract from ADWG Table 10.6.*

	Guideline values (mg/L unless otherwise specified		
Characteristic	**Health**	**Aesthetic**	**Comments**
Chlorine	5	0.6	Widely used to disinfect water, and this can produce (free) chlorinated organic by-products. Odour threshold generally 0.6 mg/L, but 0.2 mg/L for a few people. In some supplies it may be necessary to exceed the aesthetic guideline in order to maintain an effective disinfectant residual throughout the system.
Fluoride	1.5		Occurs naturally in some water from fluoride-containing rocks. Often added at up to 1 mg/L to protect against dental caries. >1.5 mg/L can cause dental fluorosis. >4 mg/L can cause skeletal fluorosis.

2.3. Drinking Water Quality Management Plan

WDRC's Drinking Water Quality Management Plan (DWQMP) has also been reviewed in this research project as it is a requirement on WDRC as a service provider by the Department of Regional Development, manufacturing and Water (DRDMW). The DWQMP structure a risk-based approach to water quality, including a minimum required water quality at different defined monitoring points within a system (Sinclair Knight Merz 2011). The DWQMP is to assist WDRC as a service provider to meet its statutory obligations under the Water Supply Safety and Reliability Act 2008, in ensuring that the water supplied to customers form schemes listed as drinking water supplies are safe for use. The DWQMP addresses the following:

- Define the performance objectives of the systems;
- Provide guidance to staff on the maintenance of water quality within the system;
- Provides a pathway for system improvements based on priority and risk;
- Formalises informal systems;
- Provides a framework to manage the system from source to customer, including incidents and emergencies;
- Maintains a standard of testing that allows a high degree of confidence in the performance of the systems and WDRC as a service provider.

The DWQMP contains a Drinking Water Quality Incident Protocol which provides response guidelines for water quality incidents based on different threat levels to customers. An incident can be an event of series of events that has the potential to compromise the ability to adequately treat of provide drinking water (WDRC, 2020). A drinking water incident includes but not limited to the following:

- Detection of E. coli;
- Detection of a pathogen;
- Water containing fluoride at a concentration greater than 1.5mg/L being supplied to or potentially being supplied to customers;
- Detection of parameter in treated water that does not meet a health guideline values in the ADWG;
- Detection of radiological substance that exceeds gross alpha and gross beta screening values in the ADWG;
- Detection of parameter for which there is no guideline value in the ADWG.

The following are potential events which may trigger a Drinking Water Quality incident:

- Prolonged water outage;
- Power outage;
- Disinfection equipment failure;
- Treatment plant equipment failure;
- Loss of SCADA or other automated control systems;
- Pump failures;
- Severe weather, storms, floods, drought, etc;

Reliable, accurate and timely information is vital to effective decision making. Every decision is a risk-taking judgement (Drucker P.F 1967), however information helps give a value to potential future alternative scenarios of what could happen. Therefore, the criticality of reliable information sources is fundamental to producing the most effective/beneficial outcomes.

2.4. Implications of Project

If successful, this project is expected to have the following implications for WDRC, and other council's, utility providers, and authorities of similar conditions:

- Provide evidence in assisting with signifying which water source should be prioritized/utilised if/when available for potable supply;
- Potential reduction in cost for the treatment of potable water for Dalby's town water supply;
- To aid in scheduling a future maintenance program in which water treatment assets should be maintained as a priority, to minimise treatment costs;
- Aid in future planning of existing/future infrastructure upgrades/replacements in the future, i.e. possible surface water plant upgrade based on value and risk.
- Provide an operating strategy based on value and risk

While this report does focus specifically on water treatment operations in the Western Downs area, it is expected similar results would be achieved in similar situations. The conclusions from this research project will likely to be considered and potentially utilised by WDRC. The results could better inform water authorities and could potentially in turn help with the treatment and operation of the Dalby Water Treatment Plant in providing a strategy on value and risk with recommendations on a possible surface water upgrade based on value and risk.

3. Literature Review

3.1. Existing Studies/ Research of Topic

Over the world there have been numerous studies which have been previously undertaken, within the water resource management and decision making areas. This dissertation reviews the relevant literature applicable to provide a thorough understanding which is essential for informed decisions on water resource management and evaluation method analysis.

3.2. Water Resource Management

Water resource management deals with the efficient integration of water and energy resources to tackle a wide range of optimisation, operation potential design issues for systems involving both water and energy. Optimising water supply systems ensures sustainability of the water supply for increasing water demand, but also diminishes water related energy and environmental concerns (MDPI, 2020).

Water resource management objectives include:

- Minimise water consumption (demand);
- Wastewater/concentration production;
- Energy consumption;
- Operational costs;
- Capital costs;
- Renewable energy sources to offset energy used in treatment;
- Risk management.

However there are a number of factors which contribute to water resource management including the following:

- Demand
- Reliability/Sustainability
- External Considerations
- Risk Management

3.2.1. Demand

The demand for water supply is relatively complex and it has different meanings for different roles or perspectives. Because of the differing perspectives, different approaches to demand assessment can be considered.

For example, typically an engineer's concern is around the amount of water needed to supply a population. Engineers typically collect data on existing consumption patterns, types/number of facilities, the level of service in use, operation and maintenance provision, and the potential demand for future upgrades of infrastructure.

However, from an economic/business owners' perspective the main concern is the willingness to pay for a particular level of service. This involves the collection of financial and economic data on different levels of service, and could include household income, any revenue generated, subsidies available, household expenditure, etc.

The perspective from a social perspective typically considerations include accessing the priority and needs of specific groups, potential user conflicts and cultural beliefs/practices. This includes basically the human rights or needs regarding poverty, empowerment, equity in all groups within the community.

There is a direct correlation between temperature and demand of human consumption at a town level. Typically during the summer months of the year with an increase in temperature, there is an increase in water consumption. Human water consumption is higher, along with increased amounts of water used for gardening and grassed lawns. The below figure from the Bureau of Meteorology demonstrates the Australian Climate temperature and humidity as represented in the below zones:

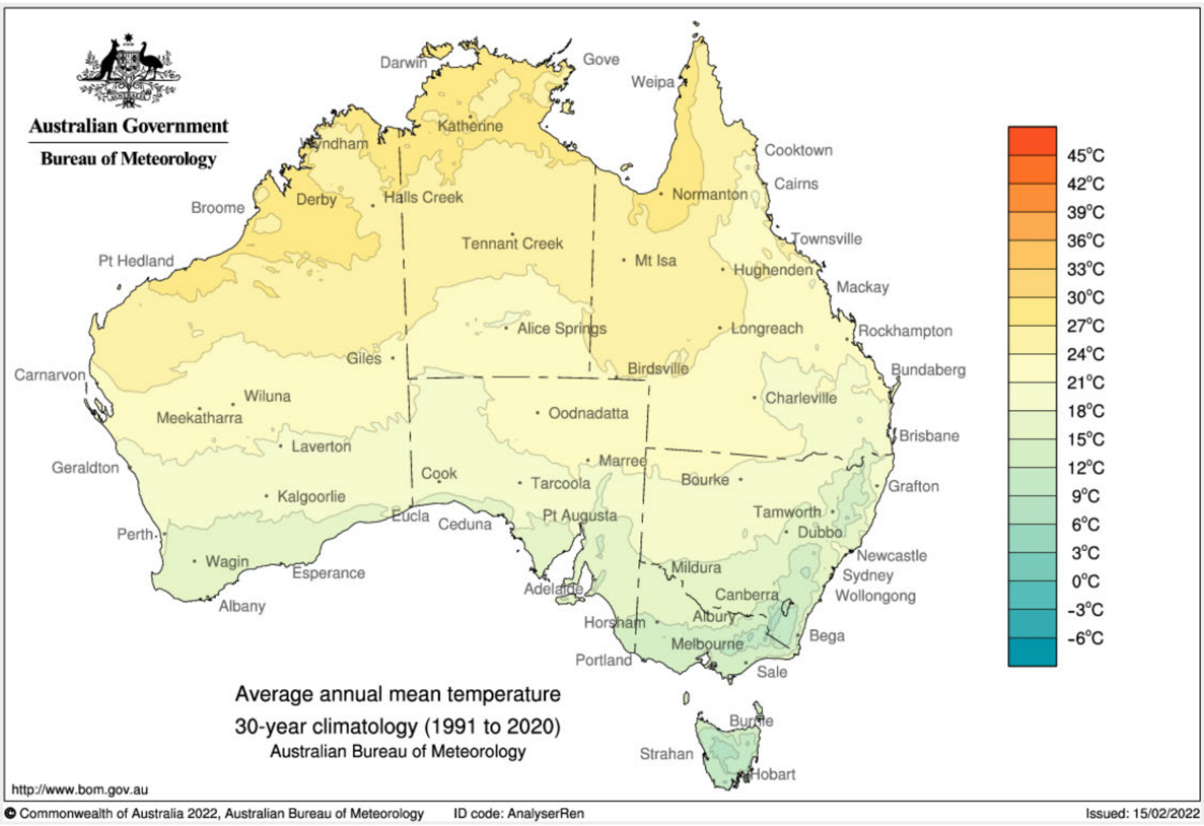

Figure 3.1: *Average Annual Mean Temperature Map (Mean Temperature, Annual Temperature Maps Australian Government Bureau of Meteorology).*

3.2.2. Reliability/Sustainability

The reliability of bore and surface water sources requires consideration in water resource management. Quite often bore water is limited by the available water you can pump from the bore, and this is often dictated by the reliability of the production layer of the target aquifer. The construction of the bores also can come into play regarding the available flowrates from the target aquifer and consideration the friction loss and recharge rates of a bore under use. There are many complexities present around flow rates, therefore blending bore water to surface water quite often is suitable, reliability, location, license allocation and cost to install infrastructure are all factors to consider in water source/treatment options.

The treatment and plant design also requires considerations in the current/future reliability considerations around using different source water. One major factor is dealing with the wastewater/concentrate, and reliability is often directly linked to the available surface/area of land available for evaporation ponds to manage the waste/concentrate water. Sizing criteria aligning the pond filling and dewater over the same life span of the liner (20 years) often is a factor. A lot of the liners for evaporation are only guaranteeing 20 years, considering the higher conductivity of the concentrate waste, and as the salt load goes up the effectiveness of the evaporation ponds goes down.

Reliable operation at higher demand requirements requires increased base load, and often the price considerations for treatment becomes less important. If there is a suitable source availability to a council and additional base load, they may want to attract industry and economic benefits the community they serve. But peak loading also needs to be considered, whether the peak loading sources are reliable and sustainably able to meet increased demands on the high peak loading of a day or increased averages during a year above average of the annual base load requirements. Designing a plant can designed on peak loading to supply large amounts of water over short periods of time. Other option is more around a base load and rely on another source or a suitable sized storage which can also provide offset the peak load and act as a buffer.

One factor to consider in the design to evaluate the reliability and sustainability of a source is the Pilot plant testing experimenting treatment of water at a lower scale mimicking a large scale treatment plant for the source water. One constraint is time to test the reliability in the production testing and pilot plant testing stage. For pump testing is common to complete a 100 hour pump test of a newly developed bore to assess the expect long term flow rates by assessing the draw down level of the bore water by slowly increasing the flow rate of the pump over a period of time. Regarding pilot plant testing at a minimum, it is recommended would want 6 weeks continued operation with no issues. So, therefore the process around pilot plant testing typically takes a minimum of 3 months, and if there are complexities and the chemistry of the water is complex, then pilot plant testing could realistically extend to 6 months for each bore quite easily.

3.2.3. External Considerations

Environmental and social impacts/consideration are just a couple of potential impacts on water source management. Environmental impacts may be simply when there is no water in the river due potentially due to no rainfall, drought period, irrigation farms extracting out of the river, there is no longer any water in the river to sustain any wildlife/ fish/ plants, a healthy ecosystem along the river and river edge.

Having no water in the river could have a negative impacts to Council as it could be perceived from the public that WDRC have pumped the river dry, and therefore affect the liveability/ recreational activity which, whether that be fishing, skying, etc in the river water. A minimum pumping needs to be established whether that low level height is close to 20% so that there can still be some water in the river for environmental considerations, maintain life/healthy ecosystem in the river, potentially also for stock watering which the stock farmers would appreciate. The existing raw water pumpstation on the Loudoun Weir cannot assess the full capacity of the Condamine River, with the pump station being affected by silt sedimentation. The desilting of the pumpstation ideally occurs during a drought period when the Condamine river is drained/ dry enough for this maintenance works to occur. Last time this maintenance works occurred in 2018, where an excavator was lowered into the river to remove some sedimentation around the pumpstation and to increase the available water to the pump station.

3.2.4. Risk Management

Risk management involves assessment, comparison, design mitigation strategies of avoiding, reducing and transferring identified risks. While some risks may be assessed from different data sources with varying degrees of reliability, the main emphasis is on prioritising issues to suggest action strategies (Palgrave Macmillan 2021).

Risk Analysis is a process for identifying what is likely to go wrong and estimating how serious the effect may be. A risk assessment is the product of two estimates:

1. The probability/likelihood of failure (Pf)
2. The consequences of failure (Cf)

Risk = Pf x Cf

Risk in relation to water source management can be defined as the probability and the concept of referring to event with very small or higher likelihood of occurring, and being able to quantifying this.

When answering questions in the value/risk assessment of contracts about risk, use the table below to identify whether a risk is low, medium or high based on likelihood of the risk arising, and consequences if it does.

(Or you can refer to your organisations risk assessment framework to answer the question about whether the risk is classified low, medium or high)

		Consequence		
		Minor	Moderate	Major
Likelihood	Likely	Medium Risk	High Risk	High Risk
	Possible	Low Risk	Medium Risk	High Risk
	Unlikely	Low Risk	Low Risk	Medium Risk

Figure 3.2: *Value/Risk Matrix assessment guide to access contract types for procurement of goods and services (State QLD, 2020).*

Figure 3.2 is an example of an assessment of risk from the Queensland Government based off likelihood and consequence, where a risk value outcome is determined on 3 category rating determined to be a range from Low, medium, and high risk. The simplicity of the 3 category selection is an advantage, however the disadvantage is that there are limited available rating results determined.

Appendix B "Table 1" provides a typical Project Risk Matrix which was used to assess the potential risks associated with the research project to ensure that the project is undertaken in a safe manner. As compared to the Queensland Government Procurement risk matrix the example project risk matrix outcome risk values is determined on 4 category rating from low, medium, high, extreme, from 5 category selections. The advantage with having more categories to assess the likelihood and consequence is that having more selection values typically provides more precise risk outcome. However the disadvantage of having more selection category ratings is that it adds more complexity to the matrix and potentially taking longer to assess a risk.

Table 3.1 is an extract from Appendix B Table 2: Risk/Hazard Management Plan conducted for the proposed research project provided below as an example of performing a risk assessment. Firstly, any potential risks are identified, the initial likelihood and Consequence is assessed by the assessor with the outcome recorded using the risk assessment matrix table. A mitigation method is proposed by the assessor and then the likelihood and consequence is again recorded assessed and the outcome recorded. If the appropriate mitigation method is selected there would typically be a reduction of the outcome risk inherit by the potential risk, and if the outcome risk inherent is reduced appropriately then the mitigation method is adopted and reviewed once in action to confirm that it is working suitably as per the original plan.

The advantage of a risk assessment in this method is that it can be performed as many times and as required, either by one or many users and is visually logged so it can be kept recorded for any employees, workers, and/or potential safety officer which may review the risk mitigation procedures taken place.

Table 3.1: *Extract from Appendix B Table 2: Risk/Hazard Management Plan conducted for the proposed project.*

Potential Risk	Likelihood	Consequence	Outcome	Mitigation Method	Likelihood	Consequence	Outcome
Approval of Project declined	Possible	Major	High	Approval of Project applied for early, and discussion with the proposal with Supervisor at earliest convenience.	Unlikely	Moderate	Medium

3.3. Decision Making

This project aims to optimise the strategy for water source development to achieve a reliable, cost effective potable water supply for Dalby QLD. Therefore decision making is important in achieving this aim. There are a number of existing methods which can be used to in decision making and as mentioned in this section. Decision making controls the progress an activity or process. Decision making affects resources in term of water resource management, this could be different water sources, time, and technologies available to perform the activities. A decision defines the activities to take place, what is to be done, how, why and who might complete a task at hand. Decision making can be defined as the process of selecting an alternative that performs the best based on various attributes/performance measures or goals. To benefit the opportunities and to be able to deal with value and risk, a robust decision making process in important.

Quantitative analysis can be used in decision making by providing a more objective and data driven approach to the decisions. Quantitative analysis allows an evaluation and comparison of different options based on benefits and risks. It can be used to make optimised decisions in water resource management by providing a systematic and objective approach.

There are two general qualitative analysis approaches to decision making, management and planning (Daniel P. Loucks, 2017):

1. Top-Down Decision Making, Management and Planning - Creating a preferred master Plan to manage the system/water resource. Less desirable if participation is required from public, planning and management activities.
2. Bottom-Up Decision Making, Planning and Management - Where there is active participation from interested stakeholders, and those potentially affected by the decision are being

considered. This process is consensus building, where different professional, agencies and organisations are working together towards an adaptive water management program/policy/plan.

3.3.1. Evaluation Methods/Models

In terms of decision making context different evaluation methods can play critical role. An evaluation method assists in selecting and shortlisting, and choosing the most favoured option in a particular scenario. Decision makers can make more suitable decisions by using both qualitative and quantitative analysis.

3.3.1.1. Contingent Valuation Method

The Contingent Valuation Methodology (CVM) is a method of estimating the value that a person places on a good (FAO 2000). The approach generally requires asking the people directly through the use of surveys' and community engagement consultation assessing their willingness to pay, or the willingness to accept a goods. This method has been typically used successfully dealing with public goods such including water supply, quality, quantity and reliability. It has also been used to estimate the willingness to pay for reductions in risk of illness typically associated with drinking water in developing countries.

Some examples of the Contingent Valuation Method being used and factors to consider:

- Comparing the difference of willingness to pay for water over different water supply options. The difference to a reticulated piped water network with a metered service to the costumer and a private trucked delivery water vending system.
- Other factors include interviews with customers uncovered significant difference in water consumption between rainy season and the dry season, and monopoly rents to the owners of the truck delivery service (who effectively prevented potential competitors from entering the market). Resident were actually paying a lot or water as it was found poor households paid up to 18 percent of their income on water, while wealthy households paid 2-3 percent of their income on water. This could infer that there is indeed a potential increase the willingness to pay for water in the Dalby region.
- To summarise what was found from (FAO 2000). found varying levels of willingness to pay for improved water supply. Factors varying the willingness to pay included:
    - The cost of obtaining water from alternative sources;
    - Individuals income;
    - Education;

- The expectations based on cultural/environmental the individual was likely to form around the reliability and quality of the service provided;
- Income stream and the individuals ability to commit to payments on regular intervals;
- Environmental factors, reduce pollutant and improve WWTP standards;

3.3.1.2. Choice Experiment Method

Choice experimental methods involves the valuation based on different preferences (Adamowicz, W.L. 1996). This method involves presenting the individual with a single scenario involving the provision different levels of options/attributes at different cost implications. An example of an option includes "do nothing", or several pairs of containing various combinations of cost, policies or good attributes. One advantage to the choice experimental method is that it encourages the respondent to concentrate on the trade-off between characteristics of the good or public options, as opposed to focusing negatively or against the problem at hand. This method also allows the evaluation of different scenarios/conditions which may or may not have historically occurred/existed.

3.3.1.3. Contingent Behaviour Method

Contingent behaviour method involves asking individuals what would do under specified hypothetical circumstances (FAO 2000). An example would be if the cost of water was increased to (insert dollar value) how much water would you expect to use. This method would help in water supply development as it would help define the acceptable value of water per kL in the community rather than just the respondent stating its simply too expensive. There would typically be that threshold value of water where the general community will consume without thinking, or they would change that habits and make more conscious decisions in conserving water based on cost for the service. This contingent behaviour method has advantage in helping predict the actual consumption/purchases after price controls/ different scenarios were enacted or lifted.

3.3.1.4. Cost Estimation

Whether the costs or benefits are economic, social or environmental, cost benefit analysis is a critical method of accessing the cost estimation and reviewing benefits of 2 or more alternative options in monetary terms. Limitations on a cost benefit analysis include intangibles that cannot be quantified in terms of monetary value or bias outlays placed to make a project more favourable one way or another. It would be proposed to reduce the limitations of a Cost benefit analysis by outlining all assumptions made in detail. By ensuring that the project is described thoroughly and with the limitations and intangibles highlighted, the research dissertation can be accessed and reviewed sufficiently.

