NSW GOVERNMENT | Public Works Advisory

Guyra Water Supply

Business Case for
Secure Yield Augmentation of Guyra Water Supply

Report Number: WSR – 17026

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ARMIDALE Regional Council

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Executive Summary

This business case has been prepared by Public Works Advisory to form a part of an application by Armidale Regional Council to seek funding under a suitable government funding program.

The town of Guyra, population 1,947 (2011 Census), is the main urban centre for the former Guyra Shire and located about 30 km North of Armidale, (population 23,674), which is the administrative and service centre for the Northern Tablelands region.

Guyra's town water is sourced from two small dams on the Gara River located 7 Km north of the town. Guyra's two dams have a combined catchment of 74 km^2, which is within the overall Malpas Dam catchment.

Historically, Guyra water supply system has proven to be relatively secure and the township has not experienced any significant water supply issues even during the millennial drought. For the past 10 years, the average annual water demand has been 423 ML, about 39% of which is supplied to the Blush tomato farm on the eastern side of Guyra.

The demand however has steadily increased due to other commercial and industrial development, including a new glasshouse tomato farm off the New England Highway, and further residential and tourism growth in the district. Following a rapid decline of dam storage levels due to an extended period of drier weather, Council introduced water restrictions for the first time in January 2014.

Council estimated that over the next 30 years, the future average annual water extraction is expected to grow to 525 ML, and the dry year extraction to 633 ML. Recently, the WREMA Pty Ltd., a consultant commissioned by Council estimated secure yield of the existing Guyra Dams, is only 277 ML/year thus laying bare the severe water security issues facing the township and the surrounding district. Lack of security of water supply will severely affect not only the existing customers but also undermine the prospects for Guyra to attract a fair share of regional growth and development opportunities coming up in the near future.

Armidale Regional Council has investigated a number of options with a view to improve the water security of Guyra water supply scheme and has identified that transferring water from Malpas Dam to Guyra water treatment plant (WTP) is the only feasible option to achieve the same. The main features of this option are:

- Town demand is supplied from the current Guyra Dam
- When Guyra Dam drops below a pre-determined level, town water supply will be taken from Malpas Dam
- Peak day demands would be met by supplementing water from Guyra Dam
- The pipeline from Malpas dam will be sized to transfer 2.1 ML/day

The estimated capital and operation& maintenance cost of this option is shown below.

Cost	Water Transfer from Malpas Dam to Guyra WTP Option
Estimated Capital Cost, $	9,482,519
Estimated additional O&M Cost, $/year	50,091
Pumping Cost, $/ML	305

As part of the business case, an economic appraisal compared the proposed option of transfer of water from Malpas Dam to Guyra WTP with a 'Do Nothing/ Business As Usual' option for assessing the value for money aspects of the proposed project. A summary of benefits and costs of the 'Do Nothing' and the proposed option are presented in the table next page.

The economic appraisal demonstrates that the proposed Malpas dam to Guyra WTP water transfer system for augmenting the secure yield of Guyra water supply scheme will offer more benefits to the community and the regional economy than continuing with the current scheme operating conditions.

The results of the benefit-cost analysis clearly establishes that the proposed project with positive net present values (NPV) and a benefit-cost ratio of well above 1.5 for all the discount rates analysed, offers significant economic benefits compared to a 'Do Nothing' option.

The NPV per dollar of capital investment of 2.01 at 7%p.a. discount rate implies that every dollar invested would likely return more than $2 worth of benefits, indicating that capital investment on augmenting the secure yield of Guyra water supply scheme offers great value for money.

The IRR of 18.1% p.a. for the proposed project indicates that the values of future benefits considered are conservative, and even at substantially lower level of the estimated benefits, this project can achieve net positive economic benefits.

Parameter	**Secure Yield Augmentation**			**Business As Usual**		
Discount rate (% p.a.)	4%	7%	10%	4%	7%	10%
Present value of costs (PVC) ($)	10,744,209	10,428,448	10,214,415	11,356,447	8,578,882	6,688,575
Present value of benefits (PVB) ($)	27,753,541	21,010,602	16,496,255	9,482,519	9,482,519	9,482,519
Net present value (NPV) ($)	17,009,332	10,582,153	6,281,839	-1,873,928	903,637	2,793,944
Benefit cost ratio (BCR)	2.58	2.01	1.61	0.83	1.11	1.42
Net present value per dollar invested (NPV/I)	3.05	1.90	1.13	N/A	N/A	N/A
Internal rate of return (IRR) (% p.a.)	18.1			5.9		

It is concluded that augmenting secure yield of Guyra water supply scheme through transfer of water from Malpas Dam will help achieve water security and increased water availability that will also boost economic growth and development in the region.

Contents

Figures

Tables

1 Introduction

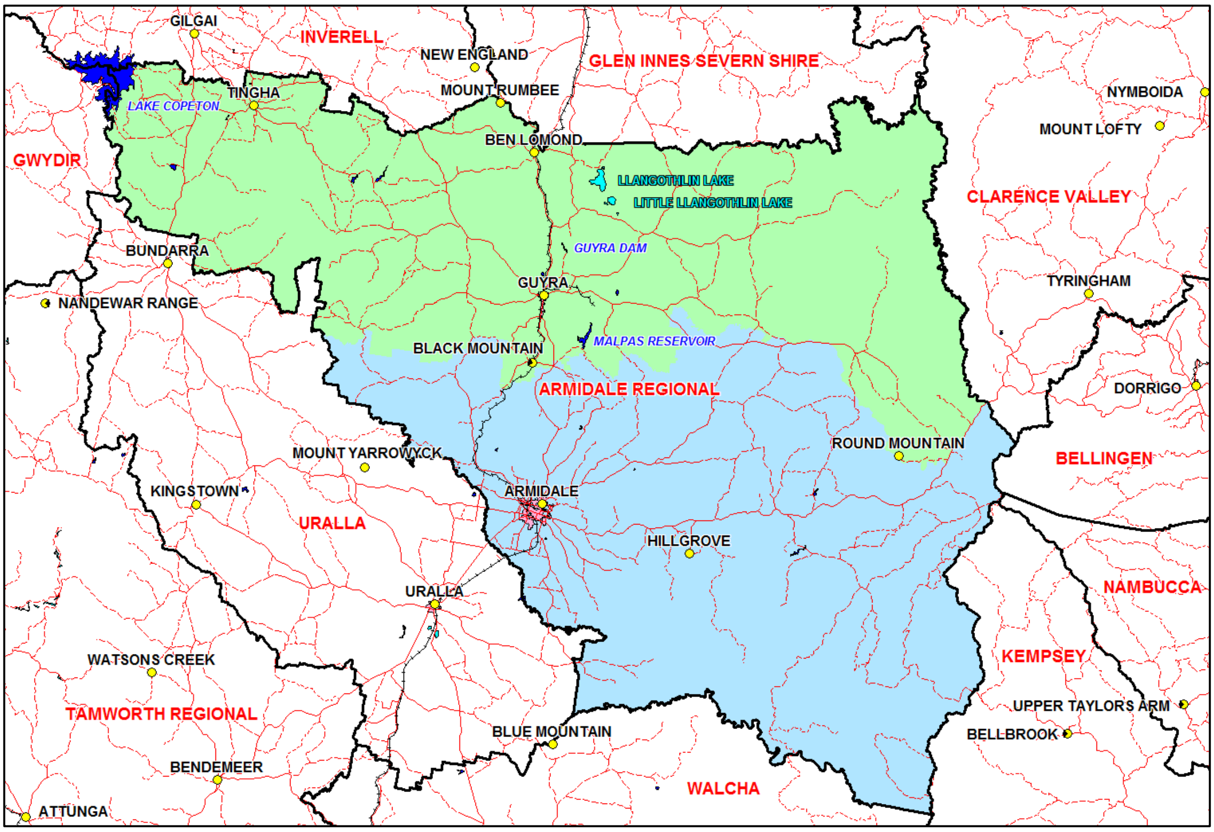
1.1 Background

The Armidale Regional Council (ARC) local government area is located in the New England Region of New South Wales, and was formed from the merger of the Armidale Dumaresq Shire and Guyra Shire in 2016.

The town of Guyra, population 1,947 (2011 Census), is the main urban centre for the former Guyra Shire and located about 30 km North of Armidale, (population 23,674), which is the administrative and service centre for the Northern Tablelands region.

At the 2011 census, 7.0% of employed people in Guyra worked in Sheep, Beef Cattle and Grain Farming. Other major industries of employment included Mushroom and Vegetable Growing 6.5%, School Education 4.1%, Local Government Administration 3.8% and Cafes, Restaurants and Takeaway Food Services 3.6%. The principal industries include fine wool and prime lambs, beef cattle, potatoes and tomatoes.

Figure 1.1: Location map of Guyra



At 1,330 metres above sea level, Guyra attracts many visitors during the depths of winter to enjoy the frequent snow falls. It is this altitude and its associated climate which helped Guyra to become a major tomato growing area. A 20 ha green house, the largest in the southern hemisphere, has been built at Guyra, which employs up to 240 workers and produces several varieties of tomatoes totalling around 12 million kg per year making it the largest producer and exporter of tomato in Australia. Following on its success, another glasshouse tomato farm has been built on the New England Highway

1.2 Guyra Water Supply Scheme Overview

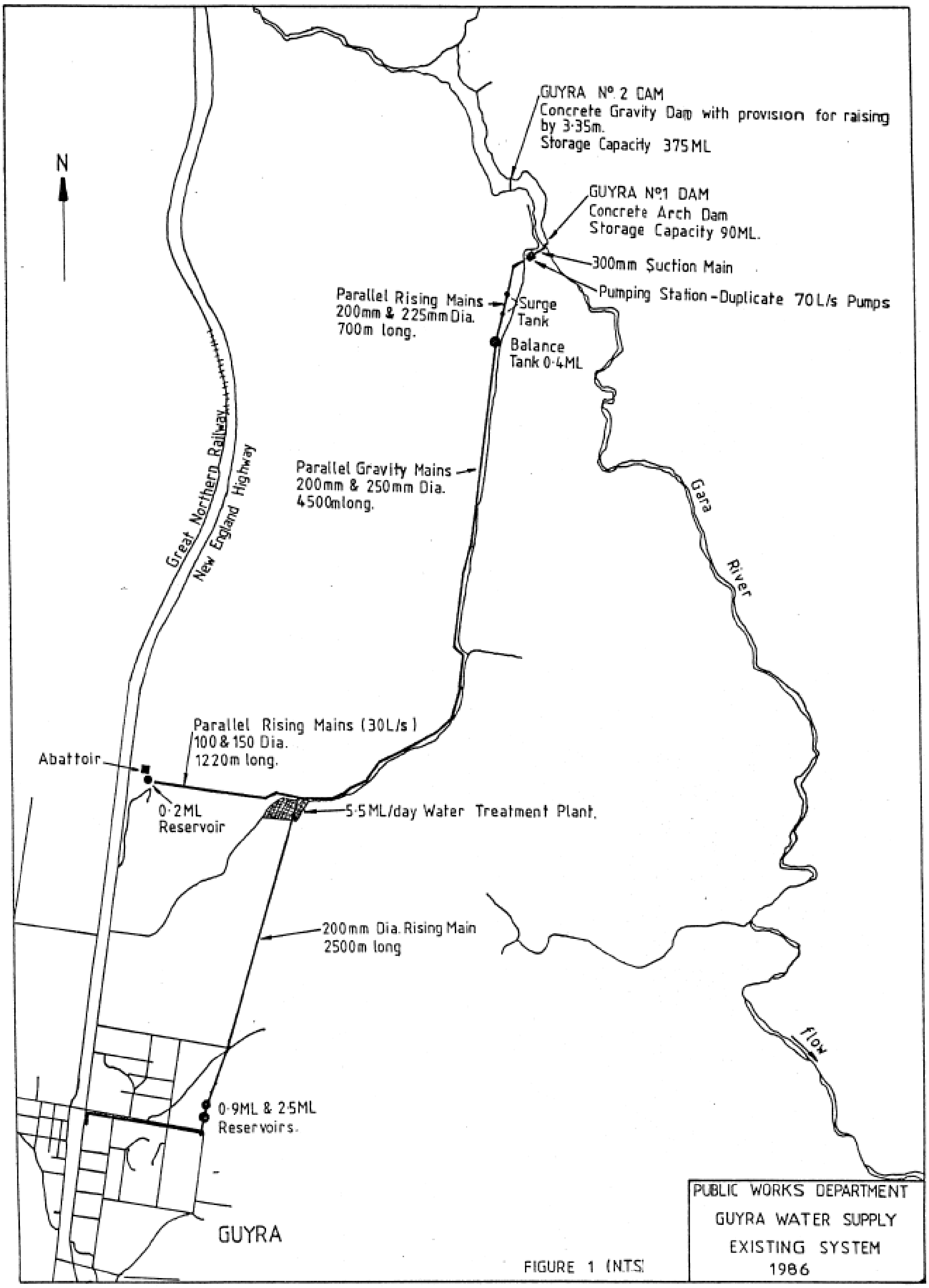
Guyra's town water is sourced from two small dams on the Gara River located 7 Km north of the town. Guyra's two dams have a combined catchment of 74 km^2 which is within the overall Malpas dam catchment. Guyra Dam No.1 is a concrete arch earth abutment dam constructed in 1957 with a storage capacity of 110 ML. Guyra Dam No.2 located upstream of Dam No.1 is a 7.7m high concrete gravity dam with a storage capacity of 350 ML. Dam No.2 overflows into the Dam No.1 to supplement the supply storage and was constructed in 1967. Both Guyra dams have a low hazard rating and they are not the 'prescribed dams' under the Dams Safety Act 1978.

Figure 1.2: Guyra Dam No.1

Figure 1.3: Guyra Dam No.2

Two 70 L/s duplicate pumps transfer raw water from Guyra #1 Dam via parallel rising mains to a 0.4 ML balancing tank and then water gravitates to the water treatment plant. The plant has a nominal capacity of 6.05 ML per day and is located approx. 2.5 km north of Guyra on Falconer Road. A schematic arrangement of the Guyra water supply is shown in Figure 1.4.

Figure 1.4: Guyra water supply scheme



After treatment, various pumps with total capacity of 39 L/s transfer treated water to two clear water reservoirs located in Guyra. The two reservoirs have capacities of 0.9 ML and 2.5 ML respectively.

From the reservoirs, water is distributed by a gravity reticulation network to consumers including a large scale glasshouse farm to grow tomatoes. One exception is the supply by a dedicated line from the treatment plant to the old abattoir site on the northern side of Guyra which now operates as a rabbit farm. Bulk water is supplied periodically to this rabbit farm on request and averages 1.4 ML per year.

2 Project Need

2.1 Current and Future Water Demand

Historically, Guyra water supply system has proven to be relatively secure in the past and the township has not experienced any significant water supply issues even during the millennial drought.

Guyra water consumption has largely been driven by the commencement of a large scale glasshouse tomato farm in 2005. The estimated 2016 average annual water consumption is 423 ML, about 39% of which is supplied to the Blush tomato greenhouse on the eastern side of Guyra.

The demand however is steadily increasing due to other commercial and industrial development, including a new glasshouse tomato farm off the New England Highway, and further residential and tourism growth in the district. The impacts of development around Guyra town and drier weather have resulted in an increased demand on the water supply system. Following a rapid decline of dam storage levels due to an extended period of drier weather, Council introduced water restrictions for the first time in January 2014.

Council's recent study for future average annual water demands under various growth scenarios indicates that annual water extraction, based on the 1.0% p.a. growth rate adopted for IWCM, is expected to grow to 525 ML, and the dry year demand to 633 ML over the next 30 years (Table 2-1)

Table 2-1: Forecast water production and extraction

		2016	2021	2026	2031	2036	2041	2046
Production	Average year (ML/year)	423	430	438	448	459	473	488
	Dry year (ML/year)	515	523	533	544	557	572	589
	Peak day (ML/day)	4.1	4.2	4.2	4.3	4.4	4.4	4.5
Extraction	Average year (ML/year)	455	462	471	481	494	508	525
	Dry year (ML/year)	554	563	573	585	599	615	633
	Peak day (ML/day)	4.4	4.5	4.5	4.6	4.7	4.8	4.8

2.2 Security of Guyra Water Supply

Secure yield is defined as the highest annual water demand that can be supplied from a water supply headworks system whilst meeting the 5/10/10 design rule prescribed by NSW Department of Primary Industries. The secure yield can be increased by providing larger storages, more water sources, increased transfer capacities or a combination of all three. The key aspects of the 5/10/10 rule are:

1. Water restrictions are in place for no more than 5% of the time
2. Water restrictions occur on average once every 10 years
3. During water restrictions, demand is reduced by 10%

The secure yield water supply modelling estimates the maximum quantity of water that can be extracted from the headworks system annually whilst conforming to the 5/10/10 rules and any other system specific constraints.

Armidale Regional Council recently commissioned WREMA Pty Ltd to estimate the secure yield in accordance with the 5/10/10 rule for the existing Guyra water supply headworks and for a range of augmentation options including a supply from Malpas dam. The results from these analyses of the current secure yield are summarised in Table 2.2.

Table 2.2: Estimated secure yield of existing Guyra water supply headworks

Dam 1 Storage Volume (ML)	Dam 2 Storage Volume (ML)	Dead Storage Volume (ML)	Above Environmental Flow Regime	Secure Yield ML/a
110	350	52	0	277

The estimated secure yield shows that the existing system, if operated in accordance with the 5/10/10 rule, will not be able to securely supply water to meet either the existing demand or the projected dry year demand (Figure 2.1).