The below financial costs for potential options were calculated and presented in Table 1.2 below, based on comparing all capital costs estimated. Summary of Capital and Operating Costs for all sources 1999/2000 PPK's report "Dalby Raw Water Source Options Study-Part B Options Report" (PPK, 1999/2000):

Table 3.2: *Summary of Capital and Operating Costs, 1999/2000 PPK's report "Dalby Raw Water Source Options Study-Part B Options Report".*

Option	Costs		High Reliability (>99%)			Low Reliability (>95%)		
	Capital $M	Operational $/a	Yield ML/a	Capital Cost $/ML	Operational Cost $/ML	Yield ML/a	Capital Cost $/ML	Operational Cost $/ML
1 Increased Usage of Loudoun Weir	0		250	-		450	-	
2 Raise Existing Loudoun Weir	Not Evaluated							
3 Construct a new Weir on Condamine River								
- 84.7 km Downstream of Loudoun Weir	16.8	0.55	2000	8,400	275			
- 27.9 km Upstream of Loudoun Weir	2.3	0.05	200	11,500	250	300	7,667	167
- 45.1 km Upstream of Loudoun Weir	1.4	0.05	200	7,000	250	300	4,667	167
4 Flood Harvesting from the Condamine River								
- 2,000 ML/a	16.0	0.4	2000	8,000	200			
- 1,000 ML/a	8.3	0.2	1000	8,300	200			
5 Additional Bores in Shallow Condamine Alluvium (Layer A)								
- 2,000 ML/a	5.5	0.1	2000	2,750	50			
- 1,000 ML/a	2.7	0.05	1000	2,700	50			
6 Additional Bores into Deeper Condamine Alluvium (Layers B and C)	8.4	0.75	2000	4,200	375			
7 Hutton Sandstone Bores								
- 2,000 ML/a	17.3	0.9	2000	8,650	450			
- 1,000 ML/a	9.2	0.47	1000	9,200	470			
8 Precipice Sandstone Bores	Not Evaluated							
9 New Storage on Myall Creek North Branch	9.9	0.1				500	19,800	200
10 Flood Harvesting from Myall Creek								
- 5 m^3/s pump & 3,300 ML Ring Tank	11	0.15	750	14,667	270	1150	9,565	170
- 5 m^3/s pump & 2 - 3,300 ML Ring Tanks	14.3	0.2	1100	13,000	270	1650	8,667	180
11 Overland Flow Harvesting	Not Evaluated							
12 Stormwater Recycling	2.7	0.05	150	18,000	333	200	13,500	250
13 Effluent Recycling using Dual Supply								
- Filtration and Reverse Osmosis	17.3	0.47	1000	17,300	470			
- Filtration	12.8	0.32	1000	12,800	320			
14 Potable Water Pipeline from Oakey								
- 2,000 ML/a	9.2	1.7	2000	4,600	850			
- 1,000 ML/a	7.5	0.9	1000	7,500	900			
15 Rainwater Tanks with 100% Council Subsidy								
- 30 kL Tank	18.0	0	330	54,545	-			
- 10 kL Tank	6.8	0	165	41,212	-			

The methods used to estimate the above considered breaking the cost of a potential option into capital and operating costs based on reliability has been effectively completed by PPK, 1999/2000. As can be observed from PPK, 1999/2000 Summary of Capital and Operating Costs for all sources, it is generally evident that to increase reliability, there increase in capital and operational costs is required.

To gauge an accurate cost for chemicals and treatment cost for Dalby's water supply, WDRC were approached to provide unit rates on operational labour costs, chemical costs associated with the main chemicals being chlorine, alum and caustic used in surface water treatment, and the operational power consumption for each source. For accuracy, there costs provided by WDRC were based on internal operations and assumed to be inclusive of all overheads and on-costs. Using first principles estimation, and operation cost per kilolitre for each water source currently available to meet Dalby's supply demands was calculated.

3.3.1.5. Value Risk Matrix

A Value Risk Matrix Helps to Prioritise and visualise decisions. Some advantages of a value/risk matrix are indicated below:

- Relatively simple to use,
- Have the ability to visually compare and contrast outcomes,
- Flexibility in refining and making decisions,
- Assists in clarifying highest priority in different scenarios.

Below is an example of Value/Risk matrix provided by the Queensland Government to assess which type of contract would be more suitable for the procurement of Goods and Services (State QLD, 2020). The matrix also assists with determining the level of complexity assisting in contract management, assisting in developing a sourcing strategy, helps with developing category management plans. The benefit to using a value risk matrix due its ability to visually see the outcome based on the defined matrix. The benefits to the State QLD, 2020 value risk matrix is always a level of customisability in allowing the user flexibility in user input to the value and risk criteria. The value questions are based on capital expenditure and contract exposure.

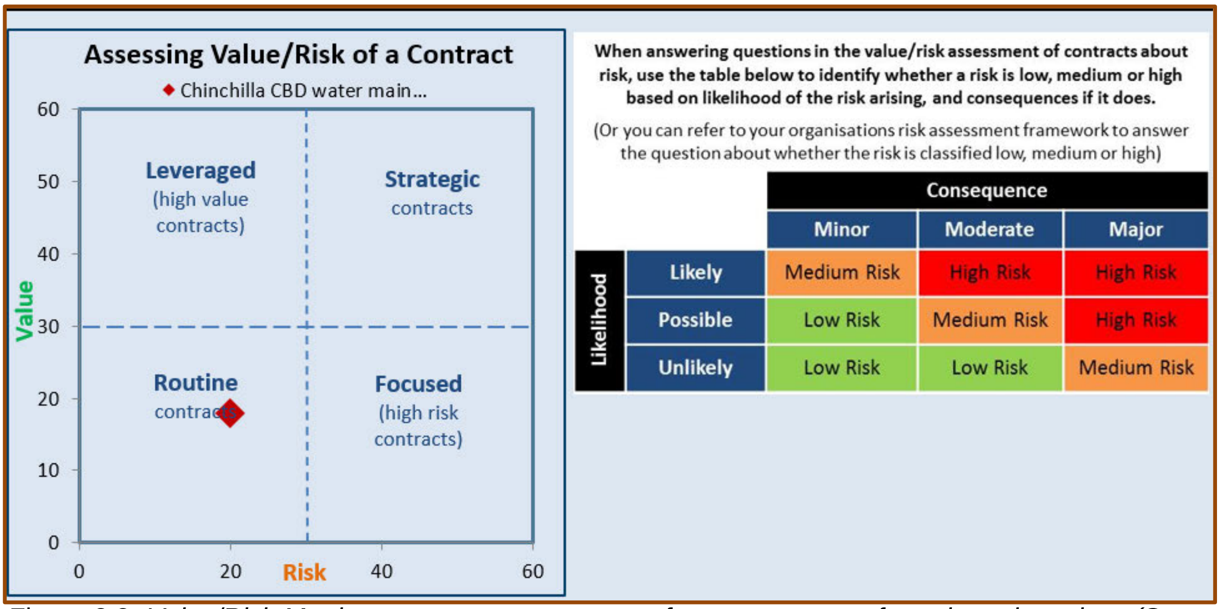

Figure 3.3: *Value/Risk Matrix to access contract types for procurement of goods and services (State QLD, 2020).*

The Procurement of Goods and Services example quantitively used value and risk framework to access the suitability and define which provided the following definitions to the classification definitions of the defined grid in the decision matrix (State QLD, 2020):

- Routine = Contracts being low value and risk, with a light touch approach being recommended.
- Focused = Contracts being higher in risk than routine contracts, but not high value. The priority for these contracts should be focused on contract management activities that help minimize risk.
- Leveraged = Contracts being high is value but low in risk. A priority for the management of these contracts recommended to be on how to leverage the value as much as possible.
- Strategic = A Contract that is defined as high value and high risk to the organization. These contract require the most amount of rigour and attention to manage, and recommends the use of experienced contract managers.

3.4. Value Risk Matrix Criteria/Factors

The following are the key identified researched parameters which could fall into the evaluation criteria for an Evaluation Method/Model:

- Demand
- Temperature - Weather
- Reliability/sustainability
- Cost
- External Considerations - Environmental Impacts, and Social considerations/perceived impacts from community/recreationally.
- Quality
- Value
- Risk

A value risk trade off is determined once the relative value and risk scores are determined, reflecting the decision as demonstrated in the below figure, which demonstrates an example concept that provides the most favourable trade off between value and risk. Figure 3.4 provides 4 concepts and in the case the highest ratio value/risk (steepest slope) is the one that provides the best value at a minimum risk among the other concepts evaluated. In Figure 3.4 concept 1 may be deemed more favourable.

In the Oil and Gas Industry example Valbuena. G, it was deemed important to incorporate the decision makers risk behaviour in the value-risk assessment. Typically it was discovered that most options offered additional value at higher levels of risk and deemed appropriate to set a risk tolerance or the decision makers. Therefore there can be scenarios found where the client maximum tolerable risk is exceeded and consequently regardless of the value assessed the concept is rejected as in concept 3 in Figure 3.4.

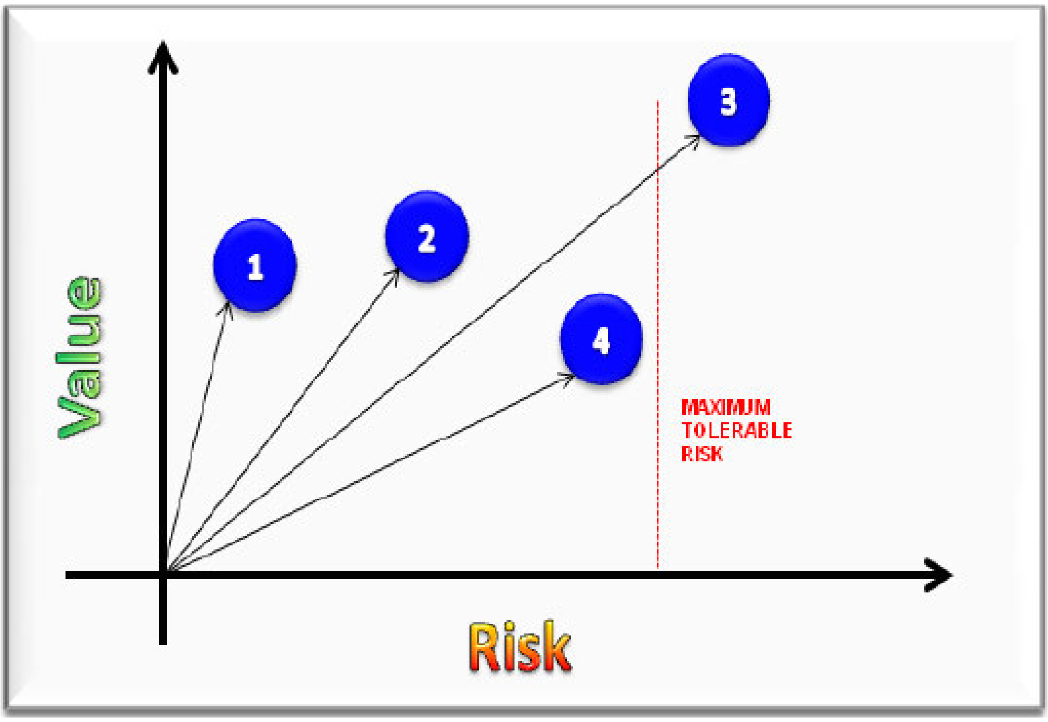

Figure 3.4: *Value Risk Trade-off Chart (Oil and Gas Industry, Valbuena. G).*

The robustness of the results in the Oil and Gas Industry example was typically assessed through sensitivity analysis (Oil and Gas Industry, Valbuena. G). Potentially their input/selection changes to the Value or Risk categories change the preferred concept, additional modifications may be required to address the sensitivities and improve the results. An example of this may identified by Valbuena. G reviewing the assumptions made, a dominating risk, or the effect and cost of certain mitigating measures, or scaling factors.

Another example of a value risk matrix to aid decision making in the manufacturing environment from L.A. Shah divided the risk and value axis into 3 parts/ranges as per in Figure 3.5. Again, the risk tolerance was defined, or a risk intolerance range was defined. However it was identified by L.A. Shah that in reality organisations may take risk beyond the maximum tolerable risk in pursuit of value creation for stakeholders. The determination of the maximum risk tolerance is subjective and depends on the company's attitude towards pursuing its objectives in both the value and risk areas (Manufacturing Environment, Shah L.A.).
As per Figure 3.5 the risk is on the y axis and value demonstrated on the x axis. A performance/ target range was established to define a lower and upper bound for both the value and risk

measures. The lower bound in Figure 3.5 is the ideal scenario while the upper bound is worst case scenario. The values are determined quantitatively. For the sake of simplicity, the study only focused on critical dimensions which included cost, time, technical performance, and employee satisfaction. To model the risk of the manufacturing scenario, the objective-orientated risk model was created and included risk areas of time, cost and quality dimensions responding to cost overrun and performance risks (Manufacturing Environment, Shah L.A.).

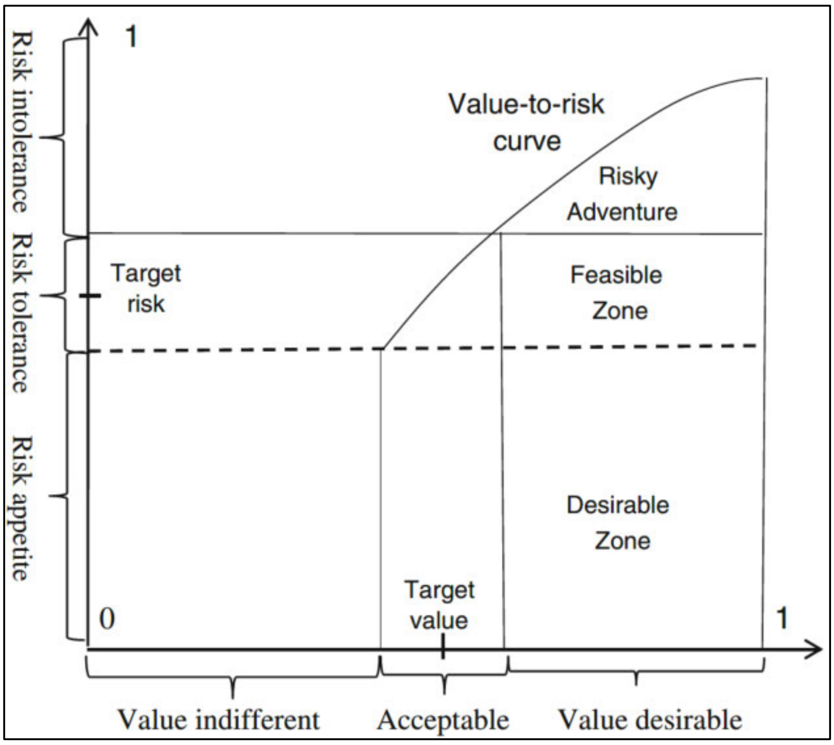

Figure 3.5: *Value risk graph example for decision making (Manufacturing Environment, Shah L.A.).*

3.5. Challenges Involving Modelling

Managing water resources often incurs many challenges based on different stakeholder needs and expectations. Fundamentally the objective of a Manager, water provider, and operator is to provide a reliable, inexpensive with high quality assurance water supply to the community (Daniel P. Loucks, 2017). While considering these factors/goals the water supplier is expected to do this at a cost no greater than what the what people are willing to pay. Keeping all stakeholders happy is not always possible and cannot be done without making compromises. Using a model to analyse can assist in identifying possible ways of achieving a goal and objective, while considering engineering, economical, environmental, ecological and social impacts. The main purpose of modelling is to provide useful and timely information to those involved in managing a system.

Models that are useful often tend to be those which are constantly being modified easily. Goals and objectives change over time based on varying factors including but not limited to water supply quality/quantities available, demand, financial constraints. These factors present a number of challenges including:

- Problem solving in different ways;
- Making decisions, and implementing considering various opinions, social values and objectives;
- History/ previous decisions and their circumstances;
- Existing regulations/legal obligations;
- A 'black and white' solution rarely exists. Objectives, demands, plans and policies evolve over time and are dynamic;
- For every larger decision, there are often smaller decisions required;
- Time available to analyse a water supply problem is often shorter than what would be needed to complete a thorough analysis to further optimise a process.;
- Communication between various stakeholders;
- Future Potential Water Quality Standard Guideline Changes and their Implications.

3.6. Key Findings of Literature Review

Key findings from the Literature review was that a Value/Risk Matrix was worth exploring further and had the potential form part of the Evaluation Method.

A Value Risk Matrix Helps to Prioritise and visualise decisions. Some advantages of a value/risk matrix are indicated below:

- Relatively simple to use,
- Have the ability to visually compare and contrast outcomes,
- Flexibility in refining and making decisions,
- Assists in clarifying highest priority in different scenarios.

3.7. Research/Knowledge Gap

From conducting a literature review there appears to be lacking information towards the theory of cost reliability of surface water vs underground water in regional Queensland/Australia. The lack of existing literature has minimal impact on the research proposal, as it is intended to request access to any data Council have available to aid in the comparison of water source selection for Dalby. Utilities members from Infrastructure Services at WDRC have been consulted and have supported the research proposal.

The development of a case study for a comparison of the water source selection based on value, risk and operational cost in the Dalby region would provide unique input into the industry and other regional Australian service providers. Furthermore, this project shall better inform WDRC on the operation of their Water Treatment Plant and which water source should be prioritised as a result of this analysis.

4. Methodology

4.1. Overview

A Value Risk matrix was selected to form part of the evaluation method for to optimise the strategy for water source development to achieve a reliable, cost effective potable water supply for Dalby QLD. A value risk matrix was selected due to its ability to prioritise and visualise decisions, and its flexibility to adapt to the value/risks required to make an inform decision. Overall the following approaches and a breakdown of key steps are outlined below to create the evaluation model:

- Standard Definition/Data Review/Criteria Selection
    - Standard of treatment Definition
    - Data collection/Review
    - Evaluation Criteria Selection
        - Precondition Criteria
        - Value Criteria
        - Risk Criteria
- Analysis Phase:
    - Operational Cost Analysis
    - Evaluation Model Creation
- Output
- Sensitivity/Analysis Approach.

4.2. Standard Definition/Data Collection/Evaluation Criteria Selection

4.2.1. Standard of Treatment Definition

The initial phase identified involved defining the key water quality parameters by reviewing the minimum standard of treatment for potable drinking water for a service provider. This step was required to outline the key parameters which was used/reviewed from WDRC's historic data.

The ADWG provides a foundation for defining the quality of water acceptance levels which is to be provided by service providers within Australia. The guidelines are intended to provide a sufficient management of drinking water supplies to assure safe use for the customers. It was proposed to review WDRC's DWQMP and confirm the appropriate parameters based on what has been historically recorded. The objectives in this phase would be obtaining the minimum standard parameters required in QLD, Australia.

The following parameters have been identified from both the ADWG and the DWQMP. The below Water Quality parameters have been selected because these values have been identified in WDRC's

DWQMP and have been historically recorded for the last 20 years for both underground and surface water when utilised:

- E.coli
- Turbidity
- Conductivity
- pH
- Total Hardness
- TDS

4.2.2. Data Collection/Review

This phase involved historic data and information collection provided by WDRC, including water quality data collected/provided by WDRC. The Data in this phase was reviewed to summarise the Maximum, Minimum, Average for both raw water and treated quality for each year for the last 10 years for each source water. The raw water quality data is summarised below provided from WDRC's DWQMP (WDRC, 2020):

Table 4.1: *Tables 5.1-5.4 of WDRC's DWQMP - Summary of Typical Water Quality results WDRC's available water sources, *Note GAB source currently not in use* (WDRC, 2020).

Table 5—1 Typical Water Quality - Loudoun Weir

Parameter	Sampling Location	Time Period	No. of Samples	Summary of Results			Confidence Grading		
				Max. Value	Average Value	Min. Value	Reliability	Accuracy	Comment
E. coli (mpn/100mL)	Raw Water Intake	Oct 2012 - Mar 2017	57	1700	136	0	A	2	
Turbidity (NTU)*	Raw Water Intake	Jul 2011 - Feb 2017	721	6000	80	4	B	3	
Conductivity (µs/cm)	Raw Water Intake	Feb 2010 - May 2020	55	1140	451	115	A	2	
pH	Raw Water Intake	Feb 2010 - May 2020	55	8.79	7.85	6.74	A	2	
Total Hardness (mg CaCO3/L)	Raw Water Intake	Feb 2010 - May 2020	55	220	120	28	A	2	
Total Dissolved Solids (mg/L)	Raw Water Intake	Feb 2010 - May 2020	55	556	244	71	A	2	
Saturation Index	Raw Water Intake	Feb 2010 - May 2020	55	1.2	-0.13	-1.9	A	2	
Sodium (mg/L)	Raw Water Intake	Feb 2010 - May 2020	55	90	35	10	A	2	
Bicarbonate (mg/L)	Raw Water Intake	Feb 2010 - May 2020	55	262	152	49	A	2	
Carbonate (mg/L)	Raw Water Intake	Feb 2010 - May 2020	55	7.8	1.5	0	A	2	
Hydroxide (mg/L)	Raw Water Intake	Feb 2010 - May 2020	55	0.1	0	0.	A	2	
Chloride (mg/L)	Raw Water Intake	Feb 2010 - May 2020	55	210	61	9	A	2	
Fluoride (mg/L)	Raw Water Intake	Feb 2010 - May 2020	55	0.54	0.19	0	A	2	
Nitrate (mg/L)	Raw Water Intake	Feb 2010 - May 2020	55	11	1.9	0	A	2	
Sulphate (mg/L)	Raw Water Intake	Feb 2010 - May 2020	55	24	7.42	2	A	2	
Iron (mg/L)	Raw Water Intake	Feb 2010 - May 2020	55	0.22	0.05	0	A	2	
Manganese (mg/L)	Raw Water Intake	Feb 2010 - May 2020	55	0.02	0.01	0	A	2	
Aluminium (mg/L)	Raw Water Intake	Feb 2010 - May 2020	55	0.24	0.08	0	A	2	
Atrazine (µg/L)	Raw Water Intake	Jan 2012 - Jan 2017	37	1	0.27	0.02	A	2	
Desethyl Atrazine (µg/L)	Raw Water Intake	Jan 2012 - Jan 2017	37	0.51	0.14	0.02	A	2	
Desisopropyl Atrazine (µg/L)	Raw Water Intake	Jan 2012 - Jan 2017	37	0.2	0.12	0.05	A	2	
Diuron (µg/L)	Raw Water Intake	Jan 2012 - Jan 2017	37	0.17	0.05	0.02	A	2	

Table 4.1 (continued): *Tables 5.1-5.4 of WDRC's DWQMP - Summary of Typical Water Quality results WDRC's available water sources, *Note GAB source currently not in use* (WDRC, 2020).