Figure 2.1: Current Secure Yield of Guyra Water Supply and Projected Extraction

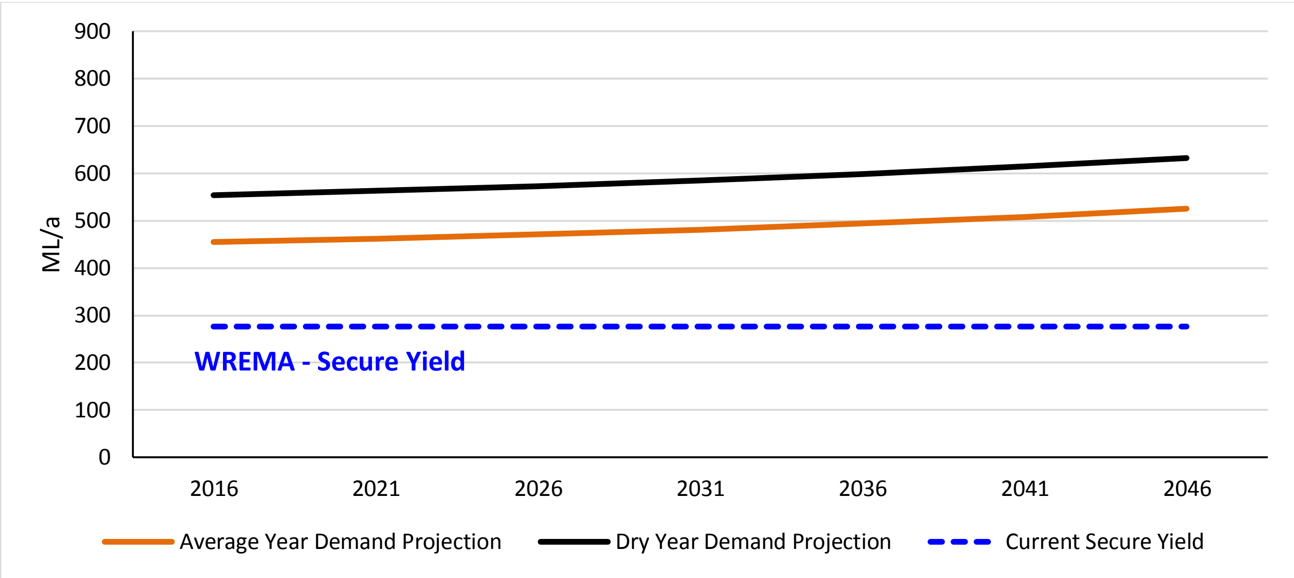
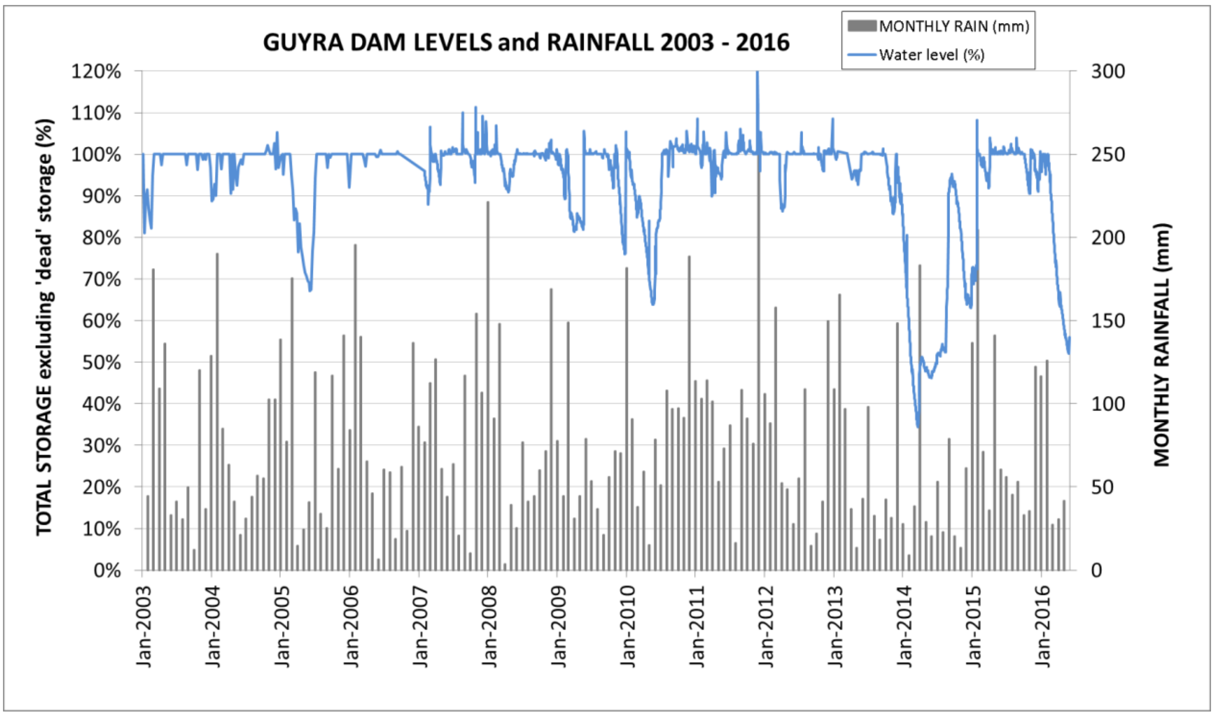


Figure 2.2: Guyra Dam Water levels and Rainfall 2003-2016



While the available catchment is large, the capacity of the dams is small with the result that short, severe droughts can rapidly deplete the storages to critical levels as can be seen from the fluctuation of dam water levels during 2003-2016 in

Figure 2.2.

2.3 Need for Augmenting Guyra Water Security

New development opportunities are presenting themselves for Guyra township and the surrounding district due to the recent Federal Government policy changes towards decentralised governance with a focus on developing the regional areas. Consequently, Guyra town and the surrounding district, after decades of slow to moderate growth, are potentially facing an exciting period of population and economic growth through new public and private sector investments in the region. The existing local businesses also are expected to pursue expansions to take advantage of the growing economy in the next decade or so.

The capacity or the lack thereof the Guyra water supply scheme would be a major if not the only, barrier in realising all the potential development opportunities. Increasing the capacity and securing the long term water future of Guyra water supply scheme will therefore not only drought-proof the existing residential and business customers of the scheme but will also provide capacity to accommodate the emerging growth and investment opportunities. Augmenting Guyra water supply scheme security, therefore, would be the critical first step for the Council to make it all happen.

This business case includes an extensive assessment of the water security issues and options available to best address the same by way of increasing infrastructure capacity. Lifecycle project cost estimates are provided for the option assessed.

3 Options Evaluation

3.1 The Proposal

Armidale Regional Council has investigated a number of options with a view to improve the level of long-term water security of Guyra town and the surrounding district by way of augmenting Guyra scheme's bulk water supply. The main criteria for identifying options is to upgrade and augment Guyra bulk water supply system to meet the projected demand, whilst maintaining an appropriate level of service for existing customers. The following augmentation options have been considered:

- Raising Guyra Dam 2;
- Building a 500 ML off-stream storage
- Transferring water from Malpas dam to Guyra WTP
- Transferring water from Malpas dam to Blush Tomato farm
- Effluent reuse for the Tomato farm to supplement town water supply.

Identification and assessment of feasible options involved:

- Estimation of the future water demands for Guyra scheme service area
- Assessment of options for the pipeline alignments
- Evaluation of sub-surface geotechnical conditions for the pipeline alignments
- Evaluation of site conditions for suitable off-stream storage sites
- Assessment of environmental risks for the pipeline alignment and off-stream storage site options
- Desktop hydraulic analysis to size the scheme components
- Lifecycle cost estimation for the identified options

3.2 Water Security Augmentation Options

The augmentation options considered are briefly described below. Detailed discussion of these options can be found in the attached report Guyra Bulk Water Supply – Upgrade options, 2017 (Appendix A).

Raising Guyra Dam 2

The existing dam has a capacity of approximately 350 ML. Raising of the existing Guyra Dam 2 by 2 m and 3 m is estimated to provide an additional 335 ML and 555 ML of storage respectively. A feasibility study into these options was undertaken by Public Works Advisory, and they were estimated to cost approximately $7.35 million and $9.20 million for the 2 m and 3 m dam raising respectively.

Off-stream Storage

Construction of a 500 ML off-stream storage has been considered. Water would be transferred to the off-stream storage from Guyra Dam 1 whenever stream flows are above a certain threshold, ensuring that town demands and environmental flow requirements are satisfied. The options investigation assessed the feasibly of constructing the storage at a dedicated site approximately 2 km north of the Guyra township in cleared farm land. The investigation estimated a cost of approximately $12.05 million for the storage.

Water Transfer from Malpas Dam

This augmentation would involve transferring water from Malpas Dam to provide security for the Guyra water supply. The water from Malpas Dam could be either supplied to the Guyra WTP or directly to the Blush Tomato Greenhouse. This augmentation will require construction of an intake at Malpas Dam, a new pumping station with power supply and a pipeline of length 15.0 km or 9.0 km for supply to Guyra WTP or the greenhouse respectively.

Effluent Reuse supply to Blush Tomato Greenhouse

In this options Sewage Treatment Plant (STP) effluent would be reused to supply some of the Tomato farm demand. The augmentation will require construction of new filtration system, UV and chlorination systems at the STP to produce an effluent suitable for commercial food crop irrigation, a reservoir for storage of treated effluent at the STP, a 6.9 km pipeline to the Blush Tomato Greenhouse and a pump station capable of pumping effluent at 10 L/s.

3.3 Preferred Option

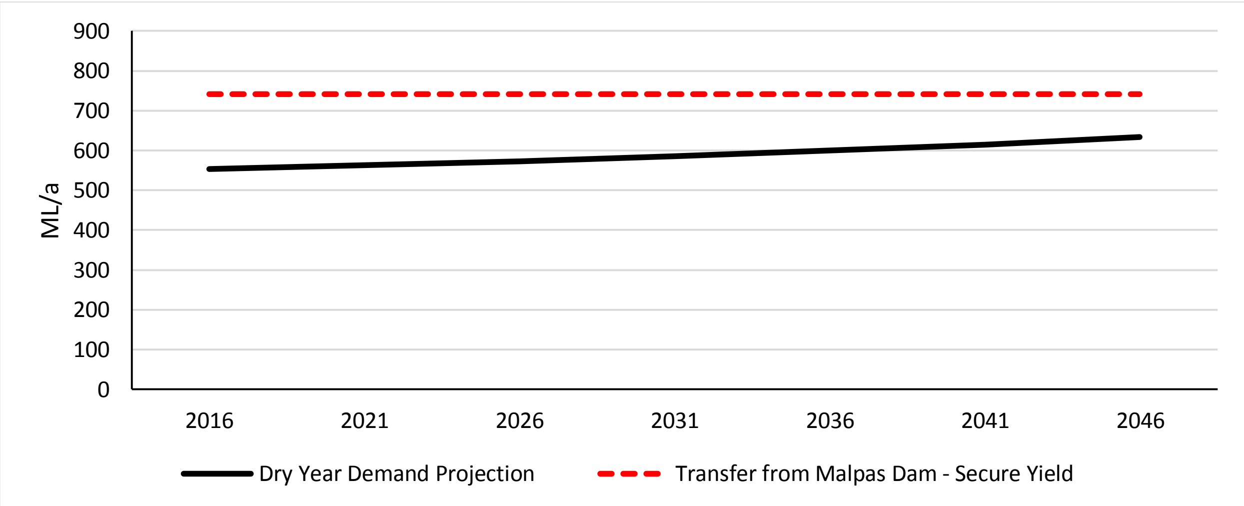
The secure yields for the options considered have been estimated by WREMA Pty Ltd the secure yield of several augmentation options. These results are presented in Table 3.1

Table 3.1: Estimated secure yield for augmentation options

Augmentation	Dam 2 Storage Volume (ML)	Above Environmental Flow Regime	Secure Yield ML/a
Raise Guyra Dam by 3m	850	0%	539
500 ML off-river storage	350	0%	554
Supply from Malpas dam to Guyra WTP	350	20%	741
Supply from Malpas dam to Tomato farm	350	0%	541
STP effluent reuse plus 3m dam raising	850	0%	588

Based on the analysis, transfer from Malpas Dam to the Guyra WTP is the only feasible option to obtain a secure yield required to meet the projected 2046 dry year extraction of 633 ML (Figure 3.1). This option will also provide additional capacity for potential future industrial developments. Hence, the option of transferring water from Malpas dam to Guyra WTP is preferred.

Figure 3.1: Comparison of secure yield by Preferred Option with projected demand



Overview of the Preferred Option

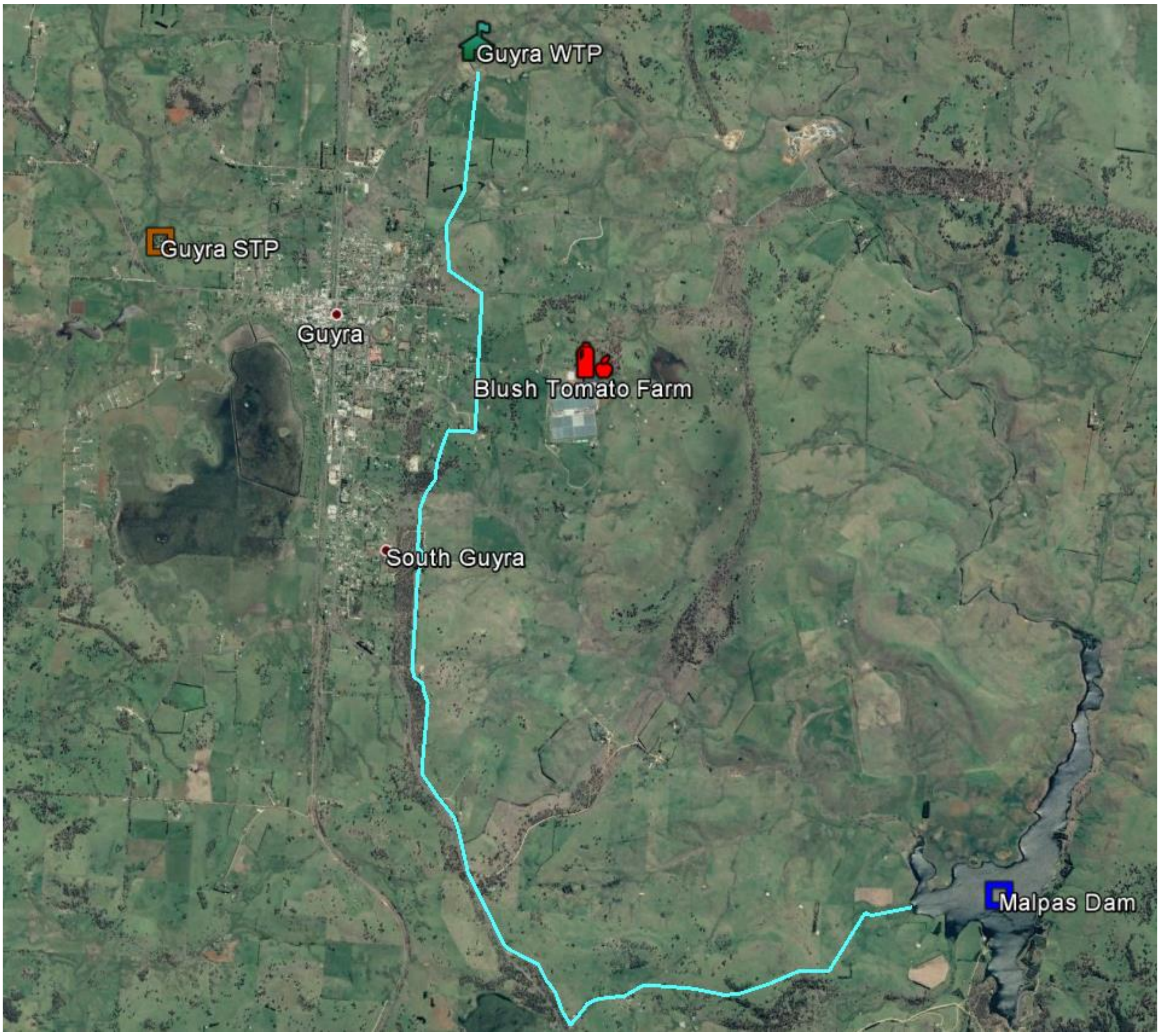
In this option water from the Malpas Dam would be transferred to the Guyra WTP. The water supply for this option would be:

- Town demand is supplied from the current Guyra Dam
- When Guyra Dam drops below a pre-determined level (to be determined), town water supply will be taken from Malpas Dam

- Peak day demands would be met by supplementing water from Guyra Dam
- The pipeline is sized to pump 2.1 ML/day (24.1 L/s). This is the estimated average day peak month demand from the projected 2046 dry year demand

The lay out of the proposed water transfer system is shown in Figure 3.2.

Figure 3.2: Layout of the Proposed Malpas Dam Water Transfer System



4 Economic Appraisal

Economic appraisal have been undertaken to compare and demonstrate the value for money of the Guyra water security improvement. For this purpose, two options, a 'business as usual/ do nothing' option and the 'secure yield augmentation through water transfer from Malpas Dam' option.

Economic appraisal is a way of systematically analysing all the costs and benefits associated with various management strategies that meet the project objectives to assess their relative desirability.

NSW Treasury Guidelines for Economic Appraisal (2007) recommends the following two techniques:

- Cost Benefit Analysis (CBA)
- Cost Effectiveness Analysis (CEA)

CBA is usually adopted where the major costs and benefits of the alternative strategies can be valued in monetary terms.

CEA is adopted when the major costs and/or benefits of a project are not readily measured in monetary terms and the outputs of options are same or similar.

For the current appraisal a cost-benefit analysis has been considered and the following has been assessed:

- Assessment of costs – Capex and lifecycle operation and maintenance costs
- Assessment of benefits
- Benefit Cost Assessment (BCA) including sensitivity testing

4.1 Option Costs

The capital and O&M costs of the options are presented in Table 4.1 below.

Pumping cost has been estimated as $305/ML using power cost of $ 0.32 per kWh. Considering a five-yearly wet and dry year cycles, it has been assumed that water transfer will be required during all the dry years for pumping water to meet the demand over and above the existing secure yield of 277 ML. In wet years no water is pumped as it is assumed water demand can be met by Guyra Dams.

Table 4.1: Option Costs

Cost	'Business As Usual' Option	'Secure Yield Augmentation' Option
Estimated Capital Cost, $	Nil	9,482,519
Estimated additional O&M Cost, $/year	Nil	50,091
Pumping Cost, $/ML	Nil	305

4.2 Option Benefits

The NSW Treasury Guidelines, 2007 indicate that the following quantifiable benefits may be relevant for economic appraisals using benefit cost analysis:

Avoided Costs – incremental costs which are unavoidable if nothing is done, but may be avoided if action is taken

Cost Savings – verifiable reductions in existing levels of expenditure if a program/ project proceeds

Revenues – incremental revenues from introduction of the project

Benefits – to project beneficiaries not reflected in revenue flows – while difficult, attempts should be made to quantify these, assumptions and methodologies clearly explained; and

Residual Value of Asset – if any

The benefits associated with the proposed Guyra secure yield augmentation through transfer from Malpas Dam have been assessed relative to the 'business as usual' case, which is a 'do nothing' scenario. Major benefits of the secure yield augmentation option are:

Economic Benefits:

The water security augmentation will address the undersupply of water demand and will facilitate, support and sustain the existing residential and commercial developments. It will also enable driving economic growth by way of attracting new commercial and industrial investments.