Table 5—2 Typical Water Quality - 'A' Level Bores

Parameter	Sampling Location	Time Period	No. of Samples	Summary of Results			Confidence Grading		
				Max. Value	Average Value	Min. Value	Reliability	Accuracy	Comment
E. coli (mpn/100mL)	Raw Water Intake	Oct 2012 - Mar 2017	67	0	0	0	A	2	
Turbidity (NTU)*	Raw Water Intake	Jul 2011 - Mar 2017	276	14.6	0.33	0.06	B	3	
Conductivity (µs/cm)	Raw Water Intake	Feb 2010 - May 2020	103	3600	1165	537	A	2	
pH	Raw Water Intake	Feb 2010 - May 2020	103	8.02	7.47	6.86	A	2	
Total Hardness mg CaCO3/L)	Raw Water Intake	Feb 2010 - May 2020	103	362	186	95	A	2	
Total Dissolved Solids (mg/L)	Raw Water Intake	Feb 2010 - May 2020	103	1940	655	1940	A	2	
Saturation Index	Raw Water Intake	Feb 2010 - May 2020	103	0.6	-0.08	-0.9	A	2	
Sodium (mg/L)	Raw Water Intake	Feb 2010 - May 2020	103	570	175	54	A	2	
Bicarbonate (mg/L)	Raw Water Intake	Feb 2010 - May 2020	103	437	328	198	A	2	
Carbonate (mg/L)	Raw Water Intake	Feb 2010 - May 2020	103	2.90	0.850	0.1	A	2	
Hydroxide (mg/L)	Raw Water Intake	Feb 2010 - May 2020	103	0	0	0	A	2	
Chloride (mg/L)	Raw Water Intake	Feb 2010 - May 2020	103	840	190.52	56	A	2	
Fluoride (mg/L)	Raw Water Intake	Feb 2010 - May 2020	103	0.25	0.08	0.05	A	2	
Nitrate (mg/L)	Raw Water Intake	Feb 2010 - May 2020	103	2.5	0.6	0	A	2	
Sulphate (mg/L)	Raw Water Intake	Feb 2010 - May 2020	103	140	30.73	4	A	2	
Iron (mg/L)	Raw Water Intake	Feb 2010 - May 2020	103	0.02	0.01	0.01	A	2	
Manganese (mg/L)	Raw Water Intake	Feb 2010 - May 2020	103	0.98	0.14	0	A	2	
Aluminium (mg/L)	Raw Water Intake	Feb 2010 - May 2020	103	0.05	0.05	0	A	2	

Table 5—3 Typical Water Quality - 'B' Level Bores

Parameter	Sampling Location	Time Period	No. of Samples	Summary of Results			Confidence Grading		
				Max. Value	Average Value	Min. Value	Reliability	Accuracy	Comment
E. coli (mpn/100mL)	Raw Water Intake	Oct 2012 - Mar 2017	74	0	0	0	A	2	
Turbidity (NTU)*	Raw Water Intake	Jul 2011 - Mar 2017	153	14.3	0.47	0.07	B	3	
Conductivity (µs/cm)	Raw Water Intake	Feb 2010 - May 2020	66	3950	3045	2160	A	2	
pH	Raw Water Intake	Feb 2010 - May 2020	66	8.16	7.83	7.55	A	2	
Total Hardness (mg CaCO3/L)	Raw Water Intake	Feb 2010 - May 2020	66	377	307	209	A	2	
Total Dissolved Solids (mg/L)	Raw Water Intake	Feb 2010 - May 2020	66	2200	1719	1240	A	2	
Saturation Index	Raw Water Intake	Feb 2010 - May 2020	66	0.9	0.54	0.3	A	2	
Sodium (mg/L)	Raw Water Intake	Feb 2010 - May 2020	66	660	523	393	A	2	
Bicarbonate (mg/L)	Raw Water Intake	Feb 2010 - May 2020	66	504	434	410	A	2	
Carbonate (mg/L)	Raw Water Intake	Feb 2010 - May 2020	66	6	2.36	0.9	A	2	
Hydroxide (mg/L)	Raw Water Intake	Feb 2010 - May 2020	66	0	0	0	A	2	
Chloride (mg/L)	Raw Water Intake	Feb 2010 - May 2020	66	1000	714	440	A	2	
Fluoride (mg/L)	Raw Water Intake	Feb 2010 - May 2020	66	0.75	0.22	0.1	A	2	
Nitrate (mg/L)	Raw Water Intake	Feb 2010 - May 2020	66	2.5	0.6	0	A	2	
Sulphate (mg/L)	Raw Water Intake	Feb 2010 - May 2020	66	150	121	86	A	2	
Iron (mg/L)	Raw Water Intake	Feb 2010 - May 2020	66	0.01	0.01	0.01	A	2	
Manganese (mg/L)	Raw Water Intake	Feb 2010 - May 2020	66	0.03	0.01	0.01	A	2	
Aluminium (mg/L)	Raw Water Intake	Feb 2010 - May 2020	66	0.05	0.05	0.05	A	2	

Table 5—4 Typical Water Quality - GAB bore

Parameter	Sampling Location	Time Period	No. of Samples	Summary of Results			Confidence Grading		
				Max. Value	Average Value	Min. Value	Reliability	Accuracy	Comment
E. coli (mpn/100mL)	GAB Bore	06/2019	0	0	0	0			
Turbidity (NTU)*	GAB Bore	06/2019	56	109	11.34	0.09			
Conductivity (µs/cm)	GAB Bore	06/2019	2	1500	1500	1500			
pH	GAB Bore	06/2019	2	7.23	7.22	7.18			
Total Hardness (mg CaCO3/L)	GAB Bore	06/2019	2	174	169.5	165			
Total Dissolved Solids (mg/L)	GAB Bore	06/2019	2	3700	3650	3600			
Saturation Index	GAB Bore	06/2019	2	0.39	0.365	0.34			
Sodium (mg/L)	GAB Bore	06/2019	2	1320	1270	1220			
Bicarbonate (mg/L)	GAB Bore	06/2019	2	1600	1575	1550			
Carbonate (mg/L)	GAB Bore	06/2019	2	0	0	0			
Hydroxide (mg/L)	GAB Bore	06/2019	2	0	0	0			
Chloride (mg/L)	GAB Bore	06/2019	2	1500	1500	1500			
Fluoride (mg/L)	GAB Bore	06/2019	2	0.87	0.86	0.85			
Nitrate (mg/L)	GAB Bore	06/2019	2	0	0	0			
Sulphate (mg/L)	GAB Bore	06/2019	2	5.4	5.35	5.3			
Iron (mg/L)	GAB Bore	06/2019	2	0.64	0.53	0.42			
Manganese (mg/L)	GAB Bore	06/2019	2	0.012	0.012	0.012			
Aluminium (mg/L)	GAB Bore	06/2019	0	0	0	0			

Data shown in the above table are the results of tests performed under the Verification Monitoring Plan (except where indicated).
Please refer to the overview document for confidence grading levels.
** In-house result*

To summarise the raw water quality data reviewed for the Loudoun Weir being the only surface water Weir available under current operations, the turbidity was identified to have the biggest range, with an average of 80 NTU, minimum of 4 NTU and a maximum of 6000 NTU. Typically for Loudoun Weir in Dalby experiences high turbidity of around 1,000 NTU during high flow and flood events. In low turbidity conditions the Loudoun Weir turbidity is typically 10-20NTU which typically coincides with prolonged no flow periods from the Condamine River.

The treated quality of water is blended together in the clear water tank and therefore it is difficult to separate the treated water quality of each individual source. All sources are typically blended in the clear water tank before chlorination and fluoridation is completed in the initial chamber of the clear water tank. The clearwater tank is created in a chamber like way which allows sufficient retention of chlorination prior to pumping into the low-level reservoirs through the rising water main. The treated quality of each source has been ignored and assumed that the same treated water quality is achieved from each water source in use.

From a treatment perspective GAB sourced water can be quite hot, and can often be mineralised with various amounts of dissolved salts, carbonates and fluoride. Alluvial water is generally cool and clear but with various levels of mineralisation and low levels of fluorides. Some alluviums are closely linked to surface water with direct recharge from the sand river beds of streams and rivers. Water from deeper alluvial deposits have TDS's above the ADWG but are generally protected from surface contamination.

Average demand has also been considered to estimate the consumption for demand consideration for Dalby. 4.58 ML/day has been assumed to be used as the average baseline demand to be achieved. 1999/2000 PPK's report "Dalby Raw Water Source Options Study-Part B Options Report" reported the daily average consumption/demand for Dalby of 4.58ML/day (PPK, 1999/2000). Therefore, the adopted annual daily average demand used in this scenario was 4.58ML/day. To support this, WDRC's historic data available from 2012-2022 consumption data was reviewed. The consumption remained relatively stable with an average consumption/demand of 4.48ML/day, therefore adopting the slightly larger demand of 4.58 ML/day as the annual daily average water consumption for Dalby.

1999/2000 PPK's report "Dalby Raw Water Source Options Study-Part B Options Report" predicted that the average consumption could increase to 5 ML/day in another 10 years (PPK, 1999/2000). After reviewing WDRC's daily average consumption of the full year data available from 2012 through to 2022 it has remained relatively stable with an average consumption/demand of 4.48ML/day, a minimum annual average daily consumption of 4.04ML/day, and a maximum annual average daily consumption of 5.137ML/day. Therefore the Future Predicted Demand Scenario adopted in assessing the source selection based on an increase in demand of 5 ML/day daily average annual consumption was noted to be assessed the model.

The peak/maximum daily demand was reviewed against WDRC data collected for historical analysis and reporting obligations. The maximum daily consumption recorded by WDRC from January 2012 through to December 2022, being the full year data range available for this dissertation provided by WDRC (Fagg, T 2023, pers. comm, 14 July). The month observed to have the largest daily consumption in this ten-year period was in January 2014 of 9.16ML/day, therefore being a logical demand shortlisted to confirm the source priority options available in the decision matrix.

In reviewing the maximum available quantities of the available sources it can be noted that ground water sources has slightly more available daily quantity of half a megalitre as compared to the surface water. The limitations of the sources in regard to demand is by the infrastructure currently available to transfer and treat the source water. There a number of factors which may dictate the design flow rate for a treatment plant. One factor includes that there would be increased operational and maintenance costs if the largest possible plant was to be installed. Surface area and site constraints may dictate maximum capacities. Reliability, sustainability, regulatory, licensing conditions and raw water quality of the source water also may dictate the available quantities from a water source. For this dissertation to assist reviewing and optimise the strategy for water source development to achieve a reliable, cost effective potable water supply for Dalby QLD, the current infrastructure and WDRC recorded maximum available quantities and limitations have been adopted to be assessed against the decision matrix.

The current available sources and their maximum available quantities based on existing infrastructure limitations and conditions are outlined in Table 4.2 below:

Table 4.2: *Dalby's available sources and maximum available quantities provided by WDRC (Fagg, T 2023, pers. comm, 14 July).*

Available Sources	***Maximum Available Quantity (ML/Day)***
Loudoun Weir	6
'A' lvl Bores	2
B' lvl Bores	4.5
Total	**12.5**

4.2.3. Evaluation Criteria Selection

Due to the opportunity in utilising a decision matrix the Value and Risk have been identified to become the main two criteria. With this considered, there a number of overarching criteria which has been considered to form the precondition criteria for the value and risk criteria:

4.2.3.1. Precondition Criteria

The following precondition criteria and the weightings input into the model are as follows with their justification as to how/why it was chosen:

- Demand = Input value in ML/day. The increase in demand increases the value/operational cost overall for the day. An increase in demand in certain conditions increase the risk. The higher the demand, the higher the risk increase due the increase in the required demand of the day, and in turn inducing more stress into the current infrastructure by pushing existing infrastructure to maintain higher flow rates and operate at higher pressures. This increased demand can force existing infrastructure to operate close or at their limitations during operation. But temperature can also be considered and linked to demand:
    - Temperature has been decided to fall under the demand as there is a link as defined in Section 3.2.1 Demand of the Literature Review. As a result of the external ambient temperature, the demand of the day will be partly dictated by this. Temperature will not be considered further then by the change in demand for model. An increase in the average temperature for the day will result in a higher average demand for the day. While a reduction in temperature for the day will typically result in a reduced demand.
- Source Availability (Reliability/sustainability) = Yes/No for each source. Source availability dictates the value, and the more sources in use in certain scenarios increase the risk due to an increase in operational staff/resources, and potential infrastructure stress due to unavailability of water sources.
- Raw Water Quality = Surface Water Turbidity. Raw water quality for bore water is relatively stable (Fagg, T 2023, pers. comm, 14 July), and therefore considered a constant. Not considered by the model in this dissertation as it has been considered stable, as the changes are minimal, gradual and could be considered in longer term analysis. From a treatment perspective GAB sourced water can be quite hot, and can often be mineralised with various amounts of dissolved salts, carbonates and fluoride. Alluvial water is generally cool and clear but with various levels of mineralisation and low levels of fluorides. Some alluviums are closely linked to surface water with direct recharge from the sand river beds of streams and rivers. Water from deeper alluvial deposits have TDS's above the ADWG but are generally protected from surface contamination. Raw water quality of the surface water is to be included in both value and risk criteria areas. Using poor a level of raw water quality will increase the operational cost of the water treated. However, the risk can also increase with raw water quality changes by using a poorer quality raw water source.

4.2.3.2. Value Criteria

The following value criteria and the weightings input into the model are as follows with their justification as to how/why it was chosen:

- Operational Labor cost was sourced from WDRC and averaged between the relevant hourly rates and multiplied against the labour operating hours provided by WDRC in Table 4.3 and 4.4 respectfully (Fagg, T 2023, pers. comm, 14 July).

Table 4.3: *Operational Labour costs provided by WDRC (Fagg, T 2023, pers. comm, 14 July).*

Labour Cost	***Unit***	***Rate ($)***
Labourer	Hr	40
Plant Operator	Hr	42
Supervisor	Hr	59
Average	**Hr**	**47**

Table 4.4: *Labour Operating Hours for each Source per day provided by WDRC (Fagg, T 2023, pers. comm, 14 July).*

Source	***NTU***	***Labour*** Operating Hours (per day)
Loudoun Weir	20	8
Loudoun Weir	100	8
Loudoun Weir	250	8
'A' Lvl Bores	-	2
'B' Lvl Bores	-	4

- Power was sourced from the Canstar Blue which provided a power cost = 0.3 ($/hr) (Canstar Blue, 2023). The power in regards to electrical use includes the power demand requirements in electrical monitoring equipment, pumping draw, and treatment power consumption in a rate of kilowatt hours per kilolitre have been provided by WDRC and displayed in Table 4.5 (Fagg, T 2023, pers. comm, 14 July).

Table 4.5: *Power use for each source provided by WDRC (Fagg, T 2023, pers. comm, 14 July).*

Source	***NTU***	***Power*** kWhour/kL
Loudoun Weir	20	0.2
Loudoun Weir	100	0.2
Loudoun Weir	250	0.2
'A' Lvl Bores	-	0.45
'B' Lvl Bores	-	1

- Chemical dosing rates in milligrams per litre and the estimated dollar per litre value for the following chemicals have been provided by WDRC (Fagg, T 2023, pers. comm, 14 July) in Table 4.6:

Table 4.6: *Chemical costs provided by WDRC (Fagg, T 2023, pers. comm, 14 July).*

Source	***NTU***	***Chlorine*** mg/L	***Chlorine*** $/L	***Allum*** mg/L	***Allum*** $/kg	***Caustic*** mg/L	***Caustic*** $/kg
Loudoun Weir	20	7	$0.38	70	$1.00	0	$1.00
Loudoun Weir	100	15	$0.38	110	$1.00	10	$1.00
Loudoun Weir	250	15	$0.38	170	$1.00	60	$1.00
'A' Lvl Bores	-	3	$0.38	-	-	-	-
'B' Lvl Bores	-	3	$0.38	-	-	-	-

- Raw Water Quality was also considered for calculating the value criteria, considering the turbidity plays a major factor in the cost of treatment from an operational perspective for the use of surface water. With regard to the surface water source, the required amount of chemical increases as demand increases and as the turbidity increases respectfully.

4.2.3.3. Risk Criteria

The following risk criteria and the weightings input into the model are as follows with their justification as to how/why the criteria selected was chosen:

- Criticality to the System (Are there any Critical control point risks). This criteria is important in risk management and was identified from the Queensland Government Procurement risk value matrix. A similar question was presented regarding the suitability of a contract for the good/services and criticality to the organisation. Another area which was present from the procurement contract value risk matrix was if the supplier defaults during the contract execution, what is the level of interruption to the accessors organisation's core operation. With consideration to water source management, infrastructure criticality should be required to be assessed against risk to the organization and is therefore adopted based on a combination of previous experience and Queensland Government Risk Value Matrix (State QLD, 2020).

- Regulatory risks – of using a particular source, whether that be meeting license conditions. This area demands weighting as it is mandated to abide by existing license conditions, with consideration needed for using a source/source combination. An example to justify the importance could be exceeding waste stream evaporation pond storage capacity, which might require heavy monitoring in using a water source which relies on managing the waste stream through the use of the evaporation pond. In an extreme case a water source linked to the evaporation pond might not simply be available or to mitigate the risk there may be close monitoring required to ensure no breach of license conditions. The DWQMP is to assist WDRC as a service provider to meet its statutory obligations under the Water Supply Safety and Reliability Act 2008, and incorporates regulatory and licensing required to be follow by service providers as stated in Section 2.3 and therefore justified as a criteria to be selected in the risk criteria (WDRC, 2020).
- There are also Potential Reputational / Social or Perceived risks, An example of this would be the water level in the Loudoun Weir and how that may be perceived from the public in using that source. As provided in the literature review Section 3.2.3 External Considerations this criteria demand consideration and would likely have increased relevance in the transition from a full weir to slowly depleting surface water source due to evaporation, seepage, and stakeholder use including a water service provider. Based on experience, Reputational risk forms part of the risk analysis criteria.
- Health/Safety (to an operator – whether that be a trip hazard, or a risk of working at heights due to particular infrastructure for that source being in use). This criteria demands consideration as it is important to consider for oneself and others within the workplace. WDRC underlying value in their Corporate Plan is safety and has been adopted by the brand they have created for the employes and community WDRC services (WDRC values, 2023). Therefore safety is critical in the risk criteria.
- Operational risks - Potentially in operator errors. This can be linked to the treatment infrastructure type and condition present at Dalby WTP. A plant designed 50 years ago would face different operational risks as compared to one designed utilising latest technology. The 50 year old design utilizing sand media filtration carries additional operator

risk correct sampling procedures ensuring high quality water is passing through the media filter. As compared to newer technology treatment plants such as ultra filtration, which technology is more relied on and ensuring operators understand the treatment process and operating pressures. Based on experience, Operational risk forms part of the risk analysis criteria.

- Operational staff resourcing, lack of staff issues may dictate if a particular source is available. Resourcing is always an issue and ensuring that employees are valued and retained. It is important for Council organisations attract employees and potential operators to their organization. WDRC promote work/life balance, financial benefits, health, wellbeing, career progression/development with learning development opportunities (WDRC values, 2023). Based on experience and a link to WDRC's Corporate Plan, operational staff resourcing risks forms part of the risk analysis criteria.
- Risk unique to source: This area commands consideration with regard to water resource management. Risks unique can include maintenance, reliability issues and environmental. The intent of this area is to highlight any maintenance, past performance issues and any unusual changes in raw water quality. The unique criteria area also provides an opportunity to convey flexibility in assessing the risks present and being able to customize the questions in this area to suit the need of the user/organisation. Based on experience risks unique to the source forms part of the risk analysis as there can quite quickly be changes to the present risks, which can be appropriately captured in the evaluation model.

4.3. Analysis Phase

4.3.1. Operational Cost Analysis

An operational cost analysis was completed to establish a operational treatment cost per kilolitre for each water source based on demand and surface water turbidity. The use of Microsoft Excel was utilised for this phase.

The following steps were completed in completing the operational cost analysis to access the current cost, and current/future risks of water supply for Dalby:

- The operational labour hourly rates and labour operating hours were provided by WDRC in Table 4.3 and 4.4 (Fagg, T 2023, pers. comm, 14 July). Operational Labor cost was averaged between the hourly rates provided to adopt 47 per hour rate and multiplied against the labour operating hours. The surface water labour operating hour requirement fundamentally is that 8 labour operating hours are required for every two megalitres of water demand (Fagg, T (2023), pers. Comm, 14 July). The labour hours is calculated for every two hours based on the adjusted available quantity calculated in the decision matrix. An example of his is if there is 1.48ML/day required from the surface water source, the labour cost will round up to the nearest 0.5ML required(demand) of this source (1.5ML/day) and multiply 2 operating hours for every 0.5ML required. In this example, if there is 1.48ML/day required quantity from Loudoun Weir, six hours per day of operating hours is calculated in the cost analysis.

- Chemical costs associated with each of the different treatment process based on the water quality and method. Chemical dosing rates in milligrams per litre and estimated dollar per litre value for the common chemicals including chlorine, alum and caustic were provided by WDRC as per Table 4.6 (Fagg, T 2023, pers. comm, 14 July). The chemical costs are multiplied by the required demand calculating a dollar per kilolitre for chlorine, allum and caustic.
- Power was sourced from Canstar Blue which provided a power cost = 0.3 ($/hr) (Canstar Blue, 2023). The power use includes the electrical demand requirements in electrical monitoring equipment, pumping draw, and treatment power consumption in a rate of kilowatt hours per kilolitre have been provided by WDRC (Fagg, T 2023, pers. comm, 14 July). The power cost is multiplied with the kilowatt hour per kilolitre to calculate a cost per kilolitre for power for each water source.
- The operational costs dependent on the demand required for each sources is added to the chemical and power dollar per kilolitre values to calculate a total dollar per kilolitre value as summarised in Table 4.7.

The estimated operational cost forms part of the evaluation model, with the operational cost per kilolitre of each source having common input parameters which can be modified and changed as circumstances change, operating factors change and the rates provided by council require revising. The costs defined for each source will carry over to the evaluation model and is calculated based on the adjusted available quantity calculated in the decision matrix. Table 4.7 is a summary of the operational cost calculated, used in creating the value score for the value risk matrix for each source combination.

Table 4.7: *Operational Cost Analysis Summary based off the information provided by WDRC.*

Source	*NTU*	Total $/kL	Power Cost $/kL	Labour Cost $/kL	Chlorine $/kL	Alum $/kL	Caustic $/kL
Loudoun Weir	20	0.33	0.06	0.2005293	0.00266	0.07	0
Loudoun Weir	100	0.38	0.06	0.2005293	0.0057	0.11	0.01
Loudoun Weir	250	0.49	0.06	0.2005293	0.0057	0.17	0.06
'A' Lvl Bores		0.18	0.135	0.0626673	0.00114		
'B' Lvl Bores		0.43	0.3	0.1253346	0.00114		
Hutton		0.46	0.33	0.1253346			
GAB (Precipice)		0.5	0.375	0.1253346			

4.3.2. Evaluation Model Creation

This Phase involved creating an evaluation method/model and integrate the evaluation selection criteria as input values in the model. This model created a decision matrix utilising Microsoft Excel, where a spreadsheet was developed which generated a value and risk score for each source combination. A value score was calculated by using the operational cost adopted from Section 4.3.1. and multiplied by the adjusted available demand for each source. The value axis of the value risk matrix shifts to allow for varying cost ranges. The risk score is based on establishing a weighting for the defined risk questions, and assessing the risk questions against the water sources available using a Matrix Table assessing consequence and likelihood. A risk score is calculated for a water source combination. The risk input evaluation criteria was established as part of the literature review and as defined in the Evaluation Criteria Selection Section 4.2.3.3. Different quantitative assessment methods were trialled and weighted average method was adopted including a risk axis range from zero to ten. The value and risk score calculated by the model is used to create a point on the value risk matrix. The steps are repeated against the different source combinations available, and compiled together on the same value risk matrix for visual comparison. A table is also generated to numerically review the results generated.

The value and risk score calculation and justification for the methods adopted are broken down and discussed in detail.

4.3.2.1. Value

The following value instruction steps are taken in assessing the value score. The value criteria and the weightings input into the model can be found in Section 4.2.3.1. and 4.2.3.2. along with the following instructions/steps:

- Demand = The user first inputs the total average demand required in megalitres per day in the light blue cell. Note that as per Table 4.2 the total available demand which can be input is 12.5 ML/day (assuming that all sources are available).
- Source Availability (Reliability/sustainability) = The user selects Yes/No for each source.

- Raw Water Quality = Surface Water Turbidity. Refer to Section 4.2.3.1. for justification. In reviewing the typical raw water quality provided by WDRC three Turbidity scenarios were adopted for selection of the Loudoun Weir turbidity as shown in Table 4.1 (Fagg, T 2023, pers. comm, 14 July). The user either collects a sample and matches to the closest three turbidity values available, or assumes based of user input being:
  - 20 NTU = Little to no flow in the Condamine River;
  - 100 NTU = Small to medium flow;
  - >250 NTU = Large to extreme flow (high rainfall event/flood);
- The model calculated the source percentage of use based on availability and the adjusted quantities between the available sources by using a XLookup (refer to Table 4.8). IF functions and first principles were used to further adjust the available quantities to cater for the current available sources and their maximum available quantities based on existing infrastructure limitations and conditions as outlined in Table 4.2. The model assumes an even split across the available sources and adjusts based on maximum available capacities for the source.

Table 4.8: *X Lookup Source Availability and Percentage Distribution.*

Turbidity NTU	Source Availability Loudoun Weir	Source Availability 'A' Lvl Bores	Source Availability 'B' Lvl Bores	% Loudoun Weir	% 'A' Lvl Bores	% 'B' Lvl Bores
20	Yes	Yes	No	50	50	0
20	Yes	No	No	100	0	0
20	No	Yes	No	0	100	0
100	Yes	Yes	No	50	50	0
100	Yes	No	No	100	0	0
100	No	Yes	No	0	100	0
250	Yes	Yes	No	50	50	0
250	Yes	No	No	100	0	0
250	No	Yes	No	0	100	0
20	Yes	Yes	Yes	33.334	33.333	33.333
20	Yes	No	Yes	50	0	50
20	No	Yes	Yes	0	50	50
100	Yes	Yes	Yes	33.334	33.333	33.333
100	Yes	No	Yes	50	0	50
100	No	Yes	Yes	0	50	50
250	Yes	Yes	Yes	33.334	33.333	33.333
250	Yes	No	Yes	50	0	50
250	No	Yes	Yes	0	50	50
20	No	No	Yes	0	0	100
100	No	No	Yes	0	0	100
250	No	No	Yes	0	0	100

- The operational cost adopted from Section 4.3.1. and as summarized in Table 4.7 is multiplied by the adjusted available quantity for each source. The value of each available source is summed together to create a total value score which is used as a y position on the value risk matrix for that source combination. The value axis of the value risk matrix shifts to allow for varying cost ranges.
- The steps are repeated against the different source combinations available, and compiled together on the same value risk matrix for visual comparison. A table is also generated to numerically review the results generated.

Figure 4.1 provides a screenshot from the evaluation model. The blue cell is where the demand is input by the user, the user is to select source availability and the surface water turbidity in the coloured cells, and the model will calculate a total value using the demand and operational costs calculated as per Section 4.3.2.

	Criteria:		Precondition Selection/Input			Score						
		Input Value	Total Avg Demand ML/day	4.5								
					Surface Water		Condamine Alluvium Bores					
					Loudoun Weir		'A' Lvl Bores		'B' Lvl Bores			
	Criteria:		Source precondition Questions		Answer	Score	Answer	Score	Answer	Score		
	Yes	No	Is the source available?		Yes	1	Yes	1	Yes	1		
20 NTU	100 NTU	>250 NTU	Turbidity (NTU)		20 NTU	20	N/A		N/A			
	Criteria:		Output								Subtotal	Value
	%		Source Percentage Use (%)		33.33		33.33		33.33		100	$ 1,437.71
	Limit =	12.5	Adjusted Available quantity (ML/day)		1.50		1.50		1.50		4.5	
	%		Adjusted Source Percentage Use (%)		33%		33%		33%		100%	
	$		Source Cost per Kilolitre ($/kL)		$ 0.33		$ 0.20		$ 0.43		$ 0.96	
	$		Total Cost $		$ 499.79		$ 298.21		$ 639.71		$ 1,437.71	

Figure 4.1: *Screenshot from the Evaluation Model of the Value score area (Screenshot of Decision Matrix).*

4.3.2.2. Risk

This Phase involved breaking down the current/future risks of water supply for Dalby. A risk score is calculated based on likelihood and consequence of the user answering risk questions. The following risk instruction steps are taken in calculating the risk score. The risk criteria and the weightings input into the model can be found in Section 4.2.3.3. along with the following instructions/steps:

- The user first inputs/adjusts the criteria weighting against the risk criteria/risk questions. The model requires the user to ensure that the weighting percentages input across the ten risk questions sum up to a total of 100%. This can be validated by the model autonomously summing the risk weighting to ensure the 100% total in this area. The weighting percentage was placed in between the criteria topic name and the risk questions to assist in the usability of the model. For justification on the criteria of the question which have been selected for the risk questions refer to Section 4.2.3.3. The selected questions are summarised in Figure 4.2. Note that the Unique Risk Questions are selected based on the users assessment on any specific risks to address, and therefore can be modified to ensure that any risks present are fully captured in the evaluation model.

- The next step requires the user to answer/assess the risk questions against the water sources available using Table 4.9 Risk Question Matrix Table, assessing consequence and likelihood. As a guide the coloured cells in this section of the evaluation model requires the user to select out of 5 predefined selection criteria varying from low to high risk. Each selection is assigned a score from two through to ten, with ten being worst case (high risk). A risk score is calculated for the considered water source combination. The risk input evaluation criteria were established as part of the literature review and as defined in the Evaluation Criteria Selection Section 4.2.3.3.

Table 4.9: *Risk Questions Matrix Table, including recommended action guide.*

Risk Questions Matrix Table					
Consequence					
Probability/ Likelihood	**Insignificant**	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost Certain	Med	Med-Hig	Med-Hig	High	High
Likely	Low-Med	Med	Med-Hig	Med-Hig	High
Possible	Low-Med	Low-Med	Med	Med-Hig	Med-Hig
Unlikely	Low	Low-Med	Med	Med	Med
Rare	Low	Low	Low-Med	Low-Med	Low-Med
Definition: Recommended Action Guide					
High:	High = High Risk - Task MUST NOT proceed				
Medium-High:	Med-Hig = Medium-High Risk - Special Procedures Required				
Medium:	Med = Medium Risk - A Risk Management Plan / Safe Work Method Statement is required				
Low-Medium	Low-Med = Low-Medium Risk - Manage by routine procedures				
Low:	Low = Low Risk - Manage by routine procedures				

- The following different quantitative assessment methods were trialed and reviewed. Refer to Figure 4.2 for the condition input/selection criteria assessed and Table 4.10 of the method assessment results reviewed:

Table 4.10: *Qualitative Assessment Methods Comparison Table.*

Risk Score	Quantitative Assessment Method
3.33	Average
8	Max Value
33	Sum
3.55	Weighting Average

- Average - This method was first completed, however upon review of the suitability this method didn't appropriately capture the any high risk selection of one value. This was because all ten question answers due averaging them all together, suppressed the actual risk present from one high score value.
- Max Value - This method was assessed as the second preference of the values considered. It did capture any high risk score appropriately on the matrix. However, this assessment method was ruled out due to one high score doesn't automatically rule that source out of consideration and there are particular scenarios where loss of supply risk ultimately outweighs one high score risk in particular scenarios (Fagg, T 2023, pers. comm, 14 July).
- Sum - This method was deemed not suitable due not being able to highlight the risk present as the sum suppressed the actual risk present from one high score value.
- Weighted Average - The first preference out of the methods assessed as justified below.

It was deemed that the weighted average method would produce the most accurate risk results. The weighting on risk criteria could be customised to a particular risk question to demonstrate and more accurately highlight the risk present. The scoring of the risk questions using Table 4.9 also linked to the weighting in the criteria and the demand required of the assessed water source was appropriately connected. The suppression seen in the actual risk present from one high score value wasn't as suppressed in the weighted average method as compared to the average method. This assessment method was preferred due to one high score not automatically ruling that source out of consideration and there are particular scenarios where loss of supply risk ultimately outweighs one high risk score in particular scenarios (Fagg, T 2023, pers. comm, 14 July). A risk axis range from zero to ten was also adopted which aided in the a simple visual representation of the risk of a source combination, increasing the usability by keeping it relatively easy to understand.

- The model will calculate a total risk score using a weighted average quantitative assessment, which is used as a x position on the value risk matrix for that source combination.
- The steps are repeated against the different source combinations available, and compiled together on the same value risk matrix for visual comparison. A table is also generated to numerically review the results generated.

Figure 4.2 provides a screenshot from the evaluation model. The blue cell is where the input of the weighting on the risk questions is completed by the user. The coloured cells are where the user selects out of 5 predefined selection criteria varying from low to high risk assessing the risk questions of the available sources. Note that there is flexibility in revising the risk questions as required preferably in the unique to source questions as priority. The model will calculate a total value using a weighted average quantitative assessment to create a risk score, which is used as a x position on the value risk matrix for that source combination.

	Weighting		Loudoun Weir		'A' Lvl Bores		'B' Lvl Bores		
Criteria:	**100.00%**	**Risk Questions**	**Answer**	**Score**	**Answer**	**Score**	**Answer**	**Score**	*Subtotal*
Criticality to the System	5%	*What is the potential delay to identifying a potential issue (critical control point risks)?*	Low	2	Medium	6	Medium	6	4
Criticality to the System	20%	*What is the risk to the organisation of any critical infrastructure issues?*	Medium	6	Low	2	Low	2	3
Regulatory Risk	20%	*What is the regulatory risk to using the source?*	Low-Med	4	Low-Med	4	Low-Med	4	4
Operational	20%	*Operational risk either in operator error or lack of staff to run a source?*	Med-Hig	8	Low	2	Low-Med	4	5
Unique	2%	*Have any risks been identified that need to be managed (unique to the source)?*	Low	2	Low	2	Low	2	2
Unique	4%	*- Past performance issues with source?*	Low	2	Low	2	Low	2	2
Unique	2%	*- Maintenance issues present with plant?*	Medium	6	Low	2	Low-Med	4	4
Unique	2%	*- Unusual changes in Raw water quality present (plant may not be able to manage)?*	Low-Med	4	Low	2	Low	2	3
Reputa/social/perceived	5%	*What is the reputational/social/media/perceived risk to the organisation?*	Low-Med	4	Low	2	Low-Med	4	3
Health/Safety	20%	*What is the risk to the operators (health/ welfare/ safety)?*	Medium	6	Low	2	Low-Med	4	4
Subtotal	*100%*	*Subtotal*	*44*	*44*	*26*	*26*	*34*	*34*	*34*

Figure 4.2: *Screenshot from the Evaluation Model of the Risk score area (Screenshot of Decision Matrix).*

4.3.3. Output

This phase involved validating/testing the model created under different demand scenarios identified for exploration below:

1. Annual Average Demand Scenario
2. Steady Flow Demand Scenario
3. Flood Demand Scenario
4. Drought Demand Scenario
5. Maximum Demand Scenario
6. Future Predicted Demand Scenario

Reviewing the current available sources for Dalby's water supply, there are a total of six different source combinations as outlined in Table 4.11:

Table 4.11: *Source combinations available for Dalby's Water supply.*

Source Combinations
Loudoun Weir, 'A' lvl Bores, 'B' lvl Bores
Loudoun Weir, 'A' lvl Bores
Loudoun Weir
B' lvl Bores
A' lvl Bores, 'B' lvl Bores
A' lvl Bores (doesn't meet demand requirements)

The following risk weighting criteria, risk question selection answers and justification into the model are as follows from the summary displayed in Figure 4.4. This remains the same for all six demand scenarios:

- Criticality to the system, what is the potential delay to identifying a potential issue (critical control point risks)? Refer to Section 4.2.3.3. for justification. 5% chosen based on experience considering that this demand lower rating compared to other criteria selected. Bore sources were deemed slightly higher rating due to and assessment of the critical infrastructure in use and in normal operations once the surface water source is operational there is more direct monitoring from an operator.
- Criticality to the system, what is the risk to the organisation of any critical infrastructure issues? Refer to Section 4.2.3.3. for justification. 20% chosen based on a review of the infrastructure asset condition. Loudoun Weir risk rating higher due to the infrastructure condition and that it is near the end of its useful life (Fagg, T 2023, pers. comm, 14 July).
- Regulatory Risk, what is the regulatory risk to using the source? Refer to Section 4.2.3.3. for justification. 20% chosen based on user experience and that WDRC's statutory obligations as a service provider demands weighting to this criteria. Low-Medium score was chosen due to all sources assessed required the same level of regulatory risks, assuming that no annual licensing conditions exceeded and that scenario is within the annual quantity entitlements.
- Operational, operational risks either in operator error or lack of staff to run a source? Refer to Section 4.2.3.3. for justification. 20% chosen based on user experience that errors do happen. Loudoun Weir was scored higher than the bore sources due to the operator supervision need based of the age of the infrastructure treating the surface water.
- Unique, Have any risks been identified that need to be managed (unique to the source)? Refer to Section 4.2.3.3. for justification. 2%, 4%, 2%, and 2% respectfully across 4 questions chosen based on user experience. Unique to the source, in past performance issues, maintenance, unusual changes in raw water quality present all identified are based on an assessment of the infrastructure condition, and some of the past issues associated with the

plant (user experience).

- Reputational/Social/Perceived, what is the reputational, social, perceived risk to the organization? Refer to Section 4.2.3.3. for justification. 5% chosen based on user experience of the site.
- Health/Safety, What is the risk to the operators (health/welfare/safety)? Refer to Section 4.2.3.3. for justification. 5% chosen based on WDRC's underlying value adopted aligns with safety.

	Weighting		Loudoun Weir		'A' Lvl Bores		'B' Lvl Bores
Criteria:	**100.00%**	**Risk Questions**	**Answer**	**Score**	**Answer**	**Score**	**Answer**
Criticality to the System	5%	***Vhat is the potential delay to identifying a potential issue (critical control point risks)?***	Low	*2*	Medium	*6*	Medium
Criticality to the System	20%	***What is the risk to the organisation of any critical infrastructure issues?***	Medium	*6*	Low	*2*	Low
Regulatory Risk	20%	***What is the regulatory risk to using the source?***	Low-Med	*4*	Low-Med	*4*	Low-Med
Operational	20%	***Operational risk either in operator error or lack of staff to run a source?***	Med-Hig	*8*	Low	*2*	Low-Med
Unique	2%	***Have any risks been identified that need to be managed (unique to the source)?***	Low	*2*	Low	*2*	Low
Unique	4%	***- Past performance issues with source?***	Low	*2*	Low	*2*	Low
Unique	2%	***- Maintenance issues present with plant?***	Medium	*6*	Low	*2*	Low-Med
Unique	2%	***- Unusual changes in Raw water quality present (plant may not be able to manage)?***	Low-Med	*4*	Low	*2*	Low
Reputa/social/perceived	5%	***What is the reputational/social/media/perceived risk to the organisation?***	Low-Med	*4*	Low	*2*	Low-Med
Health/Safety	20%	***What is the risk to the operators (health/ welfare/ safety)?***	Medium	*6*	Low	*2*	Low-Med
Subtotal	***100%***	*Subtotal*	***44***	***44***	***26***	***26***	***34***

Figure 4.3: *Risk Criteria weighting and Answers to Risk Questions for all six demand scenarios (from decision matrix)*

Figure 4.4 is an example of the output from the value risk matrix created for a demand scenario. The higher the value and risk, the least preferred a source combination is.