In order to provide an indicative estimate of value added to the local economy, it has been conservatively estimated the project capital investment will provide a direct local job opportunity for 29 FTE (full-time equivalent) during the construction stage, and is expected to sustain these jobs through new commercial and industrial capital investments. Estimation of the number of jobs has been done based on the Australian National Accounts, Input – Output Table 6 published by Australian Bureau of Statistics, 2014, according to which the employment component for every $100 investment in water supply related capital investment is $15.58.

At the median personal income level of $42,200 per year, the value of the 29 FTE job has been estimated to be $1,223,800/year based on the capital investment proposed to be made for the project.

Social Benefits:

One of the major benefits that will be achieved by the proposed project is to avoid water restrictions to the customers. The Production Commission Inquiry Report on Australia's Urban Water Sector (2011) reported the outcomes of studies undertaken to assess the impact of water restrictions on customers. The studies suggest, customers are willing to pay on an average up to $200/year (adjusted for 2016/17). For Guyra scheme customers with an average water consumption of 177 KL, this transpires as approximately $1.15 per KL of consumption. The annual benefit of avoiding water restrictions for all the customers has then been estimated using these values. Note, the loss of amenity due to permanent and ongoing water restriction will be a cost for community, if water security augmentation is not proceeded with.

Project Benefits:

The project will make additional water available for sale. The value of water due to the project has been estimated as to have at minimum value equal to the price of bulk water guaranteed by the proposed transfer system.

For the additional secure yield of 464 ML guaranteed by the project at $50 per ML bulk raw water, the benefit has been estimated as $23,200/ year.

4.3 Benefit-Cost Analysis

The economic appraisal of both options has been carried out based on a discounted cash flow analysis of the costs and benefits identified over a period of 20 years. Following assumptions have been made for the benefit cost analysis:

- Present values are in 2016/17 $
- The evaluation period is 20 years
- The useful economic life of the assets constructed under the project will be 80 years
- The residual value of the assets at the end of the evaluation period will be at a level pro-rata to the remaining useful lives

Table 4.2 presents the present value of costs (PVC), present value of benefits (PVB), net present value (NPV), benefit cost ratio (BCR), net present value per dollar of capital investment (NPV/I) and the internal rate of return (IRR) for the options.

In accordance with the NSW Treasury Guidelines, the sensitivity of the net present value has been tested at discount rates of 4% p.a. and 10% p.a. and the results of sensitivity analysis also are presented in Table 3-1.

Details of the discounted cash flow analysis benefits and costs are presented in Appendix B.

Table 4.2: Summary of Cost Benefit Analysis

Parameter	Secure Yield Augmentation			Business As Usual		
Discount rate (% p.a.)	4%	7%	10%	4%	7%	10%
Present value of costs (PVC) ($)	10,744,209	10,428,448	10,214,415	11,356,447	8,578,882	6,688,575
Present value of benefits (PVB) ($)	27,753,541	21,010,602	16,496,255	9,482,519	9,482,519	9,482,519
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Benefit cost ratio (BCR)	2.58	2.01	1.61	0.83	1.11	1.42
Net present value per dollar invested (NPV/I)	3.05	1.90	1.13	N/A	N/A	N/A
Internal rate of return (IRR) (% p.a.)	18.1			5.9		

4.4 Conclusions

The results of the benefit-cost analysis clearly establish that 'Secure Yield Augmentation' option with positive Net Present Values and a benefit-cost ratio well above 1.5 for all the discount rates offers significant economic benefits compared to the 'do nothing' option.

The NPV per dollar of capital investment of 2.01 at 7% discount rate implies that every dollar invested would likely yield more than $2 in return on investment, thus indicating that augmenting secure yield of Guyra water supply scheme offers great value for money.

The IRR of 18.1% p.a. for the preferred option for secure yield augmentation indicates that the values of future benefits considered are conservative, and even at substantially lower level of the estimated benefits, this project can achieve net positive economic benefits.

4.5 Recommendations

This economic appraisal compared the option of augmenting secure yield of Guyra water supply scheme to address water security issues with a 'Do Nothing' option.

The benefit cost analysis indicate that the proposed project for secure yield augmentation will have a cost benefit ratio (BCR) and an internal rate of return (IRR) well above those for the 'Do Nothing' option. Sensitivity testing also indicates that even with a lower-bound benefit evaluation, the proposed project would be a more attractive economic proposition than the 'Do Nothing' option.

Based on the benefit cost analysis, the proposed Malpas to Guyra WTP water transfer system for augmenting secure yield of Guyra water supply scheme is recommended for implementation as it is expected to provide substantial economic benefits to the community and the region.

5 Project Planning and Delivery

A market based procurement strategy will be implemented to procure this project. Council will approach the market to encourage competition and to be consistent with government procurement obligations. Four phases have been identified for the procurement of this project, these being:

- Concept Design
- Detailed Design
- Construction, testing & commissioning
- Operation and Maintenance

Armidale Regional Council (ARC) implements a robust procurement strategy for procuring and managing a number of recently completed infrastructure projects. As part of the procurement strategy internal approval was obtained prior to proceeding, confirming the availability of funds and resources for managing the procurement. Council called open tenders; tenders were fairly evaluated in accordance with the NSW Government Tendering Guidelines.

Once funding approvals have been finalised for the remaining phases of the project Council will implement the remainder of the procurement strategy to deliver the detailed design, construction and maintenance phases of the project.

5.1 Establish Governance Structure

Council recognises the establishment of good project governance, reporting structure and communication channels are paramount to the success of the project. ARC has appointed a project team and allocated roles and responsibilities within the team.

The Council Project Director will be responsible for carriage of the project. The Project Director will delegate tasks where required for the delivery of the project to meet program and budget requirements.

Internal reporting will require bimonthly reporting during investigation /design and monthly reporting during construction. Project Handover report will be required at end of construction.

Changes to the project scope can only be authorised by the Project Manager after receipt of formal agreement from the Project Director. Such agreement and authorisation will include reference to the implication of change in relation to the project program and project budget.

5.2 Determine Market Approach (Procurement Strategy)

The procurement strategy is based on the complexities of the project. For example complexities within the design phases include procurement of specialist consultants to undertake the geotechnical, environmental assessments and field studies along with extensive community consultation should property acquisitions be required. Complexities within the construction phase include geographic locations and market capabilities.

In addition, ARC has given due consideration to the high level of probity required from NSW Local Government, sustainable procurement practices, and the utilisation of local resources where possible.

Concept and Detail Design Phase	
Activity	**Systems/Reports**
Project management policies and procedures	Project management procedures Reporting systems and delegations Project approval processes

Concept and Detail Design Phase	
Reports	Desktop feasibility study report
Procured services	Feasibility Study
Services to be procured	• Survey & Geotechnical investigation • Review of Environmental Factors • Concept Design • Detail Design & documentation • Constructions
Key project consideration	• Specialist consultants • Government Agency approvals • Property acquisitions if required

Construction Phase	
Activity	**Systems/Reports**
Project management policies and procedures	Project management procedures Reporting systems and delegations Project approval processes
Reports	Geotechnical investigation Environmental Assessment Tender Document
Services to be procured	Construction of the Pumping Stations and Transfer Main
Nature of the Contract	Lump sum with GC21 commercial conditions of contract
Key project consideration	• Geographic location • Market capabilities • Competitiveness for Government work, probity, fairness and transparency

5.3 Approvals and Agreements

This Project will require a number of approvals and agreements with other Government Agencies during the design development phase. The following table highlights some of the approvals that may be required should the pipeline route cross for example a classified road or through Crown Lands. As part of the design process a Review of Environmental Factors will be undertaken, depending on the outcome of the review specialist field studies maybe procured.

A preliminary assessment of the pipeline alignment has been undertaken to assess the sub-surface conditions and site topography. A desktop environmental review has also been undertaken to identify any significant environmental issues.

Table 5-1: Project Approvals and Agreements Required

Responsible Organisation	Approval/License/Permit
Armidale Regional Council	Determination under Part 5 of the EP&A Act if no significant impacts on the environment are identified.
NPWS	If any Aboriginal sites are impacted s90 permit under National Parks and Wildlife Act 1974. This process can take several months.
DPI Water	Consult with DPI Water to establish whether additional water access licence/s and other approvals is required under the Water Management Act 2000/Water Act 1912
NSW Fisheries	If undertaking open trenching across waterways gain a permit for the proposed works under s199 of Fisheries Management Act 1994.
Energy supply authority	Consult concerning energy supply requirements.
RMS	Potential for the need for road occupancy consent under s138 of Roads Act 1993 to lay pipeline within road reserve of New England Highway
Department of Lands	Approval to undertake work on Crown Land if Crown Land affected.
Aboriginal Heritage	An Aboriginal Heritage Impact Permit will need to be obtained if impacting on any Aboriginal Heritage
National Native Titles Tribunal	Undertake NTTT enquiry to determine if project area is affected by native title claim and, if so, to determine appropriate course of action

5.4 Project Program

The key milestones of the project would include the following activities:

- Undertake a detailed design for the transfer system;
- Undertake geotechnical investigation & survey for the pipeline alignment and pump station location;
- Prepare a Review of Environmental Factors
- Advertise tenders for construction;
- Review and award tender for construction of pipeline and pumping station.
- Construction of the work;
- Testing, demonstration and commissioning of the work
- Commissioning and handover

A preliminary assessment of the pipeline alignment has already been undertaken to assess the sub-surface condition and site topography. A desktop environmental review has also been undertaken to identify any significant environmental issues.

6 Project Risk Management

Council will identify risks by drawing on a systematic consideration of the key elements from concept development through to post-completion reviews and maintenance operation through stakeholder workshops. The workshops will involve multi-disciplinary teams. Risks may include aspects of environmental factors, land acquisitions, oversight of design development, availability of suitable tenderers and approach to maintenance responsibilities.

Risk Management

A preliminary risk management assessment has been undertaken. Risk measures are set out as remedial activities either to be undertaken by the contractor or Council. They included procedural arrangements, contract provisions or revised procurement conditions. They are set out against the individual risks in the table below. During the proposed workshops the likelihoods and consequences of each significant risk will be estimated.

Table 6-1: Project Risk Assessment

Risk	Consequence	Management Measure
Geotechnical status of the site and pipeline route is unknown	Cost increase Remediation delays	Investigate sub-surface conditions Advise tenderers of history of site
Current environmental standards change	Cost Project viability affected	Review/monitor environmental standards
Environmental review process too narrow	Project viability affected Time and/or cost impacts of required design changes	Review concept design changes Prepare an REF Liaise regularly with the community.
Land issues	Delay in obtaining land consent	Hold discussions with land owners Oversight during pipeline route assessment to necessitate timely contact with land owners Utilise local knowledge and insights
Approvals and interface with Government Agency	Delay in design process	Oversights in the Environmental Review to prevent the process being repeated
Industry does not respond to procurement strategy	No responses received for tender request Substantially higher costs than anticipated	Alter the conditions and/or documents. Invite responses from selected contractors
Latent conditions and poor management of design & construction engagements	Project overruns	Award lump sum Contract utilising GC21 general conditions. Engage a specialist project manager
Insufficient or inadequate information	Poor pricing	Initiate early contact with utilities Provide all known and available

Risk	Consequence	Management Measure
provided on which to base tender	No responses Inadequate design	information to tenderers Include PC provisions for third party costs
Total project costs not identified	High construction but low overall project costs	Economic appraisal completed Ensure appropriate risk apportionment Include statement of assumptions in tenders Include schedules for tenderers to break up their costs
Tender exceeds the cost estimate for the project	Project not viable	Review project costs, reduce/ alter scope Allocate suitable contingencies
Design is deficient	Unclear documentation Reduced asset life Inconsistent with user expectations	Develop a review/ acceptance process Ensure code and performance criteria compliance
Impacts on local community: • Access • Noise • Dust	Community resistance	Document standards to be maintained during construction in tender Comply with statutory requirements Liaise with community
Consultancy/Contractor's ongoing financial viability	Bankruptcy Takeover/merger	Assess financial capacity of Consultancy/ Contractor prior to awarding contract Contract Include termination rights and criteria in contract

7 Appendices

Appendix A Guyra Bulk Water Supply – Upgrade Options Report

Guyra Water Supply

Guyra Bulk Water Supply – Upgrade options

Addendum 1

Report Number: WSR - 17024

August 2017

NSW GOVERNMENT | Public Works Advisory

Guyra Water Supply

Guyra Bulk Water Supply System Upgrade

Report Number: WSR - 17024

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Contents

Figures

Tables

1 Introduction

This document is prepared as an addendum to the 'Guyra Bulk Water Supply – Upgrade Options' report no WSR-17024 (May 2017).

1.1 Background

The Armidale Regional Council (ARC) area is located in the New England Region of New South Wales, and has three separate water supply schemes for Armidale, Guyra and Tingha. Guyra's town water is sourced from two small dams located on the Gara River. Hydrologic studies show that the dams are too small to guarantee supply during an extended drought. ARC is considering various options to augment Guyra's bulk water supply and provide water security to the Town.

ARC engaged Public Works Advisory (PWA) to evaluate the options for Guyra's bulk water supply.

The water transfer from Malpas Dam to the Guyra WTP was identified as the preferred option to obtain a secure yield to meet the 2046 projected dry year extraction of 633 ML and provide additional yield for potential future industrial developments.

Pipeline Route Options

Two pipeline route options were considered for this transfer system. These options are shown in Figure 1.1.

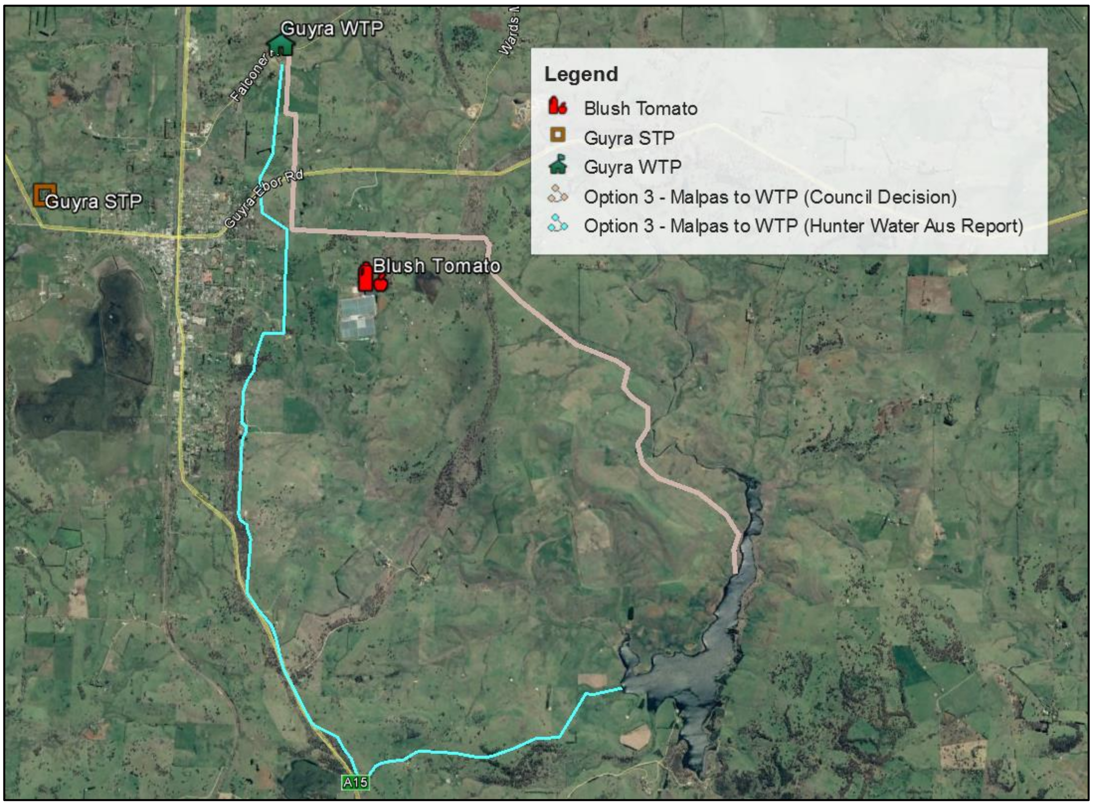

Figure 1.1: Malpas Dam to WTP pipeline options

Option 3 was identified as the preferred pipeline alignment in the report.

2 Purpose of this Addendum

Following initial consultations, Council feel that they may face some problems and delays with landholders west and southwest of Malpas Dam with pipeline routes that cross private farm land. Council would therefore like to evaluate an alternate pipeline route which follows Malpas Dam Road back southwest from the dam towards the New England Highway, then going north on the Highway similar to selected route. The new preferred alignment is shown in Figure 2.1.

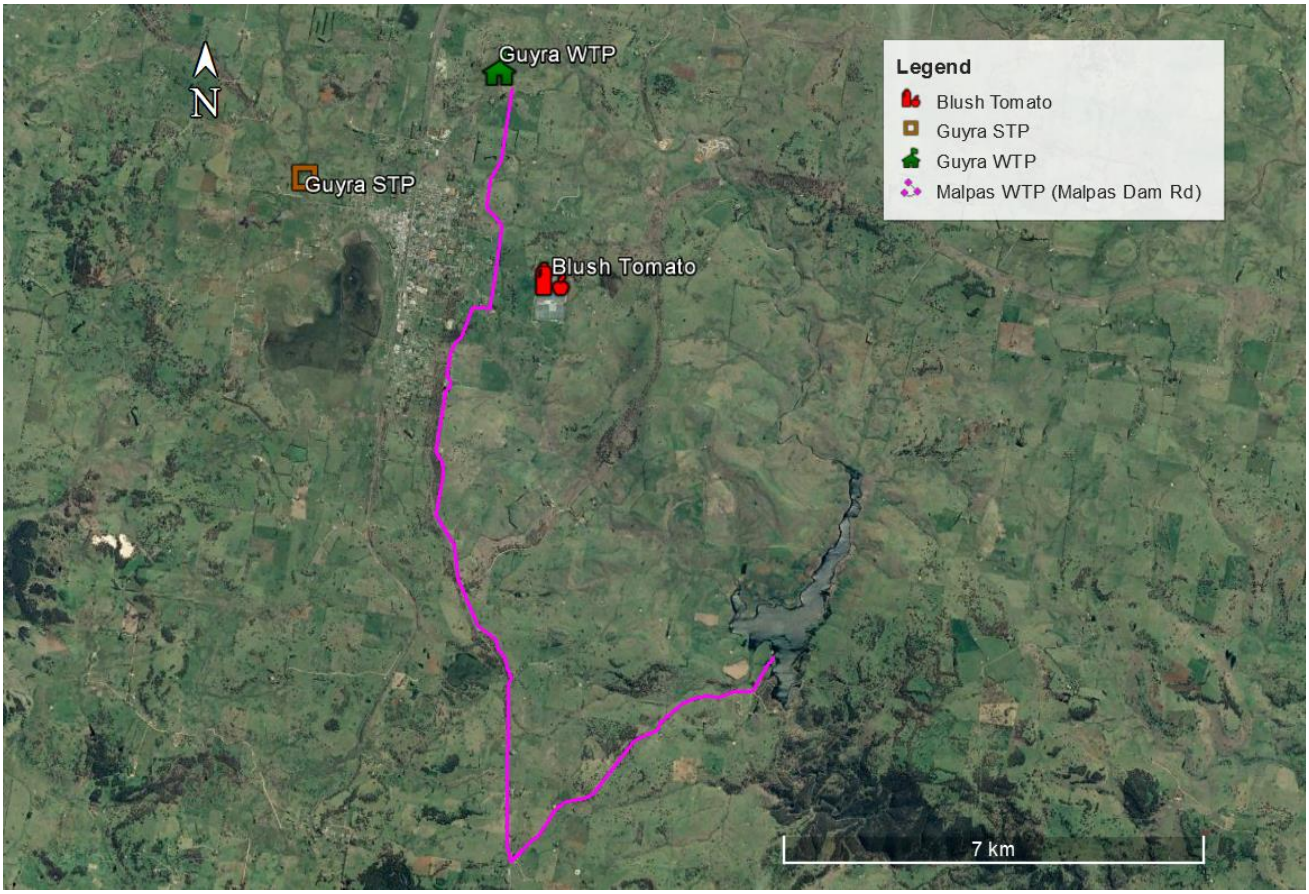

Figure 2.1: Alternate alignment for pipeline from Malpas dam to Guyra WTP

The purpose of this addendum is to assess this alternate pipeline route and review and confirm the cost estimate for the option.