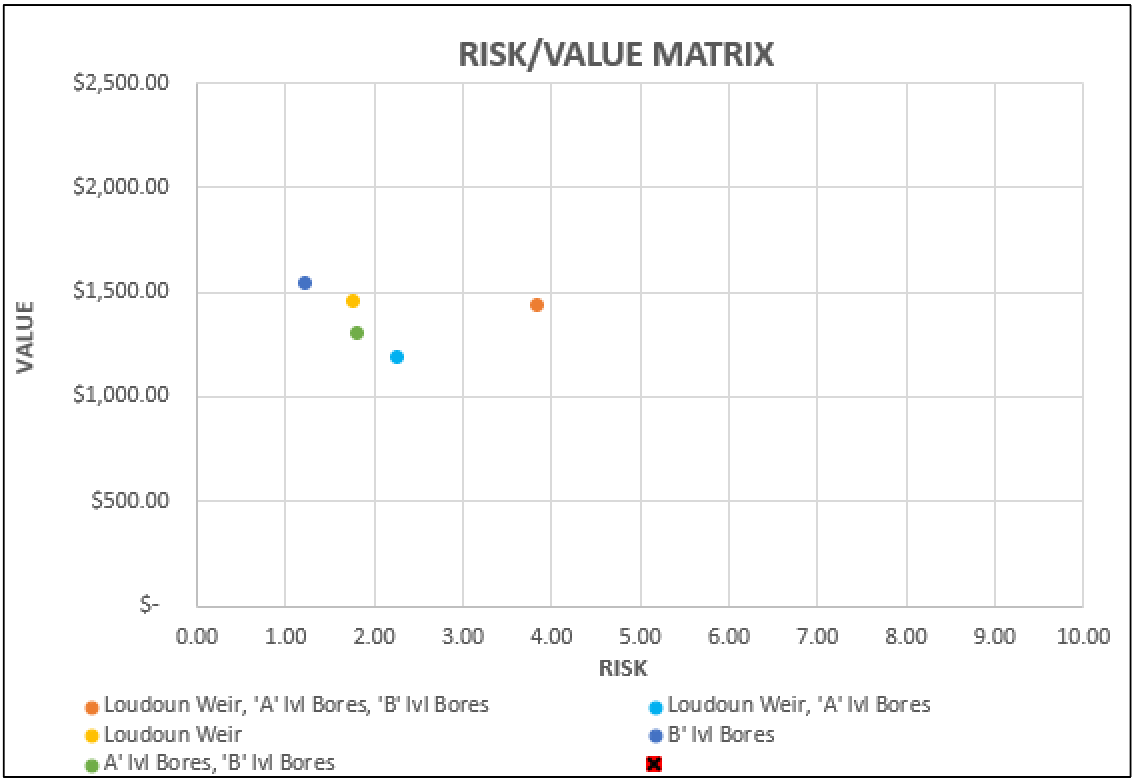

Figure 4.4: *Typical results from the value risk matrix created.*

4.3.3.1. 1. Annual Average Demand Scenario

The following selection criteria and the weightings input into the model are as follows with their justification as to how/why it was chosen:

- Demand = 4.58 ML/day (PPK, 1999/2000)
- Surface Water Turbidity = 20 NTU
- Source Availability = All sources available

The Annual Average Demand Scenario was based on the general historic average demand/operation approach. This specific scenario is important to validate and confirm the models accuracy over WDRC's historic data available from 2012-2022. The consumption remained relatively stable with an average consumption/demand of 4.48ML/day. 1999/2000 PPK's report "Dalby Raw Water Source Options Study-Part B Options Report" reported the daily average consumption/demand for Dalby of 4.58ML/day (PPK, 1999/2000). Therefore, the adopted annual daily average demand used in this scenario was 4.58ML/day.

It is assumed that all sources are available so that the comparison between all sources can be reviewed. The surface water turbidity set low at 20 NTU due to assuming minimal to no flow in the Condamine River.

Refer to Section 4.3.3 and Figure 4.3 for Risk weighting criteria, risk question selection answers and justification into the model for the risk score assessment. Note that the risk weightings, questions and risk question ratings scores remained the same/constant across all demand scenarios explored.

4.3.3.2. 2. Steady Flow Demand Scenario

The following selection criteria and the weightings input into the model are as follows with their justification as to how/why it was chosen:

- Demand = 4.58 ML/day
- Surface Water Turbidity = 100 NTU
- Source Availability = All sources available

The Steady Flow Demand Scenario was based on the 1999/2000 PPK's report "Dalby Raw Water Source Options Study-Part B Options Report" reported the daily average consumption/demand for Dalby of 4.58ML/day (PPK, 1999/2000). To support this, WDRC's historic data available from 2012-2022 consumption data was reviewed. The consumption remained relatively stable with an average consumption/demand of 4.48ML/day, therefore adopting the slightly larger demand of 4.58 ML/day.

It is assumed that all sources are available so that the comparison between all sources can be reviewed. The surface water turbidity was set moderate at 100 NTU due to assuming some flow in the

Condamine River with turbidity stirred up slightly, which may be found from a small to medium rainfall event.

Refer to Section 4.3.3 and Figure 4.3 for Risk weighting criteria, risk question selection answers and justification into the model for the risk score assessment. Note that the risk weightings, questions and risk question ratings scores remained the same/constant across all demand scenarios explored.

4.3.3.3. 3. Flood Demand Scenario

The following selection criteria and the weightings input into the model are as follows with their justification as to how/why it was chosen:

- Demand = 4.58 ML/day
- Surface Water Turbidity = >250 NTU
- Source Availability = All sources available

The Flood Demand Scenario was based on the 1999/2000 PPK's report "Dalby Raw Water Source Options Study-Part B Options Report" reported the daily average consumption/demand for Dalby of 4.58ML/day (PPK, 1999/2000). To support this, WDRC's historic data available from 2012-2022 consumption data was reviewed. The consumption remained relatively stable with an average consumption/demand of 4.48ML/day, therefore adopting the slightly larger demand of 4.58 ML/day.

It is assumed that all sources are available so that the comparison between all sources can be reviewed. The surface water turbidity set to high at 250 NTU due to assuming high flow in the Condamine River with turbidity greatly stirred up/increase as would be expected after heavy rainfall event.

Refer to Section 4.3.3 and Figure 4.3 for Risk weighting criteria, risk question selection answers and justification into the model for the risk score assessment. Note that the risk weightings, questions and risk question ratings scores remained the same/constant across all demand scenarios explored.

4.3.3.4. 4. Drought Demand Scenario

The following selection criteria and the weightings input into the model are as follows with their justification as to how/why it was chosen:

- Demand = 4.58 ML/day
- Surface Water Turbidity = N/A
- Source Availability = All sources available, except Loudoun Weir

The Drought Demand Scenario was based on the 1999/2000 PPK's report "Dalby Raw Water Source Options Study-Part B Options Report" reported the daily average consumption/demand for Dalby of 4.58ML/day (PPK, 1999/2000). To support this, WDRC's historic data available from 2012-2022 consumption data was reviewed. The consumption remained relatively stable with an average consumption/demand of 4.48ML/day, therefore adopting the slightly larger demand of 4.58 ML/day.

It is assumed that all sources except for the Loudoun Weir are available so that the comparison between available sources can be reviewed. The surface water turbidity not applicable due to surface water source not being available.

Refer to Section 4.3.3 and Figure 4.3 for Risk weighting criteria, risk question selection answers and justification into the model for the risk score assessment. Note that the risk weightings, questions and risk question ratings scores remained the same/constant across all demand scenarios explored.

4.3.3.5. 5. Maximum Demand Scenario

The following selection criteria and the weightings input into the model are as follows with their justification as to how/why it was chosen:

- Demand = 9.16 ML/day
- Surface Water Turbidity = 20 NTU
- Source Availability = All sources available

The Maximum Demand Scenario reviews the maximum daily consumption recorded by WDRC from January 2012 through to December 2022. The month observed to have the largest daily consumption was in January 2014 of 9.16ML/day, therefore being a logical demand to confirm the source options in the decision matrix.

It is assumed that all sources are available so that the comparison between all sources can be reviewed. The surface water turbidity set low at 20 NTU due to assuming minimal to no flow in the Condamine River.

Refer to Section 4.3.3 and Figure 4.3 for Risk weighting criteria, risk question selection answers and justification into the model for the risk score assessment. Note that the risk weightings, questions and risk question ratings scores remained the same/constant across all demand scenarios explored.

4.3.3.6. 6. Future Predicted Demand Scenario

The following selection criteria and the weightings input into the model are as follows with their justification as to how/why it was chosen:

- Demand = 5 ML/day (PPK, 1999/2000)
- Surface Water Turbidity = 20 NTU
- Source Availability = All sources available

1999/2000 PPK's report "Dalby Raw Water Source Options Study-Part B Options Report" predicted that the average consumption could increase to 5 ML/day in another 10 years (PPK, 1999/2000). After reviewing WDRC's daily average consumption of the full year data available from 2012 through to 2022 it has remained relatively stable with an average consumption/demand of 4.48ML/day, a minimum annual average daily consumption of 4.04ML/day, and a maximum annual average daily consumption of 5.137ML/day the Future Predicted Demand Scenario adopts the 5 ML/day daily average annual consumption.

It assumed that all sources are available so that the comparison between all sources can be reviewed. The surface water turbidity is low at 20 NTU due to assuming minimal to no flow in the Condamine River.

Refer to Section 4.3.3 and Figure 4.3 for Risk weighting criteria, risk question selection answers and justification into the model for the risk score assessment. Note that the risk weightings, questions and risk question ratings scores remained the same/constant across all demand scenarios explored.

4.3.4. Sensitivity/Analysis Approach

Evaluating model success:

In applying models in practice there are a number of ways to measure the success or failure in practice. Goeller (1988) suggested three measures as a basis for judging success:

1. Analysis Success - How the analysis was performed and presented;
2. Application success - How was it used or implemented in the management and planning process;
3. Outcome success - How the information derived from the model and its application affected the system design and/or operation and the lives of those who used the system.

It has been confirmed that the following sensitivity analysis areas are required to be investigated using the value risk matrix to simulate the sensitivity from user input/selection:

- The '**Risk Weighting Criteria**' and how the input might influence the results of the decision matrix. The following different weighting criteria scenarios have been selected for exploration against '1. Annual Average Demand Scenario' conditions as per Section 4.3.3.1., with all input/selection values remaining the same/constant except for the risk weighting criteria. Refer to Table 4.12 for the summary of the sensitivity analysis risk percentage weighting criteria scenarios:
    - **Typical Results Risk Weighting**: For the answers to the risk questions selected refer to Section 4.3.3. The results are to be used as a base line for the sensitivity analysis of the percentage weighting criteria scenarios.
    - **75% weighting in 1 Risk Weighting**: This scenario places 75% on one risk weighting

criteria. Safety has been adopted for the 75% with the remainder evenly distributed/split as reasonable as possible. For this assessment any of the criteria lines could have been selected for the 75% score, however Safety criteria was selected for the sake of the sensitivity analysis.

- **100% weighting in 1 Risk Weighting**: This scenario places 100% on one risk weighting criteria. Safety has been adopted for the 100% with the remainder of the criteria scoring a 0%. For this assessment any of the criteria lines could have been selected for the 100% score, however Safety criteria was selected for the sake of the sensitivity analysis.
- **Even Split Risk Weighting**: This scenario applies 10% on all risk weighting criteria questions. this assessment was selected to be reviewed against the 'Typical Results Risk Weighting' scenario, providing an even split of the percentages across all criteria questions.

Table 4.12: *Sensitivity Analysis Risk Percentage Weighting Criteria Scenarios.*

Sensitivity Analysis Scenarios	Typical Results Weighting	75% in 1 Weighting	100% in 1 Weighting	Even Split Weighting
Criteria:	100.00%	100.00%	100.00%	100.00%
Criticality to the System	5%	3%	0%	10%
Criticality to the System	20%	3%	0%	10%
Regulatory Risk	20%	3%	0%	10%
Operational	20%	3%	0%	10%
Unique	2%	3%	0%	10%
Unique	2%	2%	0%	10%
Unique	2%	2%	0%	10%
Reputa/social/perceived	5%	3%	0%	10%
Health/Safety	20%	75%	100%	10%
Subtotal	***100%***	***100%***	***100%***	***100%***

- The **'Answering Risk Questions Selection'** area has also been identified to assess how sensitive it is to user selection and how it might influence the results of the decision matrix. Refer to Section 4.3.3 and Figure 4.3 for Risk weighting criteria adopted for all sensitivity analysis on 'answering risk questions selection'. The following different risk question selection scenarios have been selected for exploration of the 'answering risk questions selection' in the sensitivity analysis:

- **Typical Results Risk Assessment**: Refer to Figure 4.5 for the answers to the risk questions selected as per Section 4.3.3. The results are to be used as a base line for the sensitivity analysis of the risk question selection score sensitivity analysis.

	Loudoun Weir		'A' Lvl Bores		'B' Lvl Bores	
Risk Questions	**Answer**	**Score**	**Answer**	**Score**	**Answer**	**Score**
What is the potential delay to identifying a potential issue (critical control point risks)?	Low	*2*	Medium	*6*	Medium	*6*
What is the risk to the organisation of any critical infrastructure issues?	Medium	*6*	Low	*2*	Low	*2*
What is the regulatory risk to using the source?	Low-Med	*4*	Low-Med	*4*	Low-Med	*4*
Operational risk either in operator error or lack of staff to run a source?	Med-Hig	*8*	Low	*2*	Low-Med	*4*
Have any risks been identified that need to be managed (unique to the source)?	Low	*2*	Low	*2*	Low	*2*
- Past performance issues with source?	Low	*2*	Low	*2*	Low	*2*
- Maintenance issues present with plant?	Medium	*6*	Low	*2*	Low-Med	*4*
- Unusual changes in Raw water quality present (plant may not be able to manage)?	Low-Med	*4*	Low	*2*	Low	*2*
What is the reputational/social/media/perceived risk to the organisation?	Low-Med	*4*	Low	*2*	Low-Med	*4*
What is the risk to the operators (health/ welfare/ safety)?	Medium	*6*	Low	*2*	Low-Med	*4*
Subtotal	*44*	*44*	*26*	*26*	*34*	*34*

Figure 4.5: *Answers to Risk Questions for "Typical Results Risk Assessment" Scenario.*

- **All Risk Scores Low**: Refer to Figure 4.6 for the answers to the risk questions selected. This scenario selects a low score for all risk question answers in calculating a risk value score. This has been selected due to see how the results are affected by minimal scores across all risk questions.

	Loudoun Weir		'A' Lvl Bores		'B' Lvl Bores	
Risk Questions	**Answer**	**Score**	**Answer**	**Score**	**Answer**	**Score**
What is the potential delay to identifying a potential issue (critical control point risks)?	Low	*2*	Low	*2*	Low	*2*
What is the risk to the organisation of any critical infrastructure issues?	Low	*2*	Low	*2*	Low	*2*
What is the regulatory risk to using the source?	Low	*2*	Low	*2*	Low	*2*
Operational risk either in operator error or lack of staff to run a source?	Low	*2*	Low	*2*	Low	*2*
Have any risks been identified that need to be managed (unique to the source)?	Low	*2*	Low	*2*	Low	*2*
- Past performance issues with source?	Low	*2*	Low	*2*	Low	*2*
- Maintenance issues present with plant?	Low	*2*	Low	*2*	Low	*2*
- Unusual changes in Raw water quality present (plant may not be able to manage)?	Low	*2*	Low	*2*	Low	*2*
What is the reputational/social/media/perceived risk to the organisation?	Low	*2*	Low	*2*	Low	*2*
What is the risk to the operators (health/ welfare/ safety)?	Low	*2*	Low	*2*	Low	*2*
Subtotal	*20*	*20*	*20*	*20*	*20*	*20*

Figure 4.6: *Answers to Risk Questions for "All Risk Scores Low" Scenario.*

- **All Risk Scores High**: Refer to Figure 4.7 for the answers to the risk questions selected. This scenario selects a high score for all risk question answers in calculating a risk value score. This has been selected due to see how the results are affected by high value scores across all risk questions.

	Loudoun Weir		'A' Lvl Bores		'B' Lvl Bores	
Risk Questions	Answer	Score	Answer	Score	Answer	Score
What is the potential delay to identifying a potential issue (critical control point risks)?	High	*10*	High	*10*	High	*10*
What is the risk to the organisation of any critical infrastructure issues?	High	*10*	High	*10*	High	*10*
What is the regulatory risk to using the source?	High	*10*	High	*10*	High	*10*
Operational risk either in operator error or lack of staff to run a source?	High	*10*	High	*10*	High	*10*
Have any risks been identified that need to be managed (unique to the source)?	High	*10*	High	*10*	High	*10*
- Past performance issues with source?	High	*10*	High	*10*	High	*10*
- Maintenance issues present with plant?	High	*10*	High	*10*	High	*10*
- Unusual changes in Raw water quality present (plant may not be able to manage)?	High	*10*	High	*10*	High	*10*
What is the reputational/social/media/perceived risk to the organisation?	High	*10*	High	*10*	High	*10*
What is the risk to the operators (health/ welfare/ safety)?	High	*10*	High	*10*	High	*10*
Subtotal	*100*	*100*	*100*	*100*	*100*	*100*

Figure 4.7: *Answers to Risk Questions for "All Risk Scores High" Scenario.*

- **1 x High Score**: Refer to Figure 4.8 for the answers to the risk questions selected. This scenario selects a high score 1 risk question answers in calculating a risk value score. This has been selected to align with the evaluation criteria weighting sensitivity analysis due to see how the results are affected by high value scores across all risk questions. For this assessment any of the criteria lines could have been selected for the 100% score, however Safety criteria was selected for the sake of the sensitivity analysis.

	Loudoun Weir		'A' Lvl Bores		'B' Lvl Bores	
Risk Questions	Answer	Score	Answer	Score	Answer	Score
What is the potential delay to identifying a potential issue (critical control point risks)?	Low	*2*	Medium	*6*	Medium	*6*
What is the risk to the organisation of any critical infrastructure issues?	Medium	*6*	Low	*2*	Low	*2*
What is the regulatory risk to using the source?	Low-Med	*4*	Low-Med	*4*	Low-Med	*4*
Operational risk either in operator error or lack of staff to run a source?	Med-Hig	*8*	Low	*2*	Low-Med	*4*
Have any risks been identified that need to be managed (unique to the source)?	Low	*2*	Low	*2*	Low	*2*
- Past performance issues with source?	Low	*2*	Low	*2*	Low	*2*
- Maintenance issues present with plant?	Medium	*6*	Low	*2*	Low-Med	*4*
- Unusual changes in Raw water quality present (plant may not be able to manage)?	Low-Med	*4*	Low	*2*	Low	*2*
What is the reputational/social/media/perceived risk to the organisation?	Low-Med	*4*	Low	*2*	Low-Med	*4*
What is the risk to the operators (health/ welfare/ safety)?	High	*10*	High	*10*	High	*10*
Subtotal	*48*	*48*	*34*	*34*	*40*	*40*

Figure 4.8: *Answers to Risk Questions for "1 x High Score" Scenario.*

With the intent of this project aiming to optimise the strategy for water source development to achieve a reliable, cost effective potable water supply for Dalby QLD the methodology presented achieves this aim by achieving the following objectives:

- To develop an evaluation method by which the water source development can be optimised, by creating a value risk matrix.
- Access the current operational costs, and current/future risks of water supply for Dalby, by completing an operational cost analysis.

5. *Results/Analysis*

A decision matrix for source optimisation was developed comparing value and risk of different water source combinations. Reviewing the current available sources to Dalby's water supply there are a total of six different source combinations as outlined in Table 4.11:

5.1. Demand Scenario Results

This phase involved validating/testing the model created under different demand scenarios identified to be explored below and as per Section 4.3.3.:

1. Annual Average Demand Scenario
2. Steady Flow Demand Scenario
3. Flood Demand Scenario
4. Drought Demand Scenario
5. Maximum Demand Scenario
6. Future Predicted Demand Scenario

5.1.1. 1. Annual Average Demand Scenario

The following selection criteria and the weightings input as per Section 4.3.3.1. with summary as follows, with the results of the value risk matrix displayed in Figure 5.1 and Table 5.1:

- Demand = 4.58 ML/day
- Surface Water Turbidity = 20 NTU
- Source Availability = All sources available

Table 5.1: *Annual Average Demand Scenario tabled results from the value risk matrix.*

Source Combinations	***Value***	***Risk***
Loudoun Weir, 'A' lvl Bores, 'B' lvl Bores	$1,449.11	3.81
Loudoun Weir, 'A' lvl Bores	$1,194.69	2.23
Loudoun Weir	$1,469.73	1.75
B' lvl Bores	$1,543.13	1.21
A' lvl Bores, 'B' lvl Bores	$1,325.20	1.80
A' lvl Bores (doesn't meet demand requirements)	-	-

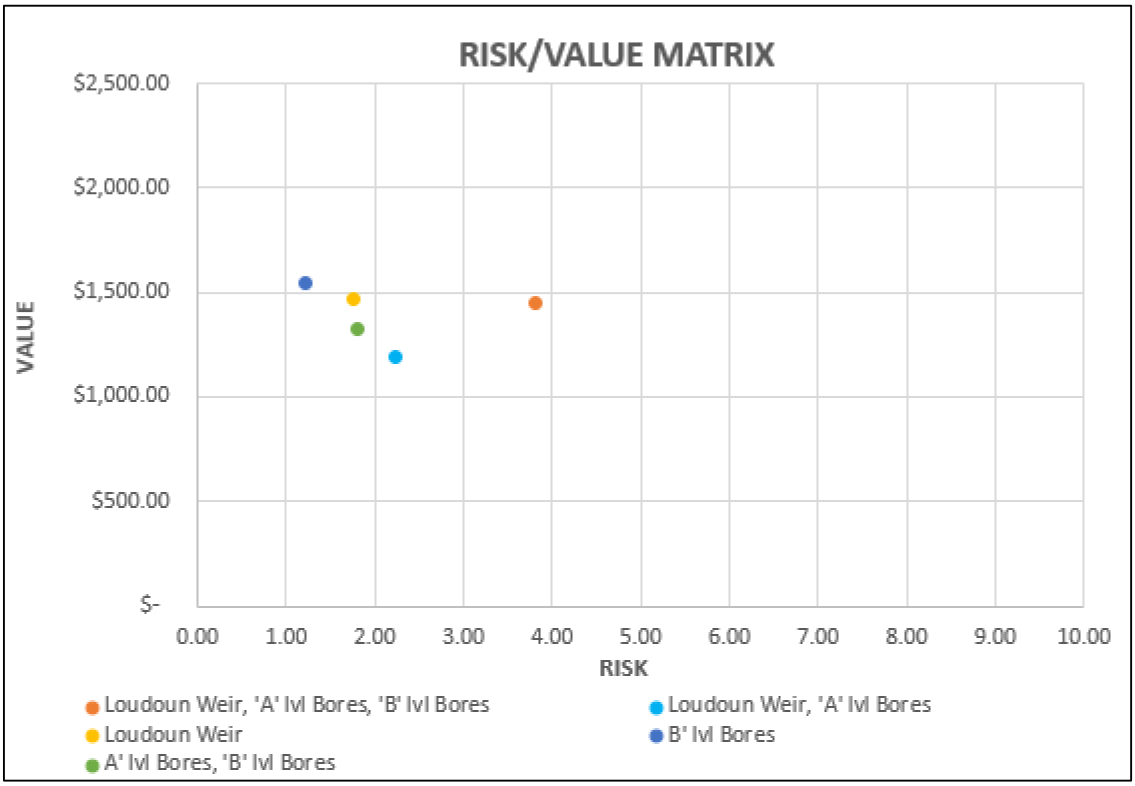

Figure 5.1: *Annual Average Demand Scenario results from the value risk matrix.*

As can be observed in both Figure 5.1 and Table 5.1 source combination "Loudoun Weir, 'A' Level Bores" can be deemed the most favourable due to the lowest value and a low risk level calculated in this particular scenario. Out of the six different source combinations available, five have been able to provide the required demand, with 'A' Level Bores not being able to meet demand requirements.