3 Malpas Dam to Guyra WTP (Guyra Dam Road Alignment)

This augmentation will enable Malpas Dam to supply up to 767 ML/annum of water to Guyra WTP in the event that Guyra Dam runs low and can no longer be used as a source of water.

The works involved in this option include:

- Construction of an intake at Malpas dam
- A new pumping station at Malpas dam
- Power supply to the new pumping station
- A pipeline from the new intake at Malpas dam to the balance tank at the WTP to transfer a maximum of 2.1 ML/day
- Modifications at the balance tank.

Table 3.1: Malpas Dam to WTP pipeline options Summary

Route	Lot Crossings	Distance (km)	Constructability
Malpas Dam to WTP (Malpas Dam Road Option)	18	19.6	Rural path, follows Malpas Dam Rd, crosses the Guyra-Ebor Rd

Hydraulic Analysis

The hydraulic analysis for the transfer system from Malpas Dam to Guyra WTP was undertaken for the Malpas Dam Road Option pipeline route direct to WTP for two sizes of pipeline. The first is a 200 mm pipeline sized to pump the estimated average day peak month demand from the projected 2046 dry year demand - 2.1 ML/day (24.1 L/s). The second is a 300 mm pipeline which can supply up to 85.0 L/s.

The selected pipes are given in Table 3.2.

Table 3.2: Malpas Dam to WTP Pipeline Selection

Pipe Type	Section	Dynamic Headloss (m/km)
200 mm pipeline	**24.1 L.s**	
DICL DN200 PN35	0 – 3.5 km	2.04
mPVC DN200 PN15	3.5 – 19.6 km	3.03
300 mm pipeline	**85.0 L.s**	
DICL DN300 PN35	0 – 5.0 km	3.00
mPVC DN300 PN15	5.0 – 19.6 km	6.24

The long section of the pipeline route was obtained from Google Earth data. The hydraulic analysis for this selected pipeline route for both pipeline sizes are presented in Figure 3.1.

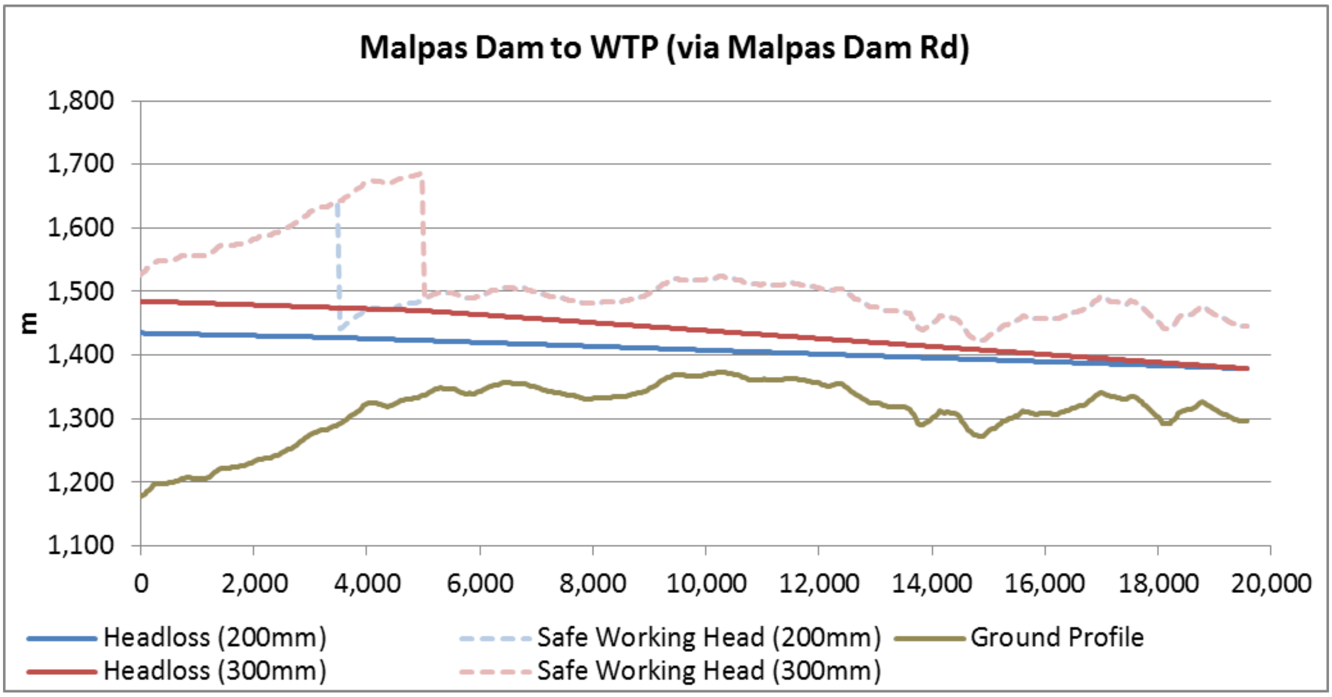

Figure 3.1: Malpas Dam to WTP Hydraulics Profile (200 mm and 300 mm pipeline)

4 Risk and Uncertainties

4.1 Subsurface Conditions

The subsurface conditions along Malpas Dam Rd are expected to be similar those along the New England Highway. As stated in the Options Report, in general, residual deposits and bouldery zone are expected to be excavatable using a backhoe or a hydraulic excavator. Hard digging conditions for a backhoe would be expected in areas where the cobbles/boulders are tightly packed.

In the cost estimate we have included an additional allowance for rock removal for 20% of the new alignment along the New England Highway and Malpas Dam Road.

4.2 Environmental Impacts

It is expected that are no additional impacts on aboriginal or European heritage, Threatened Flora and Fauna or Endangered Ecological Communities for the pipeline alignment along the Malpas Dam Road compared to the previous pipeline alignment.

5 Cost Analysis

A present worth cost analysis, with capital costs and 30-year operating cost, was undertaken for all the options. The following information was used for the analysis:

- Latest market pricing estimation from previous work completed by PWA
- Council's preferred pipeline route
- Calculated water demands for Blush Tomatoes and the town of Guyra

A summary of the present cost estimates for the 200 mm and 300 mm pipeline options are provided in Table 5.2 and Table 5.3.

Net Present Value

The net present value for 200 mm pipeline option is given in Table 5.1. Pumping cost is calculated using power cost of 32 c per kWh, and considering a 5-yearly wet and dry year cycle, water transfer from Malpas dam will be required only during the 'dry years' of the cycle. In wet years no volume is pumped as it is assumed water demand can be met by Guyra Dam.

Table 5.1: Malpas Dam to Guyra WTP Water Transfer System, Malpas Dam Road alignment (200 mm pipeline) – Net Present Value

Item	Rate	Net Present Value (NPV)		
		4%	7%	10%
Capital Cost	**$12,845,692**	**$12,845,692**	**$12,845,692**	**$12,845,692**
Operation Cost				
Pumping Cost	$1.25/ML/m head	$286,088	$248,866	$225,158
Maintenance Cost				
Maintenance Cost - Civil	0.50% of Civil Capital Cost	$434,428	$318,459	$247,635
Maintenance Cost - Mechanical and Electrical	4.00% of Mech and Elec Capital Cost	$595,589	$436,598	$339,500
Total Operation & Maintenance Costs		**$1,316,105**	**$1,003,923**	**$812,293**
Total Present Value		**$14,161,797**	**$13,849,615**	**$13,657,985**

Table 5.2: Malpas Dam to Guyra WTP Water Transfer System, Malpas Dam Road alignment (200 mm pipeline) – Cost Estimate

Item	Rate	Quantity	Amount
Pipe cost (supply and lay)			
DICL DN200 PN35	$288/m	3,500	$1,009,638
mPVC DN200 PN15	$217/m	16,084	$3,483,280
Difficult Construction			
Additional allowance for residential areas	$100/m	725	$72,500
Additional allowance for rock removal	$500/m	4,000	$2,000,000
Road Crossings			
Open Trenching (minor roads)	$1,000/m	10	$10,000
Directional Drilling (Starr rd)	$5,000/m	12	$60,000
Directional Drilling (Guyra-Ebor rd)	$5,000/m	11	$55,000
Malpas Dam Pumping Station - Mechanical and Electrical			
Pump	$150,000	2	$300,000
Valves (2 NRV, 2 GV, 2 RN)	$6,500	6	$39,000
Dismantling Joints	$10,000	4	$40,000
Flowmeter	$25,000	1	$25,000
SCA (Switchboard)	$180,000	1	$180,000
Miscellaneous (Pipework)	$30,000	1	$30,000
Malpas Dam Pumping Station - Civil			
Excavation	$40,000	1	$40,000
Fill and Embankments	$10,000	1	$10,000
Metal works	$7,000	1	$7,000
Concrete works	$250,000	1	$250,000
Epoxy Painting	$17,000	1	$17,000
Landscaping	$6,000	1	$6,000
Intake arrangement	$200,000	1	$200,000
Malpas Dam Power Supply			
Power Connection	$200,000	1	$200,000
Extras			
Powdered Activated Carbon Dosing System	$200,000	1	$200,000
Prime Costs			**$8,234,418**
General Contingency	30% of Prime Cost		$2,470,325
Direct Costs			**$10,704,743**
Design & Preconstruction Activities	10% of Direct Cost		$1,070,474
Construction Activities	10% of Direct Cost		$1,070,474
Total Capital Cost			**$12,845,692**

Table 5.3: Malpas Dam to Guyra WTP Water Transfer System, Malpas Dam Road alignment (300 mm pipeline) – Cost Estimate

Item	Rate	Quantity	Amount
Pipe cost (supply and lay)			
DICL DN300 PN35	$410/m	5,000	$2,051,725
mPVC DN300 PN15	$353/m	14,584	$5,144,245
Difficult Construction			
Additional allowance for residential areas	$100/m	725	$72,500
Additional allowance for rock removal	$500/m	4,000	$2,000,000
Road Crossings			
Open Trenching (minor roads)	$1,000/m	10	$10,000
Directional Drilling (Starr rd)	$5,000/m	12	$60,000
Directional Drilling (Guyra-Ebor rd)	$5,000/m	11	$55,000
Malpas Dam Pumping Station - Mechanical and Electrical			
Pump	$300,000	2	$600,000
Valves (2 NRV, 2 GV, 2 RN)	$15,000	6	$90,000
Dismantling Joints	$10,000	4	$40,000
Flowmeter	$35,000	1	$35,000
SCA (Switchboard)	$300,000	1	$300,000
Miscellaneous (Pipework)	$50,000	1	$50,000
Malpas Dam Pumping Station - Civil			
Excavation	$50,000	1	$50,000
Fill and Embankments	$10,000	1	$10,000
Metal works	$15,000	1	$15,000
Concrete works	$300,000	1	$300,000
Epoxy Painting	$17,000	1	$17,000
Landscaping	$6,000	1	$6,000
Intake arrangement	$300,000	1	$300,000
Malpas Dam Power Supply			
Power Connection	$200,000	1	$200,000
Extras			
Powdered Activated Carbon Dosing System	$200,000	1	$200,000
Prime Costs			**$11,606,470**
General Contingency	30% of Prime Cost		$3,481,941
Direct Costs			**$15,088,412**
Design & Preconstruction Activities	10% of Direct Cost		$1,508,841
Construction Activities	10% of Direct Cost		$1,508,841
Total Capital Cost			**$18,106,094**

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Guyra Water Supply

Guyra Bulk Water Supply – Upgrade options

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Guyra Water Supply

Guyra Bulk Water Supply System Upgrade

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Contents

Figures

Tables

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DPI Water recommends that when a Local Water Utility (LWU) is planning to undertake significant capital works, it should be based on a sound IWCM Strategy. The IWCM Strategy enables the LWU to 'right size' the works and helps ensure they provide value for money on the triple bottom line (TBL) basis. The IWCM strategy will also provide supporting information as the basis for preparing funding applications to avail of any State or Federal government grants.

ARC has engaged Public Works Advisory (PWA) to prepare an IWCM Strategy for the Guyra region of ARC. The assessment and evaluation of options for Guyra's bulk water supply and selection of the preferred option will form part of the IWCM process

1.2 This Study

This report presents the outcomes of the options investigation for the augmentation of the Guyra bulk water supply. This report and will also be used to support a business case to obtain government grants.

The objective of the study is to identify the best option to augment the Guyra bulk water supply system to meet the projected demand, whilst maintaining an appropriate level of service for existing customers. The options considered are:

- Raising Guyra dam 2;
- Building an off-stream storage
- Transferring water from Malpas dam
- Effluent reuse for the Tomato farm to supplement town water supply.

The scope of the feasibility assessment includes:

- Estimate the water demands for Guyra
- Assess options for the pipeline alignments
- Evaluate sub-surface geotechnical conditions for the pipeline alignments
- Evaluate site conditions for suitable off-stream storage sites
- Assess environmental risks for the pipeline alignment and off-stream storage site options
- Undertake a desktop hydraulic analysis to size the scheme components
- Carry out a lifecycle cost analysis for the options
- Undertake a cost benefit analysis using NSW Treasury Guidelines.

This report presents the outcomes of the study.

2 Existing water supply scheme

Armidale's primary water supply is Malpas Dam, an earthen dam located 26km NNE of Armidale and 9km SE of Guyra. The top water level of the dam is 1175.7 mAHD, which is about 140 m lower elevation than Guyra town. The Malpas catchment is 195 km^2 and the dam has a capacity of 12,260 ML.

The Guyra raw water supply is sourced from two dams on the Gara River located 7 km north of Guyra town. Guyra's two dams (top water level ~1265mAHD) have a catchment of 74km^2 which is within the overall Malpas Dam catchment. Both Guyra dams have a LOW hazard rating and are not "prescribed dams" under the Dam Safety Act 1978.

Overflow from the Guyra dams flows down the Gara River to Malpas Dam. Two 70L/s duplicate pumps transfer raw water from Guyra #1 Dam via parallel rising mains to a 0.4 ML balancing tank and then water gravitates to the water treatment plant. The plant has a nominal capacity of 6.05 ML per day and is located approx. 2.5 km north of Guyra on Falconer Road.

After treatment, various pumps with total capacity of 39 L/s transfer treated water to two clear water reservoirs located in Guyra. The two reservoirs have capacities of 0.9 ML and 2.5 ML respectively.

From the reservoirs, water is distributed by a gravity reticulation network to consumers including a large scale glasshouse farm to grow tomatoes. One exception is the supply by a dedicated line from the treatment plant to the old Abattoir site on the northern side of Guyra which now operates as a rabbit farm. Bulk water is supplied periodically to this rabbit farm on request and averages 1.4 ML per year. A schematic arrangement of the Guyra water supply is shown in Figure 2.1.

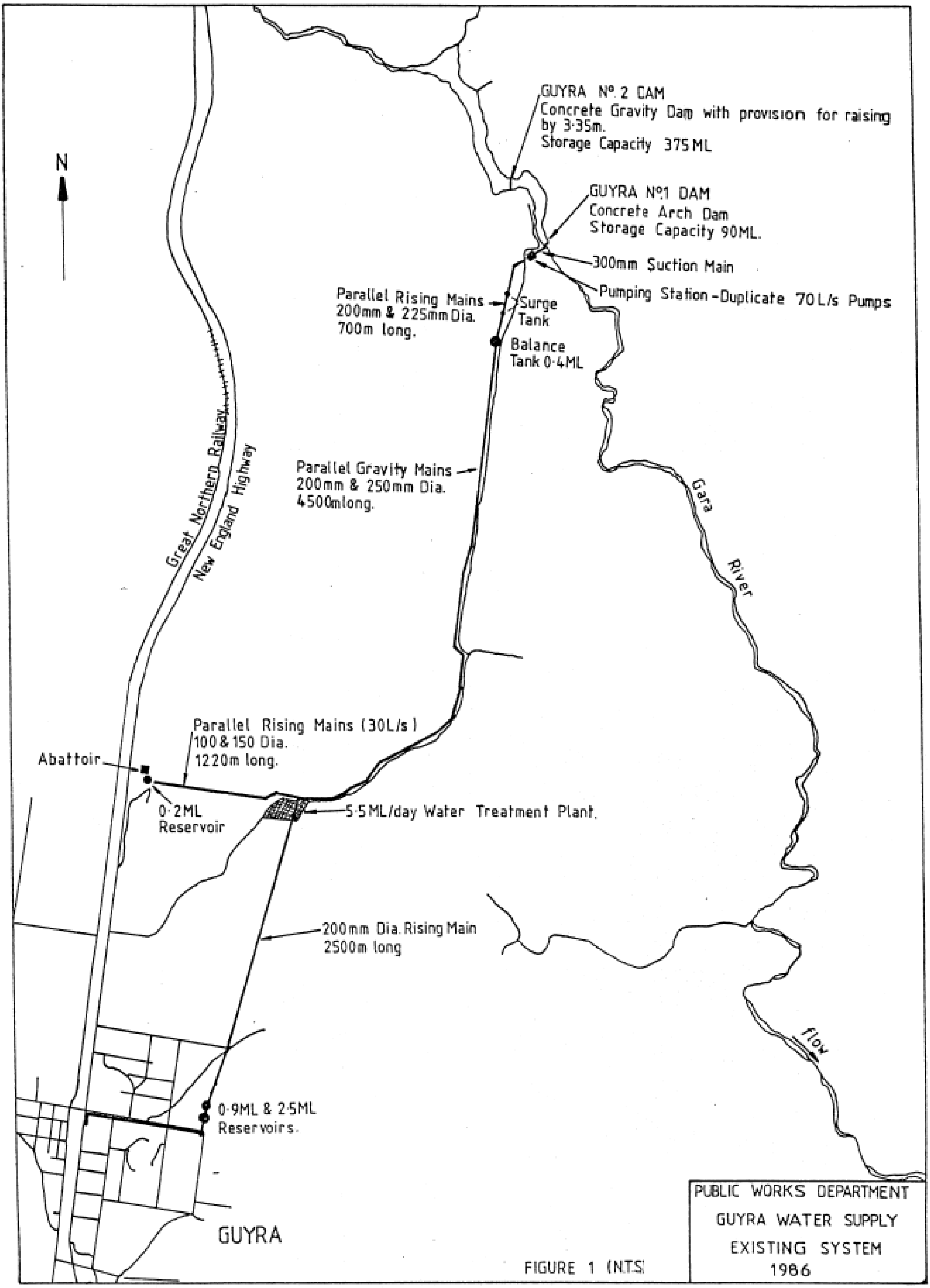

Figure 2.1: Guyra water supply scheme

3 Population and water demand analysis

3.1 Population

The historical Estimated Resident Population (ERP) for the former Guyra LGA is presented in Table 3.1.

Table 3.1: Historical Guyra Shire Estimated Resident Population

	1991	1996	2001	2006	2011	2015
Former Guyra LGA	4,927	4,468	4,441	4,333	4,520	4,551

The historical population for the Urban Centres is presented in Table 3.2. These populations are obtained from ABS Census Basic Community Profile (BCP) data.

Table 3.2: Historical Population of Guyra Urban Centre

Area	Population			Growth Rate (per year)		Historical Average Annual Growth Rate
	2001	2006	2011	2001 to 2006	2006 to 2011	
Guyra Urban Centre	1725	1,760	1,947	0.41%	2.13%	1.29%

It is noted that the town of Guyra has grown faster than the rest of the former Shire in recent times. Council believes that a one percent growth rate is realistic for the town of Guyra, and this has been adopted to project the water demands.

3.2 Water demand

PWA undertook an analysis of the water production and metered data to estimate the current demands, the unit demands and project the future demands. Production data from 1 July 2009 to 31 August 2016 was analysed. Water meter billing data was provided by Council for the duration of the 2008/19 financial year to the 2015/16 financial year. The historical average daily demands for each user class are shown in Figure 3.1.

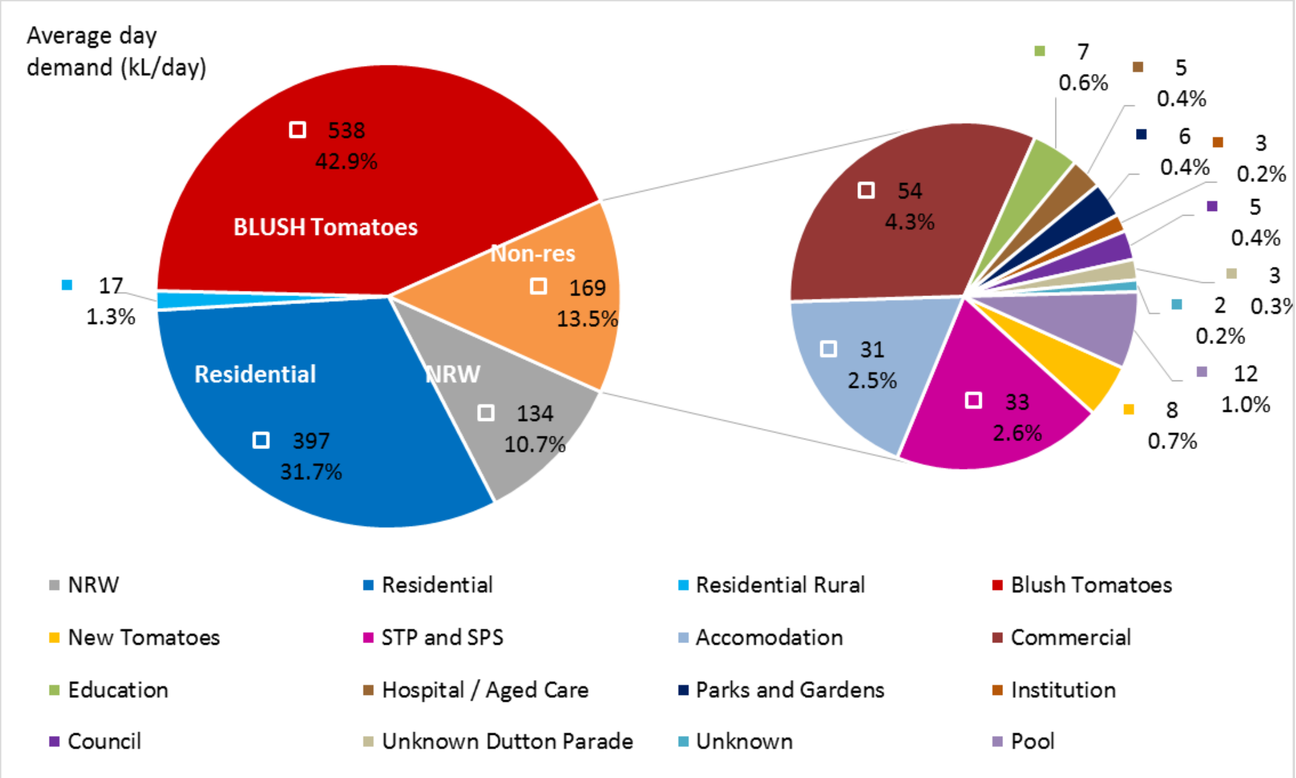

Figure 3.1: Guyra water supply – Production and demand split by major user class

The average day demand split for an average and dry year and the peak day demand split are shown in Figure 3.2. Daily Non Revenue Water (NRW) is assumed to be constant.

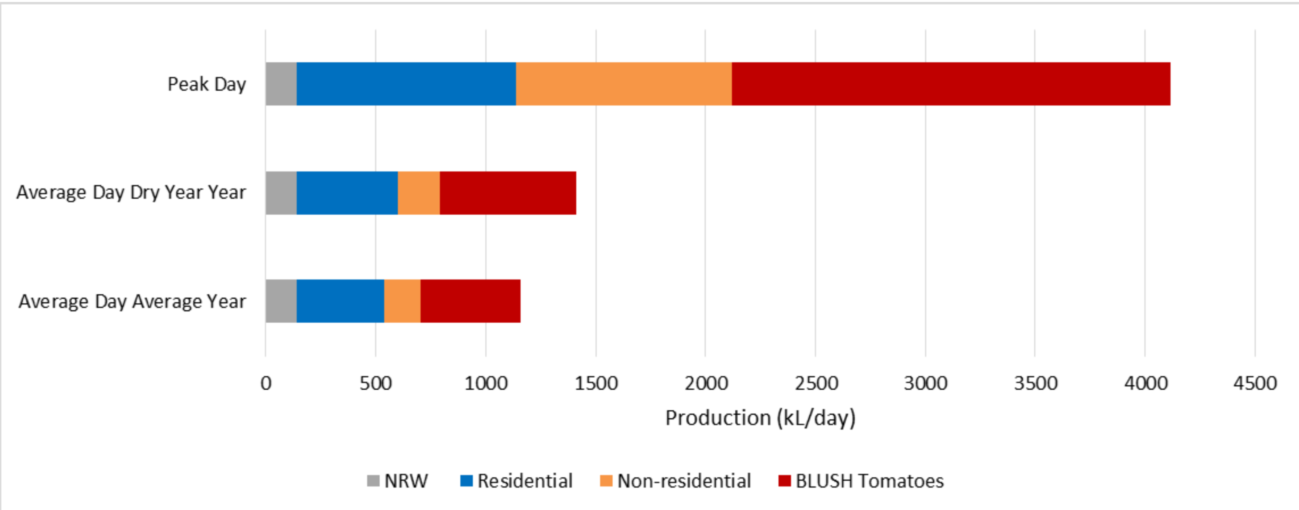

Figure 3.2: Guyra water supply production – system demand splits

The forecast water production provided in Table 3.3includes increase in demand from projected properties based on a one percent growth rate adopted for the town of Guyra.

Table 3.3: Forecast water production and extraction

		2016	2021	2026	2031	2036	2041	2046
Production	Average year (ML/year)	423	430	438	448	459	473	488
	Dry year (ML/year)	515	523	533	544	557	572	589
	Peak day (ML/day)	4.1	4.2	4.2	4.3	4.4	4.4	4.5
Extraction	Average year (ML/year)	455	462	471	481	494	508	525
	Dry year (ML/year)	554	563	573	585	599	615	633
	Peak day (ML/day)	4.4	4.5	4.5	4.6	4.7	4.8	4.8

The unit demand estimated for the Blush Tomato farm is provided in Table 3.4.

Table 3.4: Unit demand for BLUSH Tomatoes

Average year demand (ML/year)	Dry year demand (ML/year)	Dry year to average year ratio	Average day demand (kL/day)	Peak day demand (kL/day)	Peak day to average day ratio
166	226	136%	455	2000	440%

The impact of climate change on the forecast water demand was also considered using information from the CSIRO. The overall change in production under climate change scenario is expected to be a 5 percent increase in average year production and a 6 percent increase in dry year production.

4 Secure yield of existing system

Secure yield is defined as the highest annual water demand that can be supplied from a water supply headworks system whilst meeting the 5/10/10 design rule. The secure yield can be increased by providing larger storages, more water sources, increased transfer capacities or a combination of all three.

The key aspects of the 5/10/10 rule are:

1. Water restrictions are in place for no more than 5% of the time
2. Water restrictions occur on average once every 10 years
3. During water restrictions, demand is reduced by 10%

These 'rules' are utilised in the water supply modelling to determine the maximum annual demand that can be extracted from the system whilst conforming to the 5/10/10 rules' and other system specific constraints.

Hunter Water Australia completed a secure yield study and augmentation options assessment for the former Guyra Council. Hunter Water engaged NSW Urban Water Services to undertake the secure yield analysis for the Guyra headworks.

Armidale Regional Council recently engaged WREMA Pty Ltd to undertake a secure yield analysis for the existing Guyra water supply headworks and a range of augmentation options including a supply from Malpas dam.

The results from these analyses of the current secure yield are summarised in Table 4.1.

Table 4.1: Guyra water supply existing headworks secure yield results

Study	Dam 1 Storage Volume (ML)	Dam 2 Storage Volume (ML)	Dead Storage Volume (ML)	Above EFR	Secure Yield ML/a
NSW Urban Water Services	90	390	84	0	390
WREMA	110	350	52	0	277

Both studies indicated that the existing system does not have a secure yield suitable to meet the existing or projected dry year demand. This is shown in Figure 4.1.

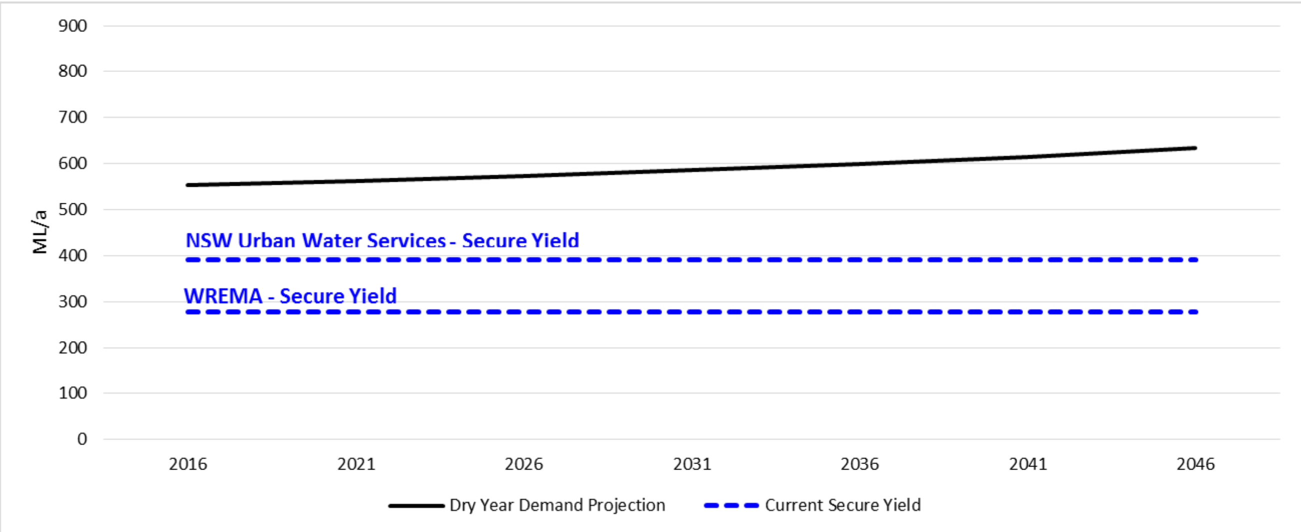

Figure 4.1: Current Secure Yield of Guyra Water Supply and Projected Dry Year Demand

In order to increase the secure yield of the Guyra water supply, the following water supply augmentations have been considered:

- Raising Guyra Dam 2;
- Building a 500 ML off-stream storage
- Transferring water from Malpas dam
- Effluent reuse for the Tomato farm to supplement town water supply.

These potential augmentations have been evaluated to:

- Assess their feasibility
- Determine the works involved
- Assess the risks to construction
- Assess the environmental impacts
- Estimate the costs.

5 Raising Guyra Dam 2

Raising of the existing Guyra Dam 2 by 2 m and 3 m has been considered.

The following is taken from the 2017 report, Guyra WS Augmentation Feasibility Study for Additional Storage by Public Works Advisory.

5.1 Guyra Dam 2

Dam 2 is located on the Gara River approximately 7.5 km north of Guyra. It is positioned immediately upstream of Dam 1 from which the town's water supply is sourced. Dam 2 was constructed in 1968 and has a storage capacity of 390 ML.

Dam 2 is of the concrete gravity type, approximately 7m high (max) and 120m long, and is keyed in to a basaltic rock foundation in the bed and in the abutments. An outlet valve at the base of the dam allows controlled releases into Dam 1 when levels are below the crest.

From investigation of the site and condition assessment of the existing dam structure, there appears no engineering impediment to dam raising. Exposed rock in the bed and abutments would be well suited for founding the raised structure and the existing dam concrete, being in good condition, would easily support any additional loading from dam raising.

From site inspection and preliminary assessments, it appears that dam raising would have minimal environmental impact other than inundation of low lying land around the storage perimeter,

5.1.1 Dam Raising by 2 m

This option provides additional storage capacity of about 335 ML. The Full Supply Level is raised by 2 m and the abutment walls are raised to accommodate the passage of the 1 in 1,000 AEP flood over the central spillway section. The extended abutment concrete walls are keyed in to the bedrock as with the existing structure. The intake structure is raised but no extension of the existing outlet valve box is required.

5.1.2 Dam Raising by 3 m

This option provides additional storage capacity of about 555 ML. The Full Supply Level is raised by 3m and the abutment walls are raised to accommodate the required 1 in 1,000 AEP flood over the central spillway section commensurate with a LOW Consequence Category dam. As with the 2 m raising, the extended abutment concrete walls are keyed in to the bedrock. Again, the intake structure is raised but no extension of the outlet valve box is required.

5.2 Consequence Category

Presently the dam is **not prescribed** in terms of the NSW Dams Safety Committee guidelines but, from visual determination and review of available data, it is assessed that the Consequence Category of the dam would be equivalent to LOW in light of it being below the 15 m high benchmark, sparse development downstream and the unlikely loss of life in the event of dam failure. For a LOW Consequence Category dam, the required flood capacity is the 1 in 1,000 AEP event.

5.3 Cost Estimate

For cost estimate for the 2 m and 3 m dam raising is given in Table 5.1.

Table 5.1: Dam Raising - Cost estimate

		2m Dam Raising		3m Dam Raising	
Item	Rate	Quantity	Amount	Quantity	Amount
Establishment/Disestablishment	LS		$150,000		$160,000
Environmental Plans/Approvals	LS		$100,000		$100,000

		2m Dam Raising		3m Dam Raising	
Item	**Rate**	**Quantity**	**Amount**	**Quantity**	**Amount**
Dewatering and Flood Protection	LS		\$100,000		\$100,000
Excavation in Existing Concrete	2000/m^3	140	\$280,000	140	\$280,000
Excavation in Rock, Foundation Preparation	50/m^3	120	\$6,000	160	\$8,000
Concrete Works	1,250/m^3	3,220	\$4,025,000	4,150	\$5,187,500
Anchor Bars	100.m	400	\$40,000	520	\$52,000
Raised Intake Works	LS		\$100,000		\$120,000
Handrails and Metalwork	LS		\$50,000		\$60,000
Raised Access	LS		\$50,000		\$65,000
ESTIMATE SUB-TOTAL			**\$4,901,000**		**\$6,132,000**
Preconstruction (10%)	LS		\$490,100		\$613,200
Contract Supervision (10%)	LS		\$490,100		\$613,200
General Contingencies (30%)	LS		\$1,470,300		\$1,839,600
ESTIMATE TOTAL (ex GST)			**\$7,351,500**		**\$9,198,000**

6 New Off-stream Storage

Construction of a 500 ML Off-stream Storage has been considered. Water would be transferred to the off-stream storage from Guyra Dam 1 whenever streamflows are above a certain threshold, ensuring that town demands and environmental flow requirements are satisfied

6.1 Alternative 500 ML storage sites

Four potential site options for the off-stream storage were inspected during a site visit by PWA engineers. These were:

- A site on a creek that joins the Gara river adjacent to the quarry,
- A site on the Gara River adjacent to the quarry
- A quarry pit site holding water
- A site approximately 2 km north of the Guyra township in cleared farm land.

The sites on the creek and on the Gara river would require wide ranging development and environmental approvals. The quarry pit site was not considered viable due to its limited storage capacity and the relatively porous nature of the rock foundations.