5.1.2. 2. Steady Flow Demand Scenario

The following selection criteria and the weightings input into the model are as per Section 4.3.3.2. with summary as follows, with the results of the value risk matrix displayed in Figure 5.2 and Table 5.2:

- Demand = 4.58 ML/day
- Surface Water Turbidity = 100 NTU
- Source Availability = All sources available

Table 5.2: *Steady Flow Demand Scenario tabled results from the value risk matrix.*

• ***Source Combinations***	***Value***	***Risk***
Loudoun Weir, 'A' lvl Bores, 'B' lvl Bores	$1,529.73	4.10
Loudoun Weir, 'A' lvl Bores	$1,330.47	2.52
Loudoun Weir	$1,711.59	2.03
B' lvl Bores	$1,543.13	1.21
A' lvl Bores, 'B' lvl Bores	$1,325.20	1.80
A' lvl Bores (doesn't meet demand requirements)	-	-

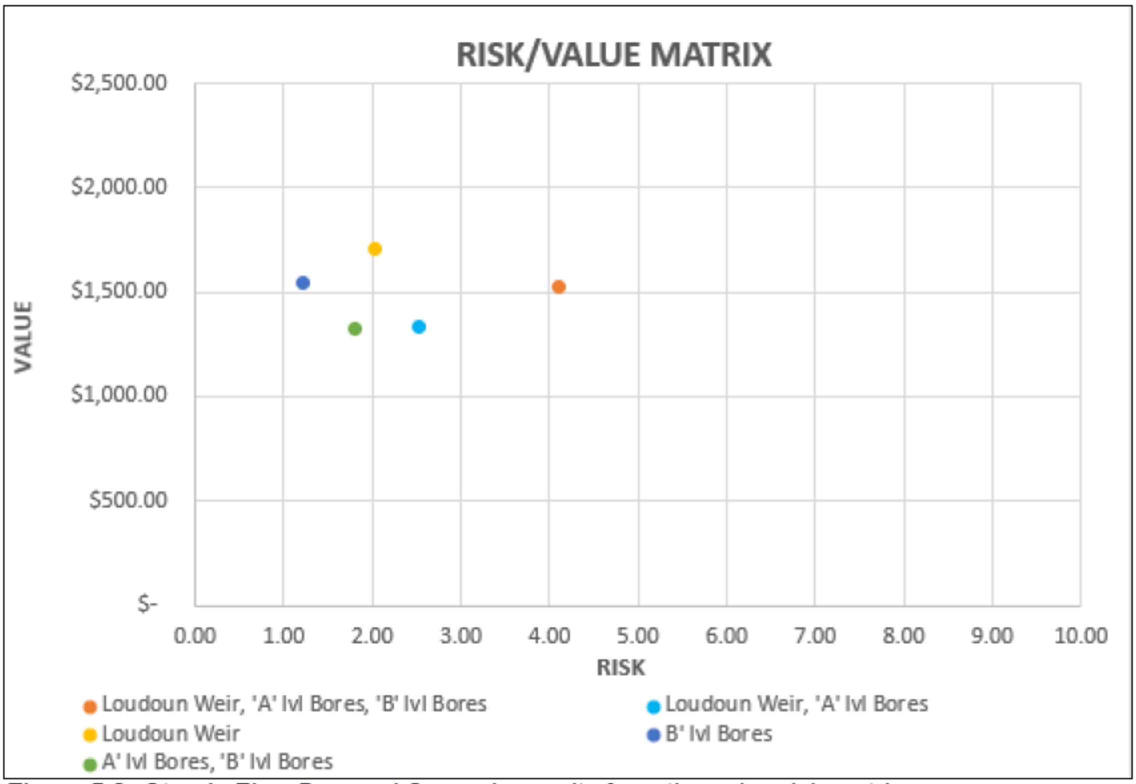

Figure 5.2: *Steady Flow Demand Scenario results from the value risk matrix.*

As can be observed in both Figure 5.2 and Table 5.2 source combination "'A' Level Bores, 'B' Level Bores " can be deemed the most favourable due to the lowest value and a low risk level calculated in this particular scenario. Out of the six different source combinations available, five have been able to provide the required demand, with 'A' Level Bores not being able to meet demand requirements.

5.1.3. 3. Flood Demand Scenario

The following selection criteria and the weightings input into the model are as per Section 4.3.3.3. with summary as follows, with the results of the value risk matrix displayed in Figure 5.3 and Table 5.3:

- Demand = 4.58 ML/day
- Surface Water Turbidity = >250 NTU
- Source Availability = All sources available

Table 5.3: *Flood Demand Scenario tabled results from the value risk matrix.*

Source Combinations	***Value***	***Risk***
Loudoun Weir, 'A' lvl Bores, 'B' lvl Bores	$1,696.93	4.69
Loudoun Weir, 'A' lvl Bores	$1,612.07	3.11
Loudoun Weir	$2,213.19	2.63
B' lvl Bores	$1,543.13	1.21
A' lvl Bores, 'B' lvl Bores	$1,325.20	1.80
A' lvl Bores (doesn't meet demand requirements)	-	-

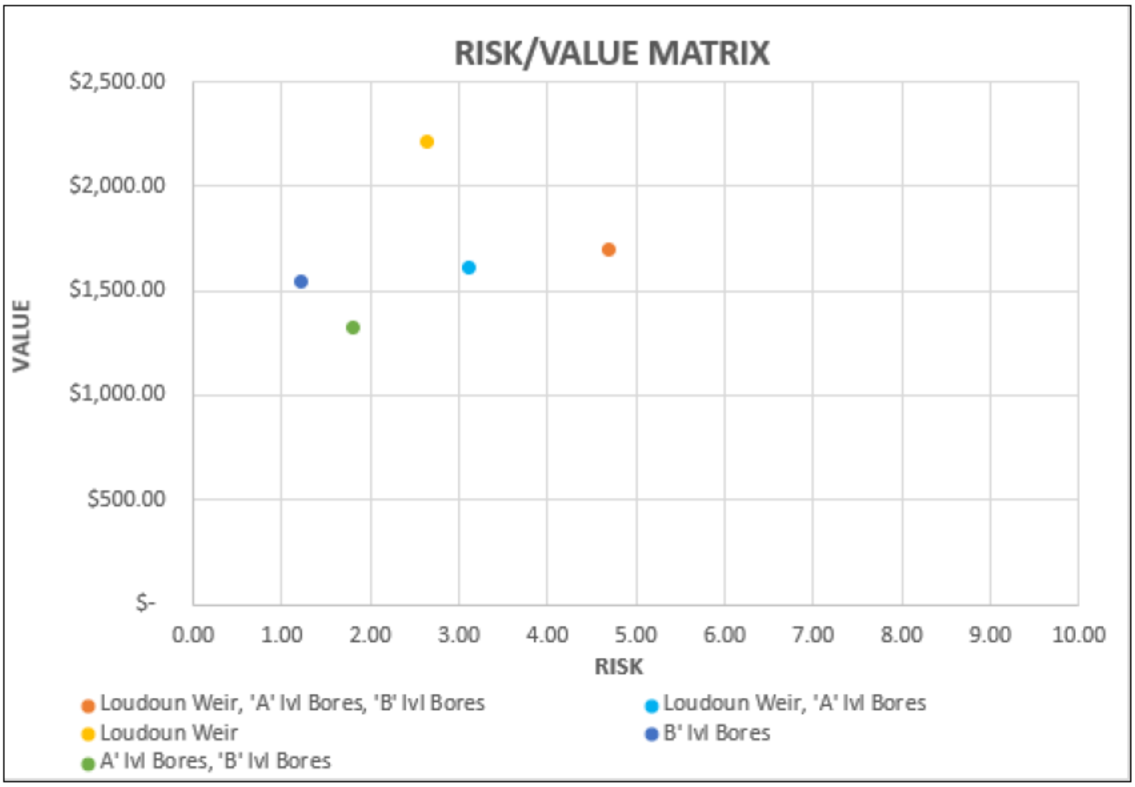

Figure 5.3: *Flood Demand Scenario results from the value risk matrix.*

As can be observed in both Figure 5.3 and Table 5.3 source combination "'A' Level Bores, 'B' Level Bores " can be deemed the most favourable due to the lowest value and a low risk level calculated in this particular scenario. Out of the six different source combinations available, five have been able to provide the required demand, with 'A' Level Bores not being able to meet demand requirements.

5.1.4. 4. Drought Demand Scenario

The following selection criteria and the weightings input into the model are as per Section 4.3.3.4. with summary as follows, with the results of the value risk matrix displayed in Figure 5.4 and Table 5.4:

- Demand = 4.58 ML/day
- Surface Water Turbidity = N/A
- Source Availability = All sources available, except Loudoun Weir

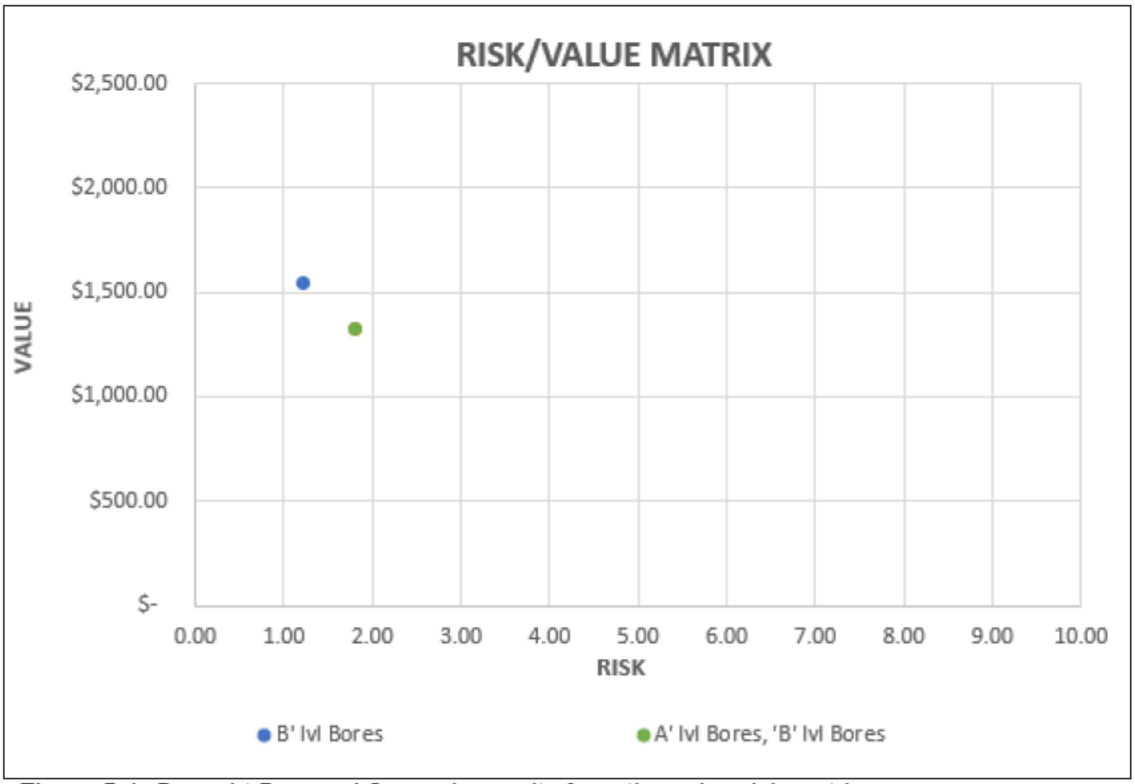

Figure 5.4: *Drought Demand Scenario results from the value risk matrix.*

Table 5.4: *Drought Demand Scenario tabled results from the value risk matrix.*

Source Combinations	***Value***	***Risk***
~~Loudoun Weir, 'A' lvl Bores, 'B' lvl Bores~~	-	-
~~Loudoun Weir, 'A' lvl Bores~~	-	-
~~Loudoun Weir~~	-	-
B' lvl Bores	$1,543.13	1.21
A' lvl Bores, 'B' lvl Bores	$1,325.20	1.80
A' lvl Bores (doesn't meet demand requirements)	-	-

As can be observed in both Figure 5.4 and Table 5.4 source combination "'A' Level Bores, 'B' Level Bores " can be deemed the most favourable due to the lowest value and a low risk level calculated in this particular scenario. Out of the six different source combinations available, two were able to provide the required demand, with 'A' Level Bores not being able to meet demand requirements. It should be noted that Loudoun Weir would be unavailable during a drought scenario therefore three source combinations not considered.

5.1.5. 5. Maximum Demand Scenario

The following selection criteria and the weightings input into the model are as per Section 4.3.3.5. with summary as follows, with the results of the value risk matrix displayed in Figure 5.5 and Table 5.5:

- Demand = 9.16 ML/day
- Surface Water Turbidity = 20 NTU
- Source Availability = All sources available

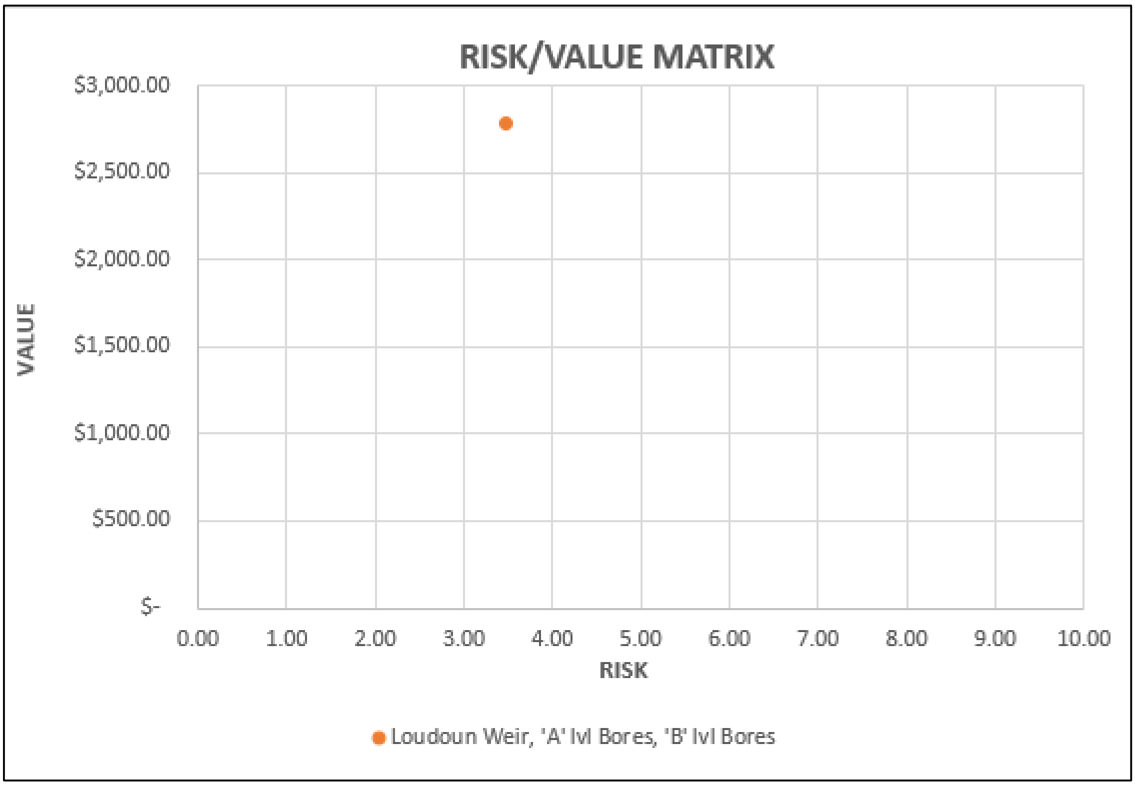

Figure 5.5: *Maximum Demand Scenario results from the value risk matrix.*

Table 5.5: *Maximum Demand Scenario tabled results from the value risk matrix.*

Source Combinations	***Value***	***Risk***
Loudoun Weir, 'A' lvl Bores, 'B' lvl Bores	$2,784.08	3.47
Loudoun Weir, 'A' lvl Bores (doesn't meet demand requirements)	-	-
Loudoun Weir (doesn't meet demand requirements)	-	-
B' lvl Bores (doesn't meet demand requirements)	-	-
A' lvl Bores, 'B' lvl Bores (doesn't meet demand requirements)	-	-
A' lvl Bores (doesn't meet demand requirements)	-	-

As can be observed in both Figure 5.5 and Table 5.5 source combination " Loudoun Weir, 'A' lvl Bores, 'B' lvl Bores" can be deemed the most favourable due to the lowest value and low/medium risk level calculated in this particular scenario. Out of the six different source combinations available, only one was deemed to be able to provide the required demand.

5.1.6. 6. Future Predicted Demand Scenario

The following selection criteria and the weightings input into the model are as per Section 4.3.3.6. with summary as follows, with the results of the value risk matrix displayed in Figure 5.6 and Table 5.6:

- Demand = 5 ML/day
- Surface Water Turbidity = 20 NTU
- Source Availability = All sources available

Table 5.6: *Future Predicted Demand Scenario tabled results from the value risk matrix.*

Source Combinations	***Value***	***Risk***
Loudoun Weir, 'A' lvl Bores, 'B' lvl Bores	$1,570.30	3.79
Loudoun Weir, 'A' lvl Bores	$1,328.26	2.21
Loudoun Weir	$1,603.30	1.74
B' lvl Bores	$1,543.13	1.21
A' lvl Bores, 'B' lvl Bores	$1,457.70	1.76
A' lvl Bores (doesn't meet demand requirements)	-	-

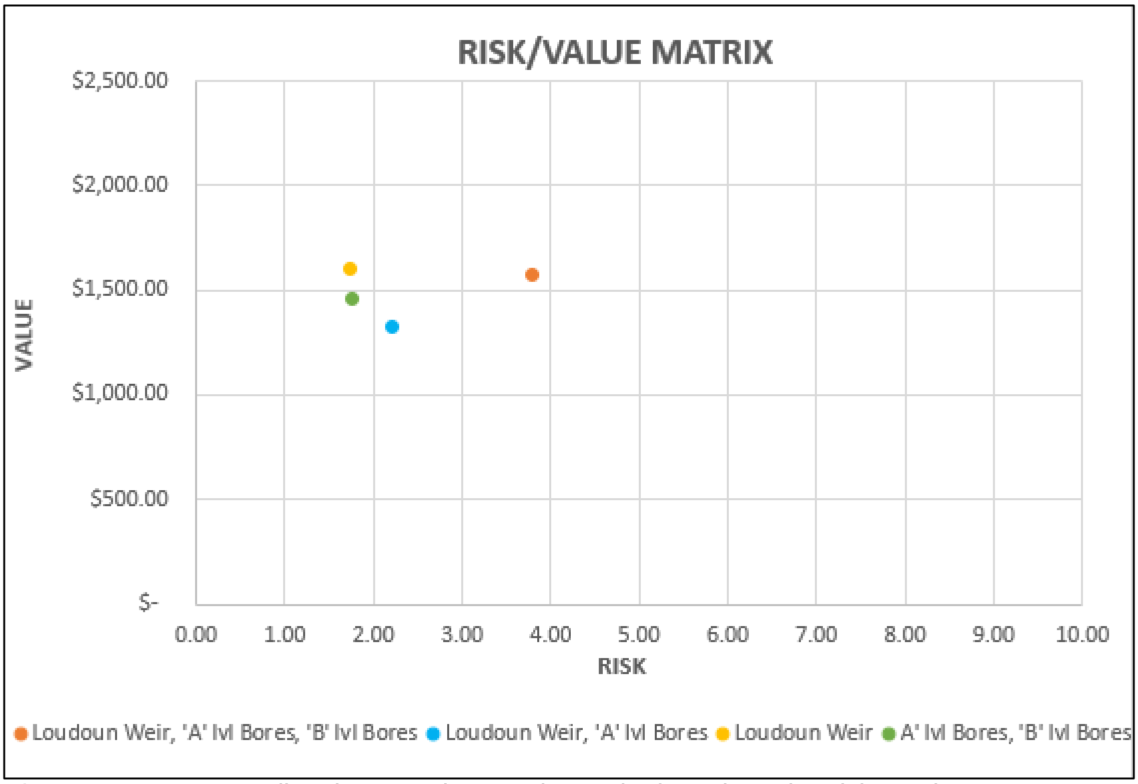

Figure 5.6: *Future Predicted Demand Scenario results from the value risk matrix.*

As can be observed in both Figure 5.6 and Table 5.6 source combination "Loudoun Weir, can be deemed the most favourable due to the lowest value and a low risk level calculated in this particular scenario. Out of the six different source combinations available, four have been able to provide the required demand.