6.2 Off-stream Storage

The site approximately 2 km north of the Guyra township in cleared farm land, was investigated further as the site for the construction of the off-stream storage.

The floor overlies the clay foundation layer and the embankments are constructed from materials imported presumably from the nearby quarry. The embankment height is 6m approximately which incorporates a 1m freeboard above the storage top water level. The embankments have side slopes of 1v to 3h and crest width of 4m. The inner slopes of the embankments are waterproofed with a geosynthetic clay liner (GCL) overlain by a gravel layer and rip-rap. The embankment crest is paved while the outer slopes are topsoiled and grassed. A 20m wide spillway is provided in which the crest and sides are protected with rock filled mattresses. An access ramp is constructed to facilitate access to the top of the embankments. Inlet and outlet pipework is provided for controlled releases which would be concrete encased when passing under the embankments. Drainage is also provided around the external toe of the embankments.

6.2.1 Delivery Pipelines to and from the Storage

Pipelines would be constructed in the ground to receive water from Dam 1 and to deliver water to the Water Treatment Plant. For this operation, it is envisaged that a new pumping station would be required at Dam 1 and at the off-stream storage site respectively.

Site 1 is located near the main northern railway line which is currently not in use. The pipeline from Dam 1 and to the Water Treatment Plant would need to cross this railway line probably by thrust boring through the line embankment.

6.2.2 Consequence Category

Because of the storage's proximity to the Guyra township and the main northern railway line, although not currently in use, it is assessed from visual inspection and review of available data that the Consequence Category of the off-stream storage embankments would be equivalent to SIGNIFICANT. Dambreak studies would be required to confirm this. Flood studies would also be required to assess any impediments to natural flows through the area.

6.2.3 Cost Estimate

The cost estimate for the off-stream storage is given in Table 6.1.

Table 6.1: Off-stream storage – Cost Estimate

Item	Rate	Quantity	Amount
Establishment/Disestablishment	LS		$300,000
Environmental Plans/Approvals	LS		$100,000
Dewatering and Flood Protection	LS		$50,000
Excavation in OTR, Foundation Preparation	2/m^3	32,000	$64,000
Excavation for Inlet/Outlet Pipework and Valve Pit	10/m^3	500	$5,000
Supply and Installation of Inlet and Outlet Pipework	LS		$600,000
Construction of Reinforced Concrete Encasement for Pipes	1,000/m^3	100	$100,000
Embankment (and Ramp) Fill	10/m^3	190,000	$1,900,000
Geotextile	20/m^2	30,000	$600,000
Gravel Layer	80/m^3	6,000	$480,000
Rip-Rap	80/m^3	6,000	$480,000
Topsoil and Grassing	30/m^2	26,000	$780,000
Crest Pavement	20/m^2	5,600	$112,000
Rockfilled Mattress Protection for Spillway and Perimeter Drain	20/m^2	3,200	$64,000
DN300 Pipeline from Dam 1 to Off-Stream Storage (2,900m)	LS		$870,000
DN300 Pipeline from Off-Stream Storage to Water Treatment Plant (2,100m)	LS		$630,000
Pump Station at Guyra Dam 1	LS		$450,000
Pump Station at Off-Steam Storage	LS		$450,000
ESTIMATE SUB-TOTAL			**$8,035,000**
Preconstruction (10%)	LS		$803,500
Contract Supervision (10%)	LS		$803,500
General Contingencies (30%)	LS		$2,410,500
ESTIMATE TOTAL (ex GST)			**$12,052,500**

7 Water Transfer from Malpas Dam

This augmentation would involve transferring water from Malpas dam to provide security for the Guyra water supply. The water from Malpas dam could be either supplied to the Guyra WTP or directly to the Blush Tomato farm.

7.1 Malpas Dam to Guyra WTP

This augmentation will enable Malpas Dam to supply up to 767 ML/annum of water to Guyra WTP in the event that Guyra Dam runs low and can no longer be used as a source of water.

The works involved in this option include:

- Construction of an intake at Malpas dam
- A new pumping station at Malpas dam
- Power supply to the new pumping station
- A pipeline from the new intake at Malpas dam to the balance tank at the WTP to transfer a maximum of 2.1 ML/day
- Modifications at the balance tank.

7.1.1 Transfer System

Pipeline Route Options

Two pipeline route options were considered for this transfer system. These options are shown in Figure 7.1 and briefly described in Table 7.1.

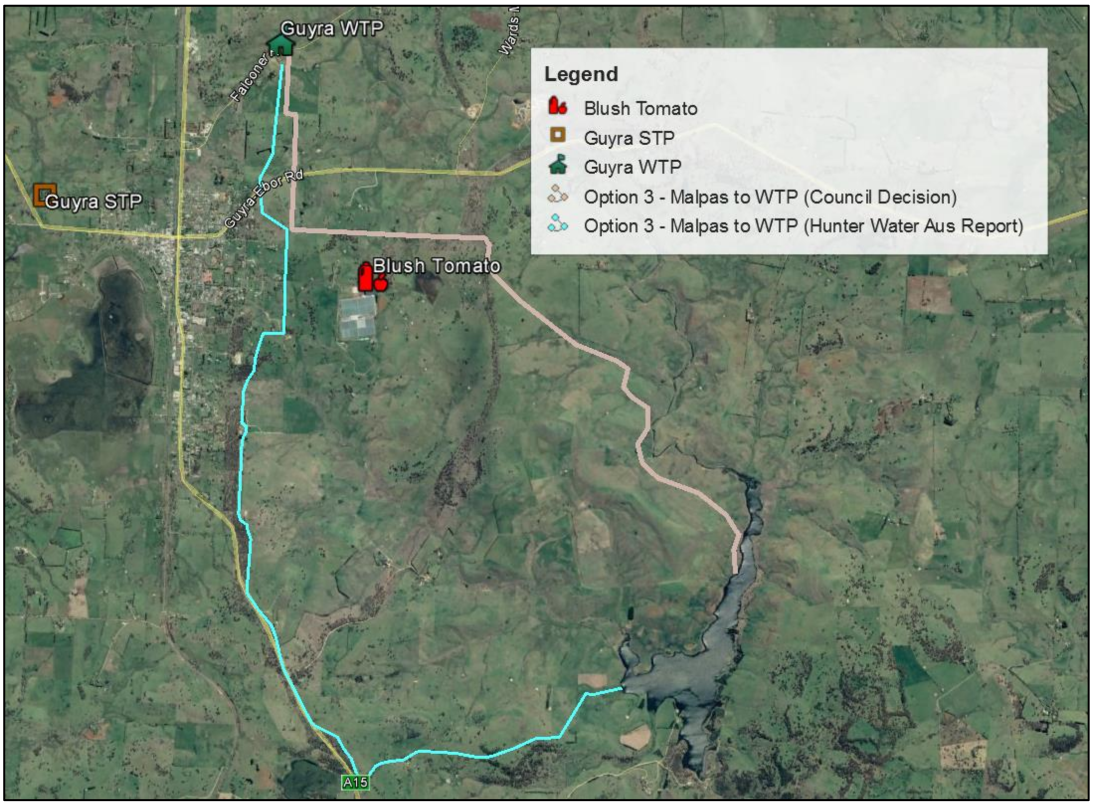

Figure 7.1: Malpas Dam to WTP pipeline options

The two pipeline route options are briefly described in Table 7.1. The route option via Blush Tomato Greenhouse was not considered further as the northern side of Malpas Dam is a shallower than the southern part and therefore the intake would have less water available should the Dam capacity run low.

Table 7.1: Malpas Dam to WTP pipeline options Summary

Route	Lot Crossings	Distance (km)	Constructability
Malpas Dam to WTP (Hunter Water Aus Report)	21	14.5	Mostly rural, crosses Elm St and Guyra-Ebor Rd
Malpas Dam to WTP (PWA selected)	9	11.9	Rural path, crosses the Guyra-Ebor Rd

Hydraulic Analysis

The hydraulic analysis for the transfer system from Malpas Dam to Guyra WTP was undertaken for the pipeline route direct to WTP for two sizes of pipeline. The first is a 200 mm pipeline sized to pump the estimated average day peak month demand from the projected 2046 dry year demand - 2.1 ML/day (24.1 L/s). The second is a 300 mm pipeline which can supply up to 85.0 L/s.

The selected pipes are given in Table 7.2.

Table 7.2: Malpas Dam to WTP Pipeline Selection

Pipe Type	Section	Dynamic Headloss (m/km)
200 mm pipeline	**24.1 L.s**	
DICL DN200 PN35	0 – 1.5 km	2.04
mPVC DN200 PN15	1.5 – 14.5 km	3.03
300 mm pipeline	**85.0 L.s**	
DICL DN300 PN35	0 – 3.5 km	3.00
mPVC DN300 PN15	3.5 – 14.5 km	6.24

The long section of the pipeline route was obtained from Google Earth data. The average demand data were provided by staff specialists at PWA. The hydraulic analysis for this selected pipeline route for both pipeline sizes are presented in Figure 7.2.

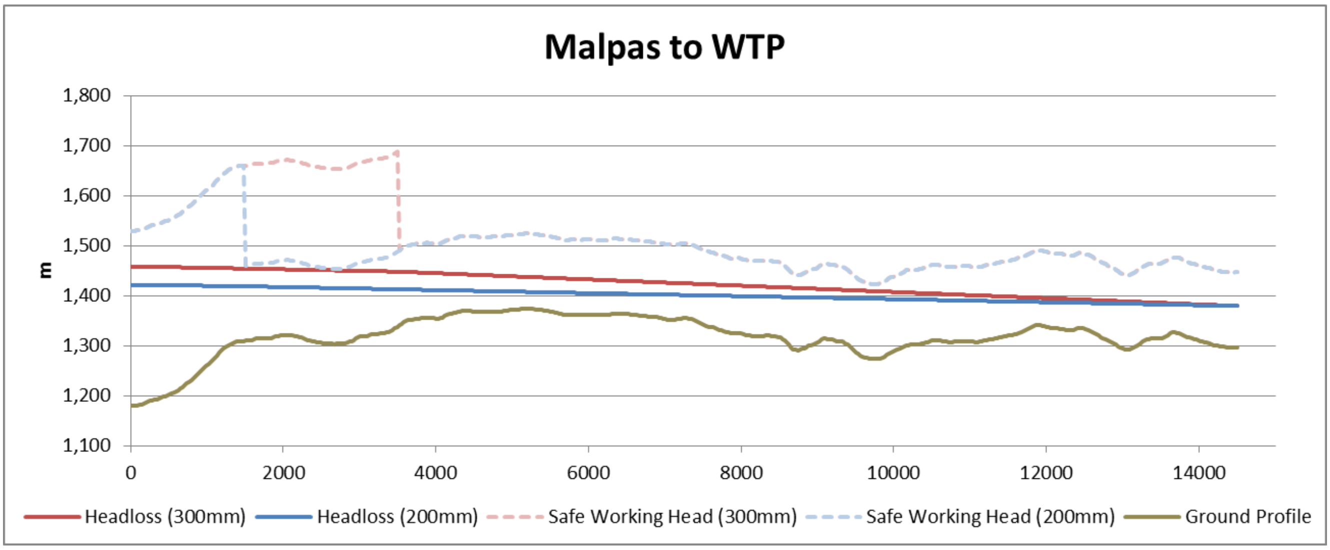

Figure 7.2: Malpas Dam to WTP Hydraulics Profile (200 mm and 300 mm pipeline)

7.2 Water Transfer from Malpas Dam to Blush Tomato Greenhouse

This augmentation will enable Malpas Dam to supply the total water demand of the Blush Tomato Greenhouse.

The works involved in this option include:

- Construction of an intake at Malpas dam
- A new pumping station at Malpas dam
- Power supply to the new pumping station
- A pipeline from the new intake at Malpas dam to the balance tank at the WTP.

7.2.1 Transfer System

Pipeline Route Options

Four pipeline route options were considered for this transfer system. These options are shown in Figure 7.3.

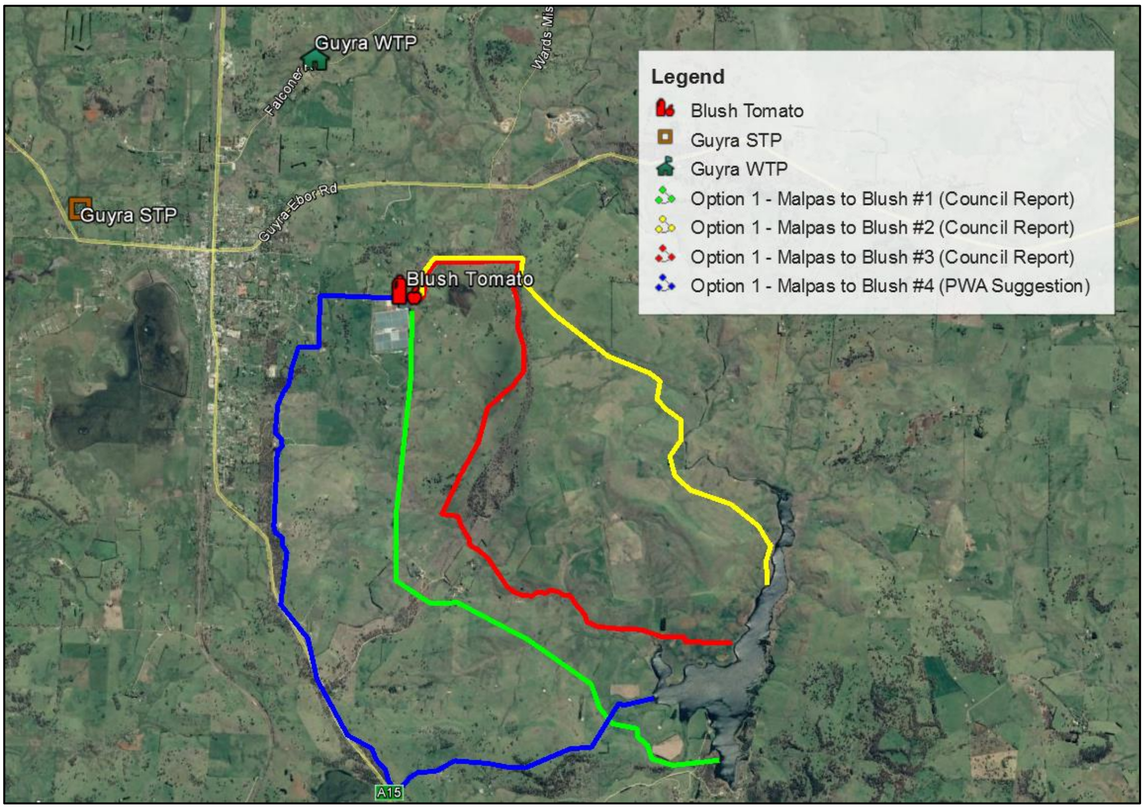

Figure 7.3: Malpas Dam to Blush Tomato Farm pipeline options

The four pipeline route options are briefly described in Table 7.3.

Route options #2 and #3 were not considered further for the following reasons:

- These route options connect to the tail end of the dam and the pipeline intake arrangement would potentially be exposed when the dam draws down
- A number of environmental issues were identified along these routes closer to the tomato farm
- There would be additional costs associated with providing power supply to the pumping stations as the power supply currently is up to the dam wall.

Table 7.3: Malpas dam to Blush Tomato farm pipeline options summary

Route	Lot Crossings	Distance (km)	Constructability
Malpas to Blush #1	13	9.0	Rural Path, crossing over 1 residential drive way
Malpas to Blush #2	7	8.3	Rural Path, furthest away from power source

Malpas to Blush #3	8	10.4	Rural Path
Malpas to Blush #4	16	13.0	Mostly Rural, crossing urban environments closer to Blush Tomatoes

Hydraulic Analysis

The hydraulic analysis for the transfer system from Malpas Dam to Blush Tomato Greenhouse was undertaken for pipeline route #1 and #4. The pipeline was sized to pump 226 ML/a (7.2 L/s) which is the projected dry year demand for Blush Tomato Greenhouse.

The selected pipes are given in Table 8.3.

Table 7.4: Malpas Dam to Blush Tomato Greenhouse Pipeline Selection

Pipe Type	Section	Dynamic Headloss (m/km)
Route #1		
mPVC DN150 PN18	0 – 0.7 km	3.99
mPVC DN150 PN15	0.7 – 9.0 km	3.66
Route #4		
DICL DN 100 PN35	0 – 4.0 km	6.57
mPVC DN100 PN15	4.0 – 13.0 km	9.55

The long section of the pipeline route was obtained from Google Earth data.

The hydraulic analysis for this selected pipeline route is presented in Figure 7.4. For Route #1, the static head of 137.2 m plus the dynamic head of 33 2 gives a total head of 170.4 m.

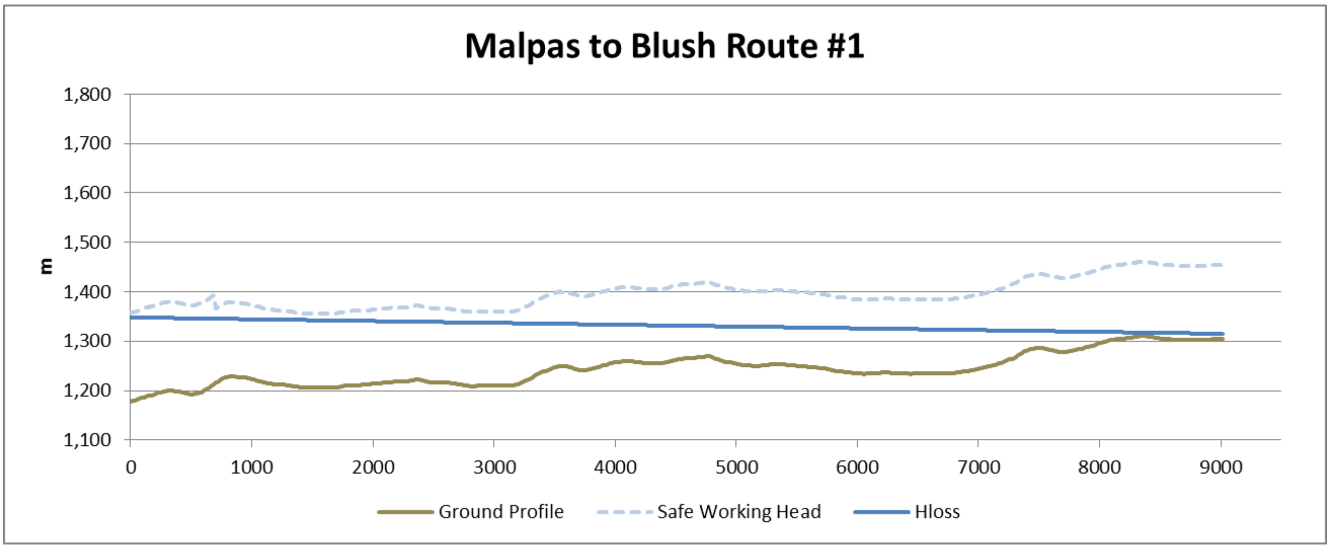

Figure 7.4: Malpas Dam to Blush Tomato Greenhouse Route #1 Hydraulics Profile

The hydraulic analysis for this selected pipeline route is presented in Figure 7.5 For Route #4, the static head of 200.2 m plus the dynamic head of 112 2 gives a total head of 312.4 m.

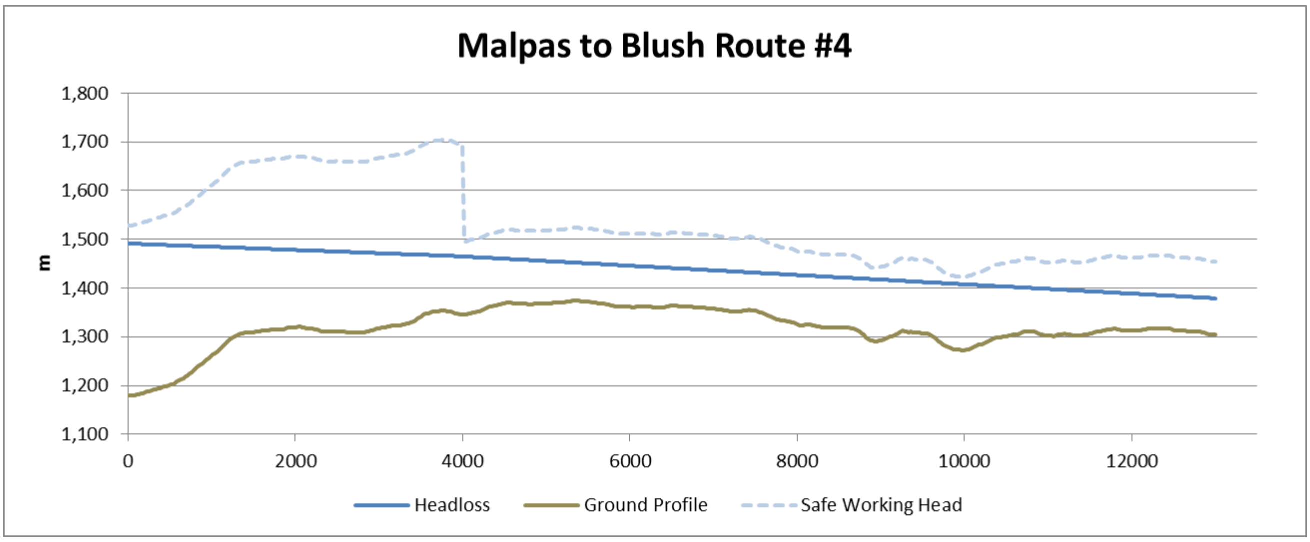

Figure 7.5: Malpas Dam to Blush Tomato Greenhouse Route #4 Hydraulics Profile

8 Effluent Reuse supply to Blush Tomato Greenhouse

In this options Sewage Treatment Plant (STP) effluent would be reused to supply some of the Tomato farm demand. Attempts have been made to contact the Tomato farm to discuss the effluent water quality requirements for the Tomato farm but the concerned person has not been available for a discussion.

This Section discusses the work involved at the STP to reuse the STP effluent at the Tomato farm.

8.1.1 Guyra STP

The Guyra STP was augmented in 2000 with the construction of a 3,300 EP continuous extended aeration (activated sludge) plant which replaced the original trickling filter unit built in the 1960s. It is located 1.8 km downstream of Guyra on a tributary of Laura Creek. There are 2 pumping stations with a combined capacity of 20kL per day located in the South Guyra service area.

The Average Dry Weather Flow (ADWF) at the STP was estimated to be 350 kL/day from STP influent data and rainfall data. The annual dry weather is considered to be the effluent available on a continuous basis to be recycled to the Tomato farm.

Effluent quality requirements

The Australian Guidelines for Water Recycling (AGWR) have documented log reduction values (LRV) to be achieved for typical effluent reuse applications. In the absence of any specific water quality requirements advised by the Tomato farm, this study has considered the requirements outlined in AGWR for the effluent water quality requirements. Table 8.1 summarises the LRV targets for commercial food crops specified in the AGWR, and an assessment of the LRV achieved by the treatment process.

Table 8.1: Log reduction targets for effluent reuse for commercial food crops

End User	Log Reduction Values		
	Protozoa	Virus	Bacteria
LRV Targets			
Commercial food crops	4.8	6.1	5.0
Indicative LRV for treatment processes			
Primary Treatment	0.0 – 0.5	0.0 – 0.1	0.0 – 0.5
Secondary Treatment (well aerated)	0.5 – 2.0	0.5 – 2.0	1.0 – 3.0
UV Disinfection *(Note 1)*	3.0 – 4.0	Adenovirus 1.0 – 4.0 Other 3.0 – 4.0	2.0 – 4.0
Total	**3.5 – 6.0**	**Adenovirus 1.5 – 6.1** **Other 3.5 – 6.1**	**3.0 – 7.5**

Note 1: It should be noted that the existing UV unit has been designed to achieve the faecal coliform requirements for discharge to Laura Creek. A new UV unit would most likely be required to achieve the target LRVs for protozoa, virus and bacteria.

STP Upgrade

Following a review of the sewage treatment process and the LRV achieved by the STP, it is expected that the following works will be required to produce the desired effluent quality and transfer it to the Tomato farm:

- Filtration system
- New UV unit
- Chlorination system

- Reservoir for storage of treated effluent
- Effluent pumping station

The size of the effluent storage reservoir has not been estimated. If effluent reuse is considered to be a preferred option then the storage size can be optimised based on the rainfall patterns in the area and the usage patterns of the Tomato farm.

Using the estimated average dry weather of 350 kL/day, the STP is estimated to provide at a minimum of 130 kL/year of effluent for irrigation.

8.1.2 Transfer System

Pipeline Route Options

Two pipeline route options were considered for this transfer system. These options are shown in Figure 8.1.

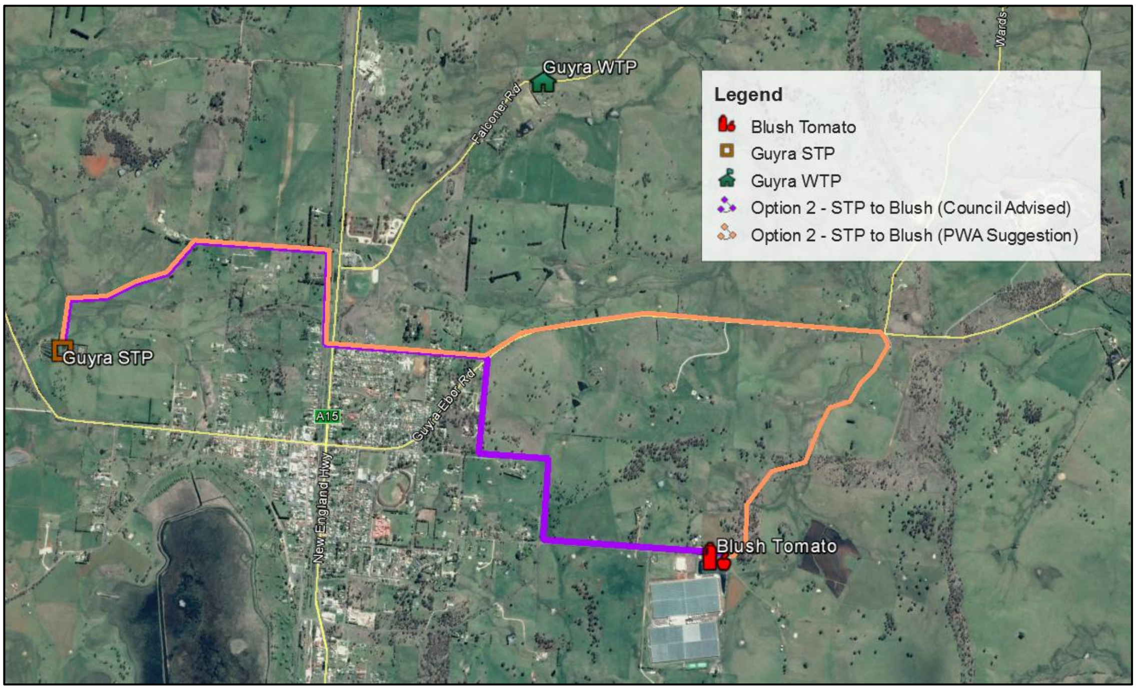

Figure 8.1 STP to Blush Tomato Farm pipeline options

The two pipeline route options are briefly described in Table 8 1.Council have selected the pipeline route via Elm St (indicated by purple line, refer to Figure 8.1). The Guyra Ebor road route option was not considered further as it is almost two kilometres longer and does not provide any significant benefit in terms of private property crossings

Table 8.2: Guyra STP to Blush Tomato farm pipeline options summary

Route	Lot Crossings	Distance (km)	Constructability
STP to Blush (Via Elm St)	8	6.9	Passes through residential area, crossing Oban St, rail crossing continuing to Sole St followed by crossing the Guyra-Ebor Rd
STP to Blush (Guyra-Ebor Rd)	4	8.8	Same as above.

Hydraulic Analysis

The hydraulic analysis for the transfer system from the STP to Blush Tomato Farm was undertaken, for the preferred pipeline alignment (route via Elm St). The pipeline was sized to pump up to 10 L/s from an effluent storage at the STP. The selected pipe is given in Table 8.3.

Table 8.3: STP to Blush Tomato Greenhouse Pipeline Selection

Pipe Type	Section	Dynamic Headloss (m/km)
PVC DN150 PN15	0 – 4 km	3.18
mPVC DN100 PN15	4 – 6.9 km	18.29

The long section of the pipeline route was obtained from Google Earth data. The effluent production data were provided by staff specialists at PWA. The hydraulic analysis for this selected pipeline route is presented in Figure 8.2. The static head of 33.5 m plus the dynamic head of 84 3 gives a total head of 117.8 m.

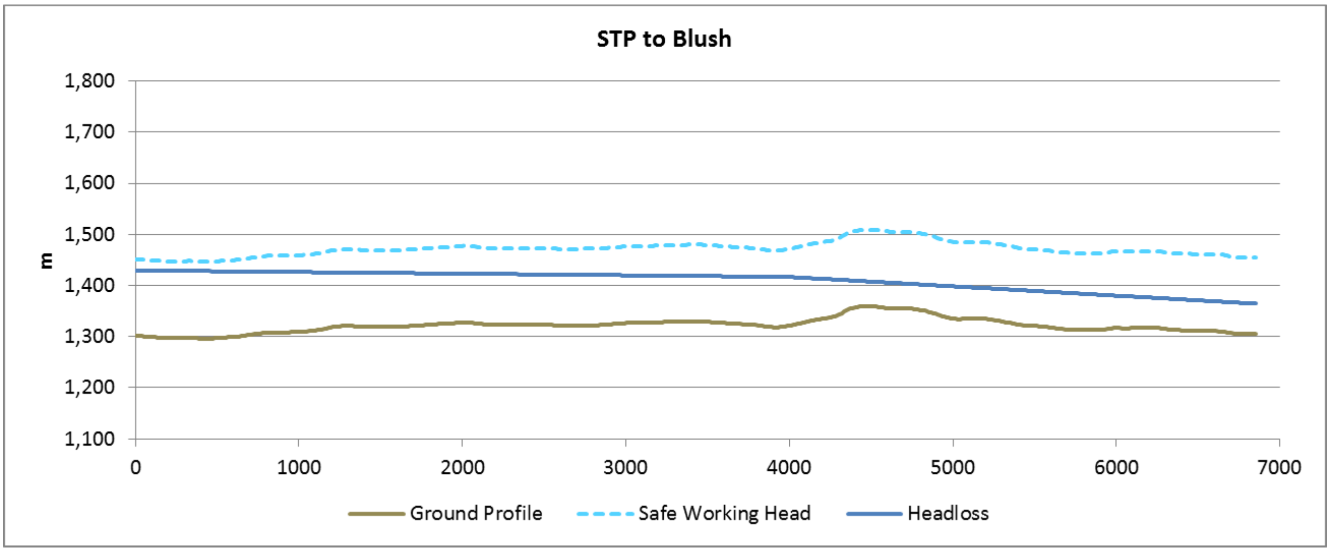

Figure 8.2: STP to Blush Tomato Greenhouse Hydraulics Profile

9 Risk and Uncertainties

9.1 Subsurface Conditions

The *Reconnaissance Geotechnical Investigation* report for the above augmentations is attached in Appendix A. A desk top study was initially undertaken of readily available geoscience data and a review of prior relevant work, followed by a site inspection in April 2017. The inspection included test pit excavations at the Off-stream Storage Site and limited laboratory testing program on samples recovered from these test pits.

The inspection and fieldwork identified a number of geotechnical constraints at the site designated for the off-stream storage if it is to be constructed by cut-and-fill. These issues are discussed in greater detail in the attached report, and include:

- Shallow depths to fractured basalt bedrock in two of the test pits.
- Shallow thicknesses of uniform silty clays.
- Variable distribution and concentrations of embedded cobbles and boulders within clay matrix.
- Potential groundwater issues.

9.2 Environmental Impacts

This section briefly discusses the potential environmental issues which may arise as a result of the construction of the pipelines. Once the concept for the preferred option is finalised, the potential environmental impacts would be assessed in a formal development/ environmental assessment which would include detailed mitigation measures.

9.2.1 Aboriginal Heritage

The Office of Environmental and Heritage (OEH) Aboriginal Heritage Information Management System (AHIMS) search returned nine known Aboriginal sites in the vicinity of the potential alignments.

Eight of the nine known sites are in the vicinity of the Blush Tomato farm, between Malpas Dam to the town of Guyra. Locations of these sites are shown in Figure 9.1. Details of each site are given in Appendix B.1.

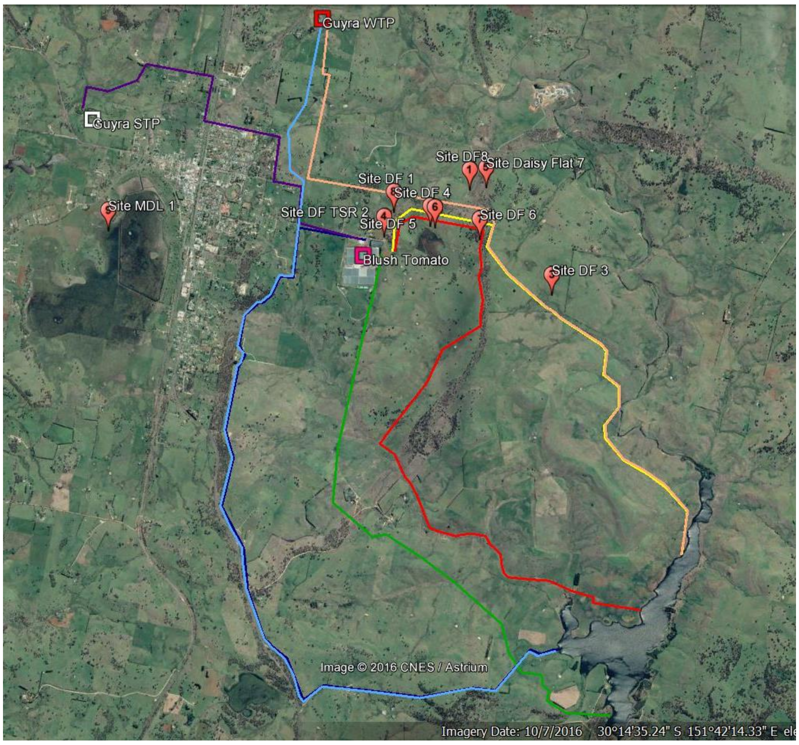

Figure 9.1: Aboriginal Heritage sites

As outlined in Section 7.2 the yellow and red pipeline route options have not been considered further. The search has not identified any known Aboriginal sites along the blue and red alignments that have been considered further for the pipeline from Malpas dam to the Tomato farm and further to the Guyra WTP.

9.2.2 European Heritage

A search of the OEH State Heritage Inventory database indicated that two European heritage items are located in Guyra; neither is in close proximity to any of the pipeline options.

It should be noted that on the NSW Planning Portal Heritage mapping there is a long tract of predominantly uncleared land running north-south, to the east of Guyra. This is a former Coach Road. Most of the former Coach Road contains relatively intact vegetation, this may indicate there could be restrictions on clearing/ building in this area.

Locations of these sites are shown in Figure 9.2. Details of each site are given in Appendix B.2.

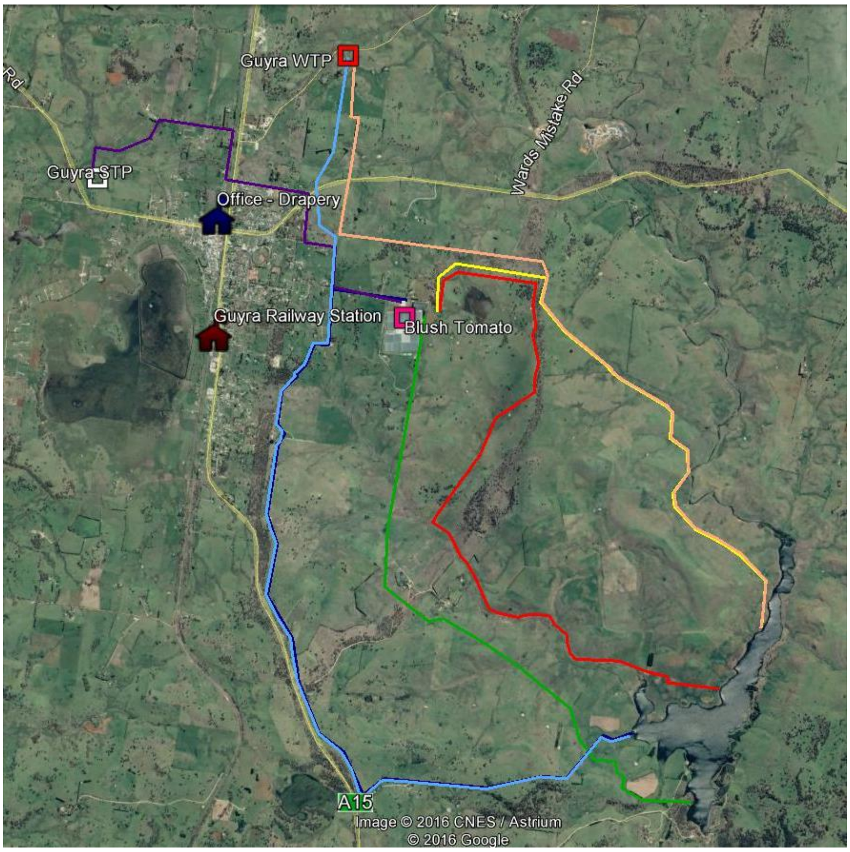

Figure 9.2: European Heritage Sites.