5.2. Sensitivity/Analysis Approach

It has been confirmed that the following sensitivity analysis areas is required to be investigated using the value risk matrix to simulate the sensitivity from user input/selection. This phase involved validating/testing the model created under different scenarios identified to be explored below and as per Section 4.3.4.:

- The '**Risk Weighting Criteria**' and how the input might influence the results of the decision matrix. The following different weighting criteria scenarios have been selected for exploration against '1. Annual Average Demand Scenario' conditions as per Section 4.3.3.1. with all input/selection values remaining the same/constant except for the risk weighting criteria. Refer to Table 4.12 for the summary of the sensitivity analysis risk percentage weighting criteria scenarios. Refer to Table 5.7 for summary of the Sensitivity Analysis Risk Percentage Weighting Criteria Scenario Results:
    - **Typical Results Risk Weighting**: For the answers to the risk questions selected refer

to Section 4.3.3. For results refer to both Figure 5.1 and Table 5.1 of this scenario.

- **75% weighting in 1 Risk Weighting**: This scenario places 75% on one risk weighting criteria. Safety has been adopted for the 75% with the remainder evenly distributed/split as reasonable as possible.
- **100% weighting in 1 Risk Weighting**: This scenario places 100% on one risk weighting criteria. Safety has been adopted for the 100% with the remainder of the criteria scoring a 0%.
- **Even Split Risk Weighting**: This scenario applies 10% on all risk weighting criteria questions.

Table 5.7: *Sensitivity Analysis Risk Percentage Weighting Criteria Scenarios.*

Sensitivity Analysis Scenarios		**Typical Results Weighting**	**75% in 1 Weighting**	**100% in 1 Weighting**	**Even Split Weighting**
Criteria:		**100.00%**	**100.00%**	**100.00%**	**100.00%**
Criticality to the System		5%	3%	0%	10%
Criticality to the System		20%	3%	0%	10%
Regulatory Risk		20%	3%	0%	10%
Operational		20%	3%	0%	10%
Unique		2%	3%	0%	10%
Unique		4%	3%	0%	10%
Unique		2%	2%	0%	10%
Unique		2%	2%	0%	10%
Reputa/social/perceived		5%	3%	0%	10%
Health/Safety		20%	75%	100%	10%
Subtotal		***100%***	***100%***	***100%***	***100%***
Source Combinations	**Value**	**Risk**	**Risk**	**Risk**	**Risk**
Loudoun Weir, 'A' lvl Bores, 'B' lvl Bores	$ 1,449.11	3.81	3.89	4.08	3.41
Loudoun Weir, 'A' lvl Bores	$ 1,194.69	2.23	2.19	2.31	1.90
Loudoun Weir	$ 1,469.73	1.75	1.79	1.93	1.42
B' lvl Bores	$ 1,543.13	1.21	1.32	1.37	1.17
A' lvl Bores, 'B' lvl Bores	$ 1,325.20	1.80	1.84	1.86	1.75
A' lvl Bores (doesn't meet demand requirements)	$ 366.28	0.48	0.40	0.37	0.48

As can be observed in the results of the sensitivity analysis the '**Risk Weighting Criteria**' does have some small influence on the results of the decision matrix. When there is a large risk weighting entered in the weighting criteria to a particular question it increases the risk score. It should be noted all input/selection values in the decision matrix remain the same/constant except for the risk weighting criteria being analysed as per Table 5.7.

- The **'Answering Risk Questions Selection'** area has also been identified to assess how sensitive it is to user selection and how it might influence the results of the decision matrix. Refer to Section 4.3.3, Section 4.3.4 and Figure 4.3 for Risk weighting criteria adopted for all sensitivity analysis on 'answering risk questions selection'. The following different risk question selection scenarios have been selected for exploration of the 'answering risk questions selection' in the sensitivity analysis:
    - **Typical Results Risk Assessment**: Refer to Figure 4.5 for the answers to the risk questions selected as per Section 4.3.3. For results refer to both Figure 5.1, Table 5.1 and Table 5.8 of this scenario.

    - **All Risk Scores Low**: Refer to Figure 4.6 for the answers to the risk questions selected. This scenario selects a low score for all risk question answers in calculating a risk value score. For results refer to both Figure 5.7 and Table 5.8 of this scenario.

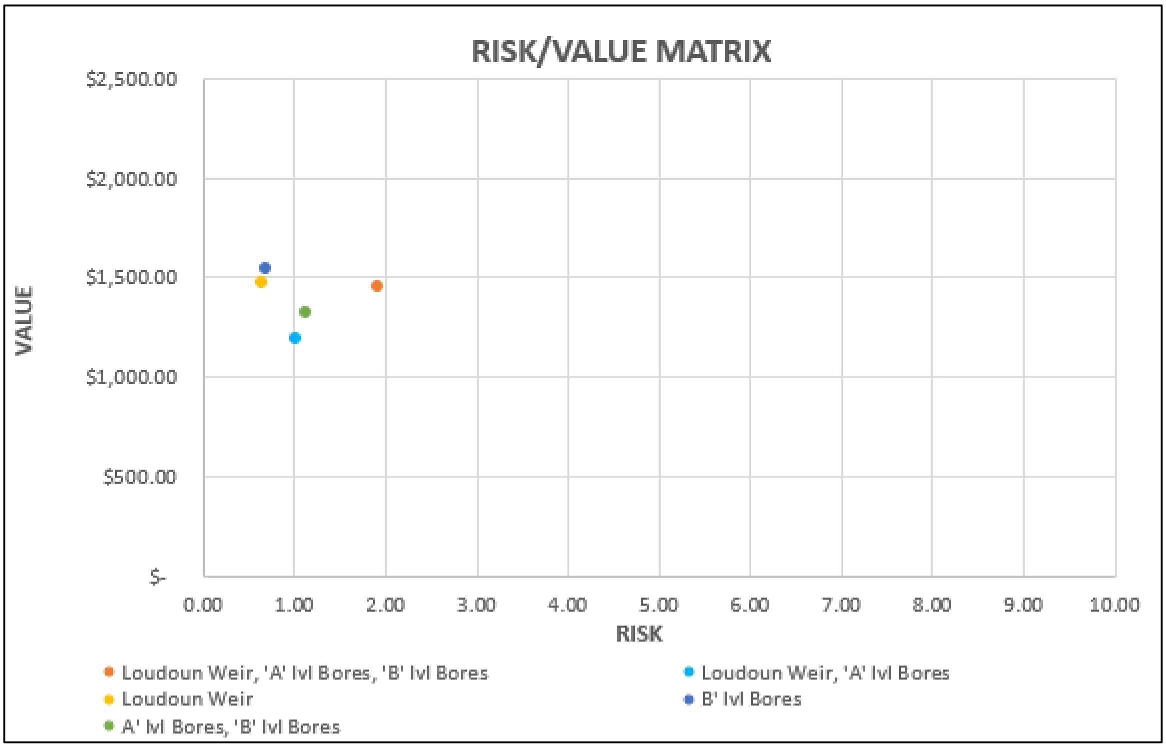

Figure 5.7: Results *Answers to Risk Questions for "All Risk Scores Low" Scenario.*

- **All Risk Scores High**: Refer to Figure 4.7 for the answers to the risk questions selected. This scenario selects a high score for all risk question answers in calculating a risk value score. For results refer to both Figure 5.8 and Table 5.8 of this scenario.

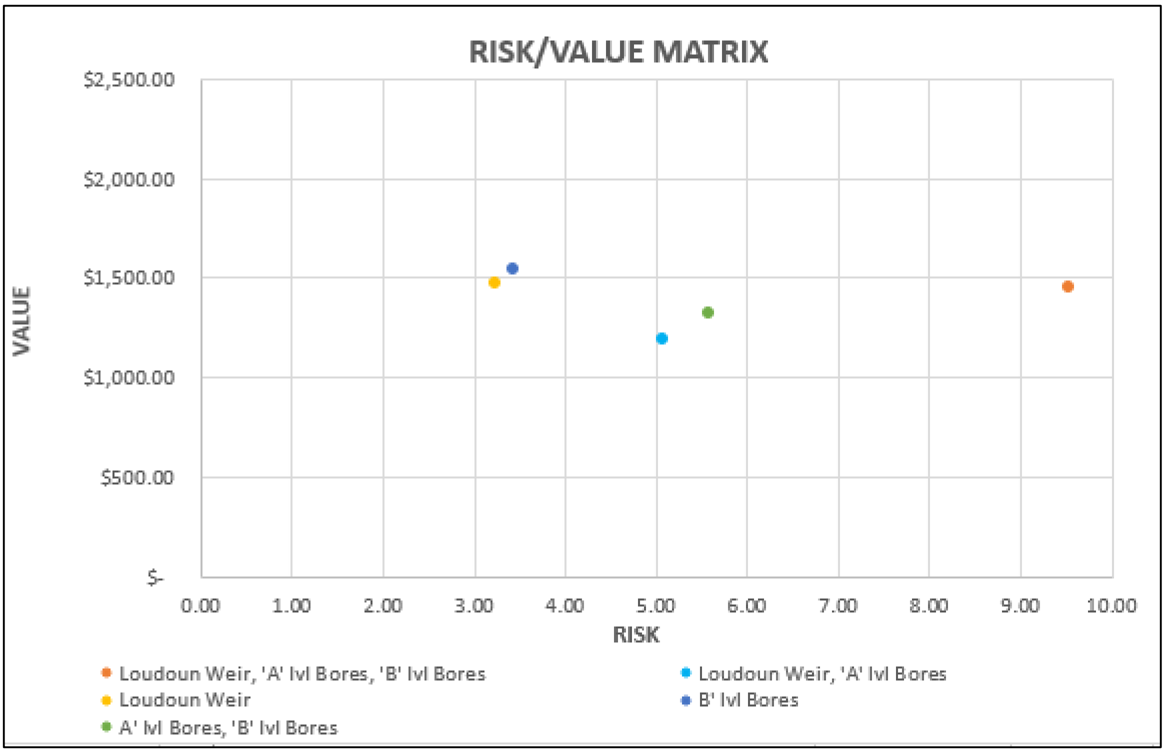

Figure 5.8: Results *Answers to Risk Questions for "All Risk Scores High" Scenario.*

- **1 x High Score**: Refer to Figure 4.8 for the answers to the risk questions selected. This scenario selects a high score 1 risk question answers in calculating a risk value score. For results refer to both Figure 5.9 and Table 5.8 of this scenario.

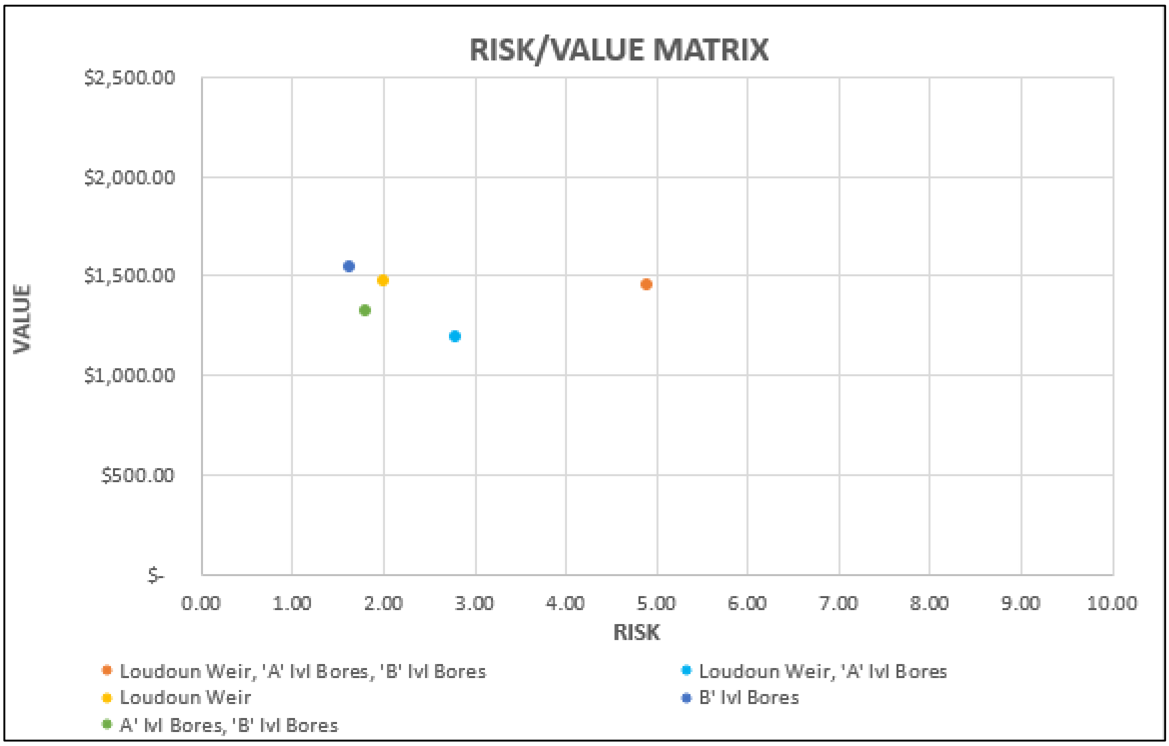

Figure 5.9: Results *Answers to Risk Questions for "1 x High Score" Scenario.*

Table 5.8: *Sensitivity Analysis 'Answering Risk Questions Selection Criteria Scenarios.*

Source Combinations	Value	Typical Results Risk Questions	All Risk Scores Low Risk Questions	All Risk Scores High Risk Questions	1 x High Score Risk Questions
Loudoun Weir, 'A' lvl Bores, 'B' lvl Bores	$ 1,449.11	3.81	1.91	9.53	4.90
Loudoun Weir, 'A' lvl Bores	$ 1,194.69	2.23	1.01	5.07	2.78
Loudoun Weir	$ 1,469.73	1.75	0.64	3.22	2.00
B' lvl Bores	$ 1,543.13	1.21	0.69	3.43	1.63
A' lvl Bores, 'B' lvl Bores	$ 1,325.20	1.80	1.12	5.58	2.54
A' lvl Bores (doesn't meet demand requirements)	$ 366.28	0.48	0.37	1.83	0.77

As can be observed in the results of the sensitivity analysis the **'Answering Risk Questions Selection**' does have an influence on the results of the decision matrix. When there is a large risk weighting entered in the weighting criteria and the selected answer is high to a particular question it noticeably increases the risk score. It should be noted all input/selection values in the decision matrix remain the same/constant except for the risk questions selection answer being analysed as per Table 5.8.

6. Discussion

From the results the 'A' level alluvium bores present the most favoured water source from a value to risk consideration from the evaluation tool created. However the 'A' level bore source alone can't solely meet the average daily demand of 4.58 ML/day for the town of Dalby. In combination with another source, this source combination ultimately becomes the most favoured source combination due to the low value and risk scores associated with the 'A' level bore. In lower turbidity conditions, from 20 NTU to 100 NTU the Loudoun Weir in combination with 'A' level bore becomes the most preferred option. However as the turbidity increases in the Loudoun Weir beyond the 100 NTU level, so does the value score associated with this source making 'B' level bores in combination with 'A' level bores the preferred source combination.

Annual Average Demand Scenario results as can be observed in both Figure 5.1 and Table 5.1 source combination "Loudoun Weir, 'A' Level Bores" can be deemed the most favourable due to the lowest value score and a low risk level calculated in this scenario. This is because the lower turbidity of 20 NTU generates a competitive value score, and when in Loudoun Weir is in combination 'A" level bore source it becomes the most preferred. An observation from the results of this scenario Loudoun Weir when compared to 'B' level bores by itself is that Loudoun Weir value score is lower.

Steady Flow Demand Scenario results as can be observed in both Figure 5.2 and Table 5.2 source combination "'A' Level Bores, 'B' Level Bores " can be deemed the most favourable due to the lowest value and a low risk level calculated in this particular scenario. The "Loudoun Weir, 'A' Level Bores" source combination performed well with only a slightly higher value present and a risk score of only 0.5 greater still presenting a strong result. As compared to the annual average demand scenario the results for any course combination including Loudoun Weir have increased slightly due to the turbidity increase from 20 NTU to 100 NTU. This has directly increased the value score to approximately the same as the "'A' Level Bores, 'B' Level Bores " source combination.

Flood Demand Scenario results as can be observed in both Figure 5.3 and Table 5.3 source combination "'A' Level Bores, 'B' Level Bores " can be deemed the most favourable due to the lowest value score and a low risk level calculated in this particular scenario. Due to the turbidity increasing to >250 NTU for the Loudoun Weir source, this has increased the value score of any source combination including Loudoun Weir and making it the least preferred source from a value perspective.

Drought Demand Scenario results as can be observed in both Figure 5.4 and Table 5.4 source combination "'A' Level Bores, 'B' Level Bores " can be deemed the most favourable due to the lowest value and a low risk level calculated in this scenario. Out of the six different source combinations available, two were able to provide the required demand. It should be noted that Loudoun Weir was assumed to be unavailable in simulating the drought scenario. The results from this scenario really highlights the importance and criticality of the 'A' and 'B' Level Bore water sources. but with the unavailability of the Loudoun Weir also does highlight the importance of this source when it is available and that there could some avenue based on the results of the dissertation that this water source could be more utilised in lower turbidity conditions.

Maximum Demand Scenario results as can be observed in both Figure 5.5 and Table 5.5 source combination " Loudoun Weir, 'A' level Bores, 'B' level Bores" can be deemed the most favourable due to the lowest value and low/medium risk level calculated in this particular scenario. Out of the six different source combinations available, only one was deemed to be able to provide the required demand. The results from this scenario really highlights the importance and criticality of all three available sources to meet peak maximum demands for Dalby. If one of these sources isn't available the treatment plant won't keep up with a peak day demand, with the Dalby low level reservoir storage having to supply the difference with the town consuming more than which the existing treatment plant can treat.

Future Predicted Demand Scenario results as can be observed in both Figure 5.6 and Table 5.6 source combination "Loudoun Weir, can be deemed the most favourable due to the lowest value and a low risk level calculated in this particular scenario. Out of the six different source combinations available, four have been able to provide the required demand. The results of this scenario suggests that Loudoun Weir should be more utilised in lower turbidity conditions.

WDRC has suggested that the cost of treating surface water compared to bore water has historically been considered to be similar value, however this has not been analysed in detail (Fagg, T 2023, pers. comm, 14 July). From an operational perspective the surface water from the Loudoun Weir on the Condamine River has historically been used for treatment/supply to offset peak demand which usually occurs in times of above average consumption in the town of Dalby. The surface water has also been relied on as backup/emergency supply intime when there may be scheduled maintenance or breakdowns of the RO's (bore water supply). Therefore, the underground (bore) water has been relied on for average daily demand of Dalby in the last 20-30 years of operation. The underground (bore) water is noted to be more a reliable source hence why in more recent times there has been a focus on any new capital infrastructure to be invested utilising underground aquifers. A review of the value to risk matrix created results supports the historical prioritisation of the sources reinforces and provides some confidence in the results of the value risk matrix in most scenarios analysed. The results of the value risk matrix also suggests that Loudoun Weir should be more utilised in lower turbidity conditions (0-100 NTU range). Therefore an upgrade to the surface water treatment plant is recommended to be undertaken to better make use of the Loudoun Weir water source.

Based on historic operation approach to Dalby's water source prioritisation generally supporting the results of the evaluation method created in the form of a value risk matrix, this evaluation tool would be beneficial as a guide in water source selection. This evaluation tool while developed specifically to assist WDRC it could also be adapted and used as a guide for other drinking water service providers in similar operating conditioned water sources.

The sensitivity analysis confirms the literature review that the determination of the maximum risk tolerance is subjective and depends on the company's attitude towards pursuing its objectives in both the value and risk areas (Manufacturing Environment, Shah L.A.). Results demonstrated with an increase in risk this can be visually represented on the value risk matrix assisting the useability of the matrix. From the sensitivity analysis completed for assessing the risk score with changes to the risk question percentage weighted criteria, not a lot of change was observed. This is due to the weighted average having more impact on the final risk score. However some change was present in the results and upon review the with an increase in the percentage to one criteria question, a small increase in the risk score to all source combinations can be observed. With the close grouping of results in the 'risk weighting percentage criteria' indicate that that the value risk matrix is robust in the risk score.

An observation from the results is that the more sources included in a particular scenario it was generally observed across all results from the value risk matrix that there is an increase in the risk score for that source combination. It is confirmed that this is typically due to when the surface water is included, that is typically increased risk in utilising the surface water as the baseline scenario assessed was weighted a slightly higher risk profile broadly due the condition of the current infrastructure linked to this source.

As can be observed in the results of the sensitivity analysis the 'Answering Risk Questions Selection' does have an influence on the results of the decision matrix. When there is a large risk weighting entered in the weighting criteria and the selected answer is high to a particular question it noticeably increases the risk score. From the sensitivity analysis completed, when contrasting the sensitivity of the 'risk weighting percentage criteria' and the 'Answering Risk Questions Selection' results, the 'Answering Risk Questions Selection' area has more noticeable impact on the results.

The originality of the project is the successful use of a value risk matrix for short to medium term water source optimisation. Based on historic operation approach to Dalby's water source prioritisation generally supporting the results of the evaluation method created in the form of a value risk matrix, this evaluation tool would be beneficial as a guide in water source selection.

7. Limitations

This dissertation acknowledges that it is a theoretical research project and the results obtained may vary on information input into the value risk matrix. Therefore, it is recommended that the results of this report be used as a guide along with sound engineering judgement to determine the suitability of the use of the value risk decision matrix.

One limitation found during creating the value risk matrix it doesn’t autonomously exclude a source combination if demand required aren't met for any particular source combination. The matrix does however highlight the limit/maximum available quantity the three sources all in combination. While this is a limitation of the evaluation model, it is ultimately due to current infrastructure constraints. There are source combinations which can't meet the required demands and in peak daily average scenarios the results from this scenario really highlights the importance and criticality of all three available sources to meet peak maximum demands for Dalby. Therefore the model is limited based on the available quantities as presented in Table 4.2.

The value risk matrix will include surface water from the Loudoun Weir for less than two megalitres per day. In reality the surface water treatment plant wouldn’t be operated unless a minimum of two megalitres is required from the surface water source (Fagg, T 2023, pers. comm, 14 July).

It is important to note that the operational cost analysis associated with the value risk matrix was based on information provided by WDRC. The value risk matrix relies heavily on the input data in the operational cost to generate the value based on source demand and availability. This is the information based one treatment plant and may differ for other regions/locations.

In order to quantify the value risk matrix as an evaluation tool several assumptions were required to be made, refer to Section 4. Methodology for these in detail. This analysis uses a selection of published data as well as historic maintenance data from WDRC to calculate as accurately as possible the feasibility of this research proposal.

8. Conclusion and Recommendations

8.1. Conclusion

This theoretical analysis has attempted, as accurately as possible, to optimise the strategy for water source development to achieve a reliable, cost effective potable water supply for Dalby QLD. The findings quantify this optimisation through the use of creating an evaluation method built in the form of a value risk matrix. An operational cost analysis was completed on each available water source and incorporated into the value risk matrix.

This project has identified that the 'A' level alluvium bores present the most favoured water source from a value to risk consideration from the evaluation tool created. However the 'A' level bore source alone can't solely meet the average daily demand of 4.58 ML/day for the town of Dalby. In combination with another source, this source combination ultimately becomes the most favoured source combination due to the low value and risk scores associated with the 'A' level bore source. In lower turbidity conditions, from 20 NTU to 100 NTU the Loudoun Weir in combination with 'A' level bores becomes the most preferred option. However as the turbidity increases in the Loudoun Weir beyond the 100 NTU level, so does the value score associated with this source making 'B' level bores in combination with 'A' level bores the preferred source combination. Based on the results of the value risk matrix suggesting that Loudoun Weir should be more utilised in lower turbidity conditions (0-100 NTU range) and on infrastructure current conditions, an upgrade to Dalby's surface water treatment plant is recommended be undertaken.

Based on historic operation approach to Dalby's water source prioritisation generally supporting the results of the evaluation method created in the form of a value risk matrix, this evaluation tool would be beneficial to be as a guide in short to medium term water source selection (one to three months). This evaluation tool while developed specifically to assist WDRC, could also be adapted and used as a guide for other drinking water service providers in similar operated water sources.

Overall, the research project has provided valuable insight to the Western Downs Regional Council providing evidence in assisting with signifying which water source should be prioritised and utilised available for Dalby's water supply. The project has provided an operation strategy based on value and risk. While this report does focus specifically on water treatment operations in the Western Downs area, it is expected similar results would be achieved in similar situations for other drinking water service providers. The conclusions from this research project will likely to be considered by Western Downs Regional Council.

8.2. Further Work

There were several topics encountered during this project that were outside the scope of the research dissertation but may potentially contribute to the progression of the evaluation model created and water source prioritisation. The following topics have been revealed during investigation of this research.

8.2.1. WDRC Water Supply Upgrade Plan

WDRC are currently planning on investing in the exploration of additional water sources in the Great Artesian Basin in both the Precipice and Hutton aquifers within the Dalby area. A Summary of the new potential infrastructure which WDRC may adopt if the bore exploration development is successful is outlines in Figure 8.1. Not only will increase water source options benefit operation flexibility and improve reliability in managing loss of supply risks, but could also open an economic avenue in attracting new business and investment opportunities to the region (WDRC values, 2023).

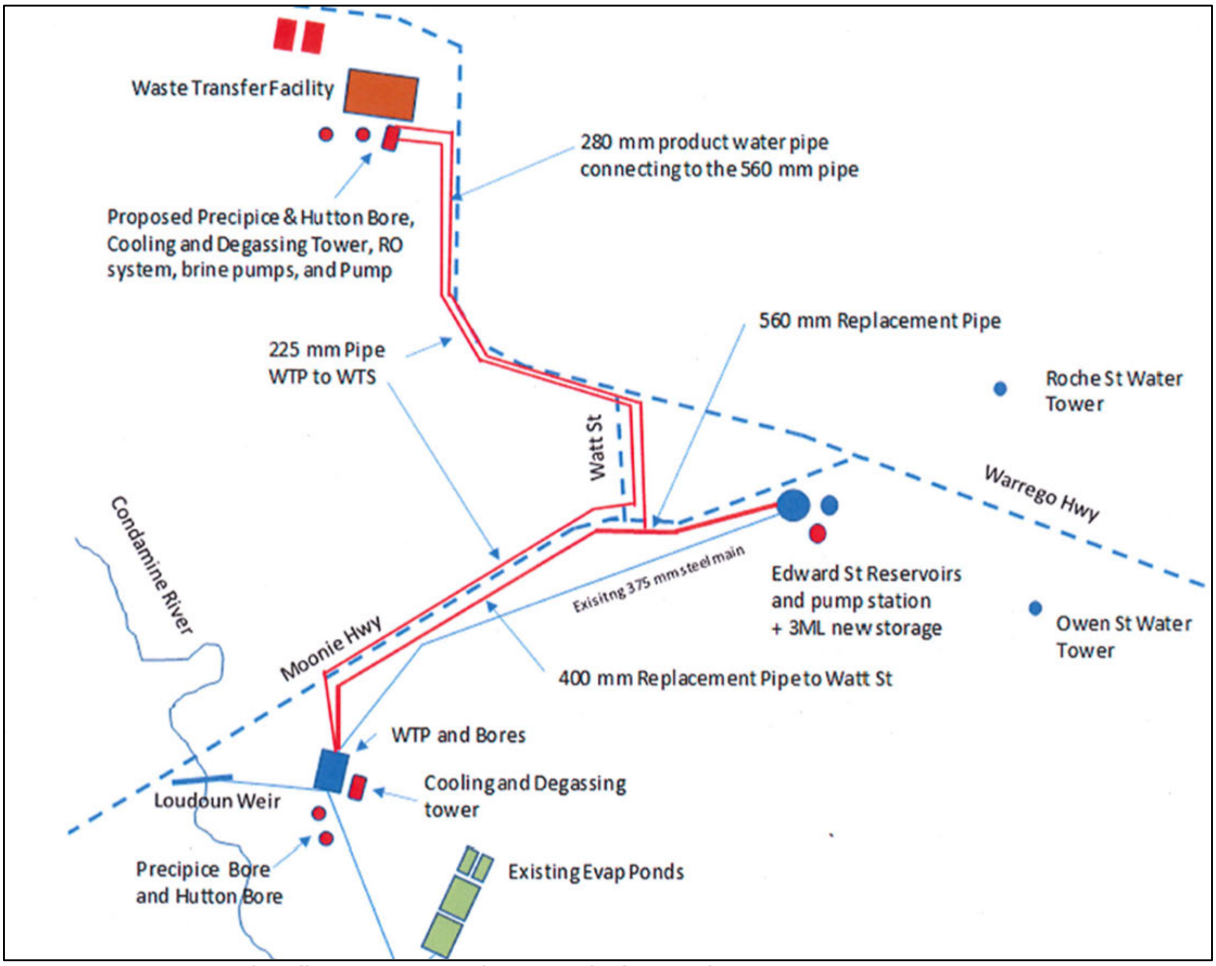

Figure 8.1: *Proposed Dalby Water Supply Upgrade (WDRC).*

8.2.2. Additional Water Sources

Addition of any new, or potential future sources to the value risk matrix would be recommended and could be a potential avenue for future exploration. Further refining the model to capture any new water sources under trial conditions and used as a guide could be beneficial for future planning for WDRC and improvement to the evaluation model created as part of this dissertation. By including new or potential sources to the risk value matrix created could assist with future scenario analysis and provide more source combinations to be assessed. In turn this could provide further prioritisation refinement and improve the accuracy and verify the results of the value risk matrix created.

Due to reliability issues present there is no cheap solution to increase the capacity or for WDRC to increase reliability of surface water source in the near future. Offsite storage is one option, however as identified in 1999/2000 PPK's report "Dalby Raw Water Source Options Study-Part B Options Report" the upfront capital costs would be expensive and would only slightly improve the reliability of the Loudoun Weir source water (PPK, 1999/2000).

There is however potential to explore additional B Alluvium bores at the proposed new water treatment site adjacent to the Waste Transfer Station. The advantage of this would be that treating the B Alluvium bore and blending with both the Precipice and Hutton aquifers, would increase the available water capacity available and improve the flexibility in operation having increased source capacity in the 'B' level bores.

8.2.3. Longer Term Outlook, Capital Cost Consideration

The evaluation tool created could be modified to consider a longer-term outlook on source prioritisation considering capital cost and whole of cycle. Capital and whole of life cost, and was disregarded in this analysis because this dissertation wanted to assess the current infrastructure and existing conditions of the infrastructure available. Capital and whole of life could severely impact the results of the value risk matrix. As these other outcomes play a key role in the decision making process, it would be beneficial for water authorities to know just how much of an overall financial impact it may have to the value scores of the decision matrix created. Determining just how much this impact may be to the results of the research project by including capital and whole of life costs may be something that could be explored in future studies.

8.2.4. Operational Cost Case Study, Maintenance Prioritisation

Due to the timeframes available, a full-scale analysis of the operational costs was impractical for this dissertation. Due to time constraints this dissertation simplified the operational cost analysis based on the available data from WDRC and considered operational labour costs, power and chemicals. The next logical step for this research project would be for a case study on all operational treatment areas with potential to include maintenance costs, and sludge management of the surface water source, to verify the information put forward in this report.

Raw water quality for bore water is relatively stable (Fagg, T 2023, pers. comm, 14 July), and therefore considered a constant. Not considered by the model in this dissertation as it has been considered stable, as the changes are minimal, gradual and could be considered in longer term analysis. The addition of raw water quality for the bore sources could be explored.

Currently the Evaluation model assumes an even split between the available source and further adjusts the available water quantities based on the maximum available quantity for each source. Further work on the decision matrix could be to adjust the quantities not based on operational costs, demand, and surface water raw water quality alone. Where the Adjusted Available quantity (ML/day) based on $ and see how that compares to the current demand split over the available sources.

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All other information used is this report, having a Certificate 3 in Carpentry, and my knowledge of the industry, as Utilities Project Officer for Western Downs Regional Council.

Appendices

Appendix A - Project Specification

For: Bernard Fitzsimmons

Title: VALUE RISK MATRIX FOR WATER SOURCE SELECTION FOR DALBY QLD

Major: Civil Engineering

Supervisors: USQ: Justine Baillie

WDRC: Terry Fagg, Leigh Cook

Enrollment: ENG4111 – EXT S1, 2021

ENG4112 – EXT S2, 2021

Project Aim: To investigate Dalby's Surface and Groundwater Treatment Plants and provide a planning/operating strategy based on reliability/priority and cost.

Programme: Version 1, 15th March 2023

- Review the minimum standard of treatment for potable drinking water for a service provider.

- Review any prior/existing studies completed in this area including engineering value risk analysis dissertations.

- Review WDRC's treatment standard/historic water quality data, to gain an understanding on the level of treatment/operation/service provided for cost.

- Operational Cost analysis on the historic/current data available from WDRC. This includes gather/review the cost data sourced by WDRC which would envisage to review the operation/labour, chemical, and electricity costs.

- Review of results and recommendations, including critically examining the results/outcomes from the cost analysis, reviewing against a risk/reliability aspect. Conclusions and recommendation to select which water source to prioritise.

If time and resources permit:

- Develop an operating and maintenance plan depending on what is achieved earlier.

- Preliminary design/cost analysis on the upgrade of Dalby's Surface Water Treatment.

Project Timeline

The schedule is a key component within the project for creating a successful research dissertation paper. To ensure that check milestones are met, time management will be the main factor required to be managed. The research project will be completed in Research Project Part 1 and 2 (ENG4111 and ENG4112), with a presentation on the findings in Professional Practice 2 ENG4903. Approval of the research proposal is anticipated to be granted by USQ by the end of 2022, which will initialise the acquiring of resources and data collection.

The following timeline is proposed for this project:

Project Phase	Dec 22	Jan 23	Feb 23	Mar 23	Apr 23	May 23	Jun 23	Jul 23	Aug 23	Sep 23	Oct 23
1. Initial Stakeholder Engagement / Authorisation											
2. Review minimum standard of treatment for potable drinking water for a service provider.											
3. Review any prior/existing studies completed in this area.											
4. Review WDRC's treatment standard, gain understanding on the level of treatment/operation/service provided for cost.											
5. Cost analysis on the historic/current data available from WDRC.											
6. Review of results and recommendations.											
7. Report preparation / Drafting Finalising / Presentation											

Figure A.1: *Project Timeline.*

Resources Required

It is expected that the following resources will be required in order to carry out this project:

- Utilities services provider - Authority governing body
- Current Australian Standards, Supplied by Uni, access should be already granted from previous courses completed through USQ;
- Computer - Supplied by Student, to prepare/complete the research project;
- Camera, supplied by student, to capture any site visits, data which may come available during the course of the project;
- Microsoft Word - Supplied by Student, to compile the research project for any word processing;
- Microsoft Excel - Supplied by Student, used to formulate any extensive calculations, and Cost Analysis (operational);
- General items, including books, printer, calculator, stationary, etc.

Limitations

The largest constraint of the project is time. The length of time determined by USQ, which requires this research dissertation is completed close of Semester 2, 2023. In order to practically execute the project the following limitations have been identified and planned for subsequently:

- WDRC Staff Availability: There is potential at critical stages, whether that is for access to sites/data of whether it is for WDRC staff to review the report due to privacy concerns for publication of confidential information. If Council can't fulfil the staff provision requirements as desired, a potential revised reduced scope may be required.
- Record Availability Reliability: Council asset historic records can vary in reliability, particularly from region to region, however due to the limited timeframe of this research project, areas with insufficient data may need to be omitted from this project, and

recommendations for revisit in these areas in future studies.

Ethics Clearance

This project will involve working closely with WDRC, accessing and analysing historic data which belongs to local Government. Therefore, ethics clearance shall be required prior to publishing this report. It would be envisaged that this clearance/agreement would be obtained, upon notice of acceptance of this proposal from USQ and by the start of Semester 1 2023. This will ensure time to ensure appropriate agreement between key stakeholders, prior to the commencement of the project semester.

Appendix B - Project Risk Management Assessment

Risk Management

An assessment of the potential risks associated with this project has been undertaken to ensure that the project is undertaken in a safe manner, which includes the measures proposed to mitigate/reduce any risks. It would be envisaged that this Risk Management Plan will be continuously reviewed and developed to cater for any newfound variable for the duration of the research proposal:

Table B.1: *Project Risk Matrix.:*

Risk Matrix					
	Consequence				
Probability/ Likelihood	**Insignificant** *No Injury* 0-$5K	**Minor** *First Aid* $5K-$50K	**Moderate** *Med Treatment* $50K-$100K	**Major** *Serious Injury* $100K-$250K	**Catastrophic** *Death* More than $250K
Almost Certain *1 in 2*	M	H	E	E	E
Likely *1 in 100*	M	H	H	E	E
Possible *1 in 1,000*	L	M	H	H	H
Unlikely *1 in 10,000*	L	L	M	M	M
Rare *1 in 1,000,000*	L	L	L	L	L
Recommended Action Guide					
Extreme:	E = Extreme Risk - Task MUST NOT proceed				
High:	H = High Risk - Special Procedures Required (Contact USQSafe) Approval by VC only				
Medium:	M = Medium Risk - A Risk Management Plan / Safe Work Method Statement is required				
Low:	L = Low Risk - Manage by routine procedures				

Table B.2: *Risk/Hazard Management Plan conducted for the proposed project.:*

Potential Risk	Likelihood	Consequence	Outcome	Mitigation Method	Likelihood	Consequence	Outcome
Approval of Project declined	Possible	Major	High	Approval of Project applied for early, and discussion with the proposal with Supervisor at earliest convenience.	Unlikely	Moderate	Medium
Restricted access to data	Possible	Moderate	High	Verbal plan with WDRC has been initiated.	Unlikely	Minor	Risk Mitigated /

from WDRC/ Resources				Written confirm to be established prior to Semester 1 2023. Intention t gather all resources before Semester 1 begins in 2023.			Very Low
Privacy concerns for publication of confidential information from WDRC	Possible	Moderate	High	Establish an agreement that final review of Research Project is conducted by WDRC to ensure no issues with the information to be published.	Unlikely	Minor	Risk Managed / Low
Limited available data from WDRC	Possible	Moderate	High	Analysing the different treatment plants costs for treatment of potable water and averaging for each method	Unlikely	Minor	Low
Timeframe to not permit a full-scale trial of proposal	Almost Certain	Moderate	Extreme	The use of historic data where possible, compared to current quotations/cost gathered to estimate future costs more accurately.	Likely	Insignificant	Medium
Quality/progress assurance throughout the project	Possible	Moderate	High	Regular contact and meetings with the proposed supervisor. Submitting the draft report of the research project which will allow for adjustments prior to final submission.	Unlikely	Minor	Low
Excess alteration required after draft and Presentation feedback	Possible	Minor	Medium	Regularly reviewing the progress compared to the proposed schedule, will allow for best opportunity to remain on schedule and provide the best draft possible.	Unlikely	Minor	Low
Site Visit exposure to chemicals, active	Possible	Major	High	Utilise/follow Councils Workplace Health and Safety Policies and	Rare	Moderate	Low

Utilities work site (Treatment Plants)				Procedures, ensuring to sign on to the Pre-Start Hazard Inspection Permit (which highlights the tasks/jobs which are occurring on the site for the day, the potential hazards, and controls which are required to be implemented to manage the risks). Safety is at the forefront at WDRC with any queries to the existing standard procedures I would seek out Councils Safety Compliance Officer for advise/guidance.			

Appendix C - RFI from Western Downs Regional Council

ENQUIRIES TO:
Bernard Fitzsimmons
[redacted]

9 October 2023

Western Downs Regional Council
[redacted]

Infrastructure Services Division

Dear WDRC Engineering Department

RE: REQUEST FOR INFORMATION - UNIVERSITY RESEARCH PROJECT

My name is Bernard Fitzsimmons and I am currently completing my final year of the bachelor of Engineering (Honours) through the University of Southern Queensland (USQ). As part of this degree, I am currently undertaking a theoretical research project in creating a Value Risk Matrix for Water Source Selection for Dalby QLD.

My dissertation focuses on aims to optimise the strategy for water source development to achieve a reliable, cost effective potable water supply for Dalby. I aim to develop an evaluation method for water source development, by assessing the current operational costs and current/future risks for Dalby.

I am writing to ask if Western Downs Regional Council are willing to assist with this project by supplying some information I require. In order to quantify the value and risk, I require current unit rates of operational costs associated with staff, chemicals, and power. As well as historical water quality and flow rate data for Dalby.

If Council is willing to provide this information to me, I would be more than willing to abide by any conditions that accompany the disclosure of this information. A confidentiality agreement with USQ can be arranged if required.

My Supervisor is Justine Baillie as and is available to contact via email (Justine.Baillie@unisq.edu.au)if you require any further information on this project.

If there is any confusion with my request, or if you wish to discuss anything further, please feel free to contact me via email or phone. Being my local Council, your support in this matter would be greatly appreciated.

Thanks for your time,

Regards,

Bernard Fitzsimmons

Figure C.1: *Request for information from WDRC,*

Bernard Fitzsimmons

From:	Leigh Cook
Sent:	Saturday, 14 October 2023 9:45 AM
To:	Bernard Fitzsimmons
Subject:	FW: Uni - Request for Information from WDRC - Bernard Fitzsimmons Dissertation
Attachments:	RFI for WDRC BF.pdf

Hi Bernard, your requested use of information is approved.

Regards

Leigh Cook
Utilities Manager

WESTERN DOWNS REGIONAL COUNCIL
PO Box 551, Dalby, Qld 4405

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From: Bernard Fitzsimmons
Sent: Friday, October 13, 2023 3:57 PM
To: Leigh Cook
Subject: FW: Uni - Request for Information from WDRC - Bernard Fitzsimmons Dissertation

Regards

Bernard Fitzsimmons
Utilities Project Officer

WESTERN DOWNS REGIONAL COUNCIL
PO Box 551, Dalby, Qld 4405

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Figure C.2: *Response to the RFI by WDRC.*