9.2.3 Threatened Flora and Fauna

The OEH Atlas Wildlife Search returned eleven threatened species of which, four of which are within the alignment areas.

The EPBC Act Protected matters search listed 18 additional threatened flora and fauna species. However, this search is quite broad-range and provides limited certainty as to whether the species would be present in the vicinity of the alignments.

The majority of fauna are birds which are mobile, so are unlikely to be significantly impacted by the works unless substantial numbers of trees with hollows are removed.

Locations of threatened species are shown in Figure 9.3. The details of the flora and fauna species sighted are included in Appendix B.3

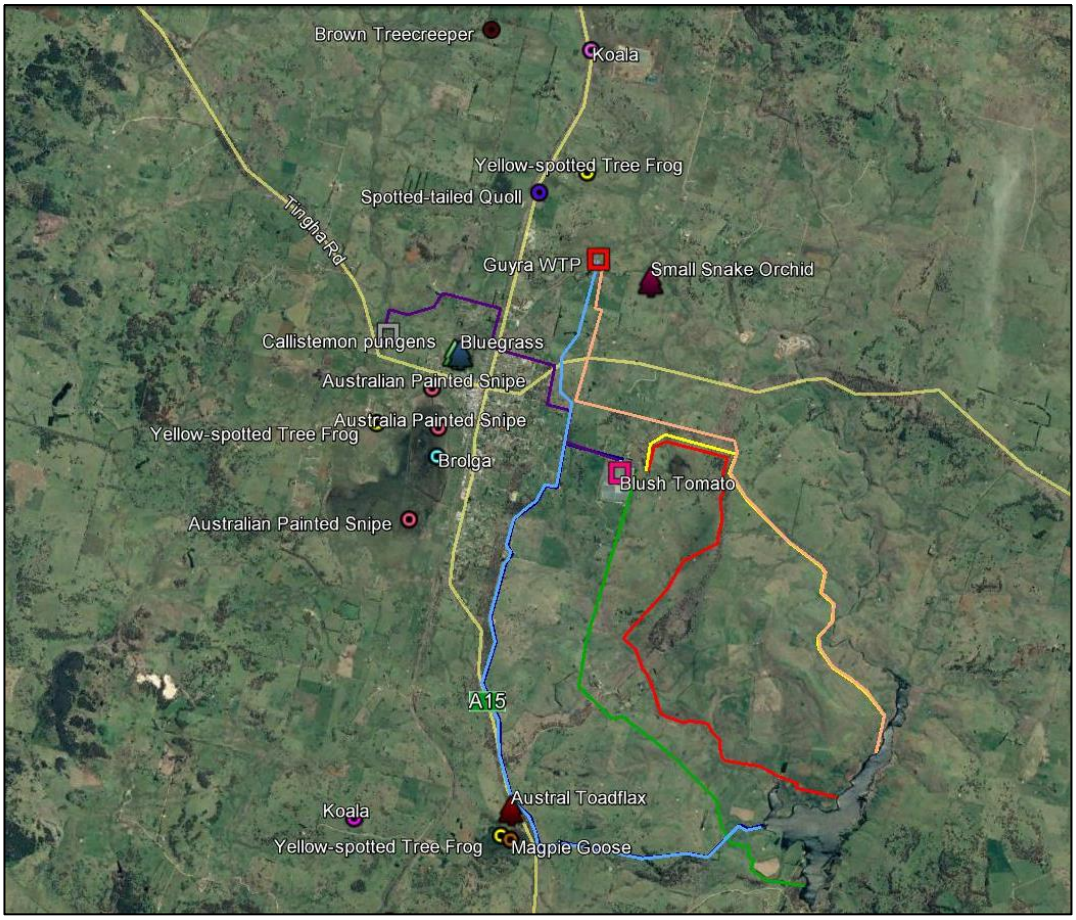

Figure 9.3: Threatened Flora and Fauna nearby to pipeline routes

9.2.4 Endangered Ecological Communities

Seven Endangered Ecological Communities (EEC's) are potentially present in the alignment areas. The seven EEC's are listed in Table 9.1

Table 9.1: Endangered Ecological Communities

Vegetation Community Name	EPBC Act Status	TSC Act Status	Type of Presence
Carex Sedgeland of the New England Tableland, Nandewar, Brigalow Belt South and NSW North Coast Bioregions	N/A	Endangered	Community known to occur within area west of Guyra Community predicted to occur within area east of Guyra
McKies Stringybark/ Blackbutt Open Forest in the Nandewar and New England Tableland Bioregions	N/A	Endangered	Community known to occur within area west of Guyra
Montane Peatlands and Swamps of the New England Tableland, NSW North Coast, Sydney Basin, South East Corner, South Eastern Highlands and Australian Alps	Endangered	Endangered	Community predicted to occur within area east of Guyra
New England Peppermint (Eucalyptus nova-anglica) Woodland on Basalts and Sediments in the New England Tableland Bioregions	Critically Endangered	Critically Endangered	Community known to occur within entire Guyra region
Ribbon Gum-Mountain Gum-Snow Gum Grassy Forest/Woodland of the New	N/A	Endangered	Community known to occur

Vegetation Community Name	EPBC Act Status	TSC Act Status	Type of Presence
England Tableland			within entire Guyra region
Upland Wetland of the Drainage Divide of the New England Tableland Bioregion	Endangered	Endangered	Community known to occur within entire Guyra region
White Box Yellow Box Blakeley's Red Gum Woodland	Critically Endangered	Endangered	Community known to occur within entire Guyra region

10 Water supply augmentation options

The secure yield studies by *NSW Urban Water Services* and *WREMA* investigated the secure yield of several augmentation options. These results are given in Table 10.1 and Table 10.2. Note the WREMA secure yields do not factor in an environmental flows

Table 10.1: Secure Yield for augmentation options – NSW Urban Water Services

Augmentation	Dam 2 Storage Volume (ML)	Above EFR	Secure Yield ML/a
Raise Guyra Dam by 2m	726	20%	610
Raise Guyra Dam by 3m	945	20%	755
500 ML off-river storage	390	20%	780

Table 10.2: Secure Yield for augmentation options – WREMA

Augmentation	Dam 2 Storage Volume (ML)	Above EFR	Secure Yield ML/a
Raise Guyra Dam by 3m	850	0%	539
500 ML off-river storage	350	0%	554
Supply from Malpas to Guyra WTP (Q_{max} = 4 ML/d, EF 75-20)	350	20%	741
Supply from Malpas to Tomato farm	350	0%	541
STP effluent reuse plus 3m dam raising	850	0%	588

Based on the analysis by WREMA, transfer from Malpas Dam to the Guyra WTP is the only feasible option to obtain a secure yield to meet the 2046 projected dry year extraction of 633 ML and provide additional yield for potential future industrial developments..

10.1 Overview of Option

In this option water from the Malpas Dam would be transferred to the Guyra WTP. The water supply for this option would be:

- Town demand is supplied from the current Guyra Dam
- When Guyra Dam drops below a certain level (still to be determined), town water supply will be taken from Malpas Dam.
- Peak day demands would be met by supplementing water from Guyra Dam.
- The pipeline is sized to pump 2.1 ML/day (24.1 L/s). This is the estimated average day peak month demand from the projected 2046 dry year extraction.

The secure yield of the water supply headworks and its comparison to the demand is shown in Figure 10.1.

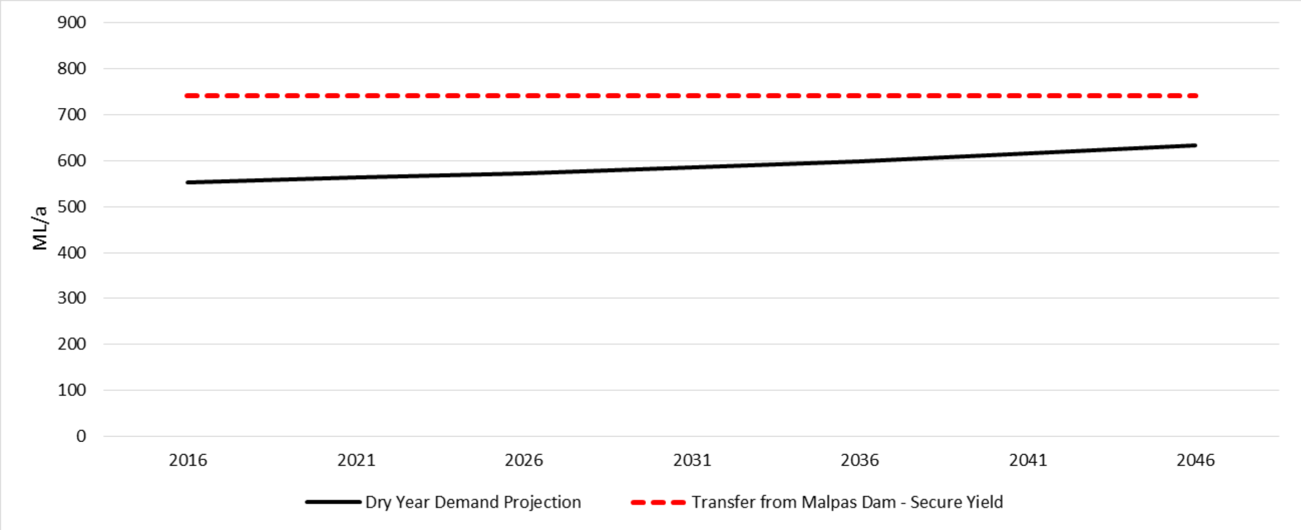

Figure 10.1: Secure yield and comparison with demand

10.2 Lifecycle cost analysis

A present worth cost analysis, with capital costs and 30-year operating cost, was undertaken for all the options. The following information was used for the analysis:

- Latest market pricing estimation from previous work completed by PWA
- Council's preferred pipeline route
- Calculated demands for Blush Tomatoes and the town of Guyra

A summary of the present cost estimates for the 200 mm and 300 mm pipeline options are provided in Table 10.3 and Table 10.4.

Table 10.3: Malpas Dam to Guyra WTP Water Transfer System (200 mm) – Cost Estimate

Item	Rate	Quantity	Amount
Pipe cost (supply and lay)			
DICL DN200 PN35	$288/m	1,500	$432,702
mPVC DN200 PN15	$217/m	13,500	$2,929,500
Difficult Construction			
Additional allowance for residential areas	$100/m	725	$72,523
Additional allowance for rock removal	$500/m	2,175	$1,087,849
Road Crossings			
Open Trenching (minor roads)	$1,000/m	10	$10,000
Directional Drilling (Starr Rd)	$5,000/m	12	$60,000
Directional Drilling (Guyra-Ebor Rd)	$5,000/m	11	$55,000
Malpas Dam Pumping Station - Mechanical and Electrical			
Pump	$150,000	2	$300,000
Valves (2 NRV, 2 GV, 2 RN)	$6,500	6	$39,000
Dismantling Joints	$10,000	4	$40,000

Item	Rate	Quantity	Amount
Flowmeter	$25,000	1	$25,000
SCA (Switchboard)	$180,000	1	$180,000
Miscellaneous (Pipework)	$30,000	1	$30,000
Malpas Dam Pumping Station - Civil			
Excavation	$40,000	1	$40,000
Fill and Embankments	$10,000	1	$10,000
Metal works	$7,000	1	$7,000
Concrete works	$180,000	1	$250,000
Epoxy Painting	$17,000	1	$17,000
Landscaping	$6,000	1	$6,000
Intake arrangement	$200,000	1	$200,000
Malpas Dam Power Supply			
Power Connection	$200,000	1	$200,000
Powdered activated carbon dosing system	$200,000	1	$200,000
Prime Costs			**$6,078,538**
General Contingency	30% of Prime Cost		$1,823,561
Direct Costs			**$7,902,099**
Design & Preconstruction Activities	10% of Direct Cost		$790,210
Construction Activities	10% of Direct Cost		$790,210
Total Capital Cost			**$9,482,520**

Table 10.4: Malpas Dam to Guyra WTP Water Transfer System (300 mm) – Cost Estimate

Item	Rate	Quantity	Amount
Pipe cost (supply and lay)			
DICL DN300 PN35	$410/m	3,500	$1,436,208
mPVC DN300 PN15	$353/m	11,000	$3,881,804
Difficult Construction			
Additional allowance for residential areas	$100/m	725	$72,523
Additional allowance for rock removal	$500/m	2,175	$1,087,849
Road Crossings			
Open Trenching (minor roads)	$1,000/m	10	$10,000
Directional Drilling (Starr Rd)	$5,000/m	12	$60,000
Directional Drilling (Guyra-Ebor Rd)	$5,000/m	11	$55,000

Item	Rate	Quantity	Amount
Malpas Dam Pumping Station - Mechanical and Electrical			
Pump	$300,000	2	$600,000
Valves (2 NRV, 2 GV, 2 RN)	$15,000	6	$90,000
Dismantling Joints	$20,000	4	$40,000
Flowmeter	$35,000	1	$35,000
SCA (Switchboard)	$300,000	1	$300,000
Miscellaneous (Pipework)	$100,000	1	$50,000
Malpas Dam Pumping Station - Civil			
Excavation	$50,000	1	$50,000
Fill and Embankments	$10,000	1	$10,000
Metal works	$15,000	1	$15,000
Concrete works	$300,000	1	$300,000
Epoxy Painting	$17,000	1	$17,000
Landscaping	$6,000	1	$6,000
Intake arrangement	$200,000	1	$300,000
Malpas Dam Power Supply			
Power Connection	$200,000	1	$200,000
Powdered activated carbon dosing system	$200,000	1	$200,000
Prime Costs			**$8,816,383**
General Contingency	30% of Prime Cost		$2,644,915
Direct Costs			**$11,201,298**
Design & Preconstruction Activities	10% of Direct Cost		$1,146,130
Construction Activities	10% of Direct Cost		$1,146,130
Total Capital Cost			**$13,753,558**

Net Present Value

The net present value for 200 mm pipeline option is given in Table 10.5. Pumping cost is calculated using power cost of 32 c per kWh, and considering a 5-yearly wet and dry year cycle, water transfer from Malpas dam will be required only during the 'dry years' of the cycle. In wet years no volume is pumped as it is assumed water demand can be met by Guyra Dam.

Table 10.5: Net Present Value

Item	Rate	Net Present Value (NPV)		
		4%	7%	10%
Capital Cost	**$9,482,519**	**$9,482,519**	**$9,482,519**	**$9,482,519**
Operation Cost				
Pumping Cost	$1.25/ML/m head	$270,703	$235,483	$213,050
Maintenance Cost				
Maintenance Cost - Civil	0.50% of Civil Capital Cost	$320,674	$235,072	$182,792
Maintenance Cost - Mechanical and Electrical	4.00% of Mech and Elec Capital Cost	$595,589	$436,598	$339,500
Total Operation & Maintenance Costs		**$1,186,967**	**$907,153**	**$735,342**
Total Present Value		**$10,669,485**	**$10,389,671**	**$10,217,861**

11 Generation of Hydroelectricity

The possibility of generating electricity from the pipeline was briefly investigated. The idea put forward by Council was to pump water from Malpas dam to the Guyra dam at night making use of the off-peak electricity tariff, when the Guyra dam is at a low level. The water would then gravitate back to Malpas and generate electricity via a small hydroelectricity set up during the day when electricity tariff. The results of this investigation are presented below.

11.1 Available systems

Generally, hydro-generators below 100kW are called “micro hydro”. For micro-hydro systems horizontally mounted units are typically used whose maximum speed can reach 1500 r/min. Usually, the horizontal hydro generators are driven by Pelton turbine.

The proposed micro hydro system is similar to the method called Pumped Storage Hydroelectricity (PSH), which is used by the Energy Generation Authorities for load balancing. At times of low electrical demand, excess generation capacity is used to pump water into the upper reservoir. When there is higher demand, water is released back into the lower reservoir through a turbine, generating electricity. Reversible turbine/generator assemblies act as a combined pump and turbine generator unit (usually a Francis turbine design). This technique is currently the most cost-effective means of storing large amounts of electrical energy, but capital costs and the presence of appropriate geography are critical decision factors in selecting pumped-storage plant sites. Usually, Francis turbines are design for large hydro system.

The total length of the proposed pipeline is about 17 km, and available static head is 90 m. Two options have been considered:

1. Hydro-power generation using gravity flow through 300mm (nominal) diameter PVC pipeline
2. Hydro-power generation using gravity flow through 200mm (nominal) diameter PVC pipeline

11.2 Opion-1: Hydro-power generation for a 300mm PVC pipeline

The following options have been considered for power generation:

Gravity flow rate, l/s	Head-loss, m/km	Total head-loss, m	Available head, m	Hydraulic Power Input, kW	Generator Power Output, kW
30	0.7	11.9	78.1	22.98	11.49
35	0.8	13.6	76.4	26.23	13.12
40	1	17	73	28.65	14.32
45	1.5	25.5	64.5	28.47	14.24
50	2	34	56	27.47	13.73
55	2.5	42.5	47.5	25.63	12.81
60	3	51	39	22.96	11.48
65	3.5	59.5	30.5	19.45	9.72
70	3.75	63.75	26.25	18.03	9.01
75	4	68	22	16.19	8.09
80	4.25	72.25	17.75	13.93	6.97

The above table shows that the most optimistic option for hydro-power generation is at gravity flow of 40 L/s which provides the highest power generation (about 15kW).

Since Sunday (all day) is off-peak, total remaining days when peak hours are applicable = 365-52 = 313 days per year. Utilising a 15kW rated hydro-generator for 15 hours (total peak hours) the maximum yearly (for 313 days) energy generation is 70425 kWh.

Cost Savings achieved

It is assumed that the power generated would be used to off-set local usage as the income from supplying this back to the grid would be minimum ($0.06/kWh). Based on local energy off-set the savings from this power generation, at the rate of $0.32/kWh, would be $22,536 per year.

Water pumping cost

In order to deliver 90 L/sec at 275m head, typically it would require installation of a 350kW (standard) rated motor. This motor typically must run for about 7 hours to deliver required quantity water for gravity flow to the Hydro-generator. The annual energy cost for this transfer, assuming an off-peak rate of $0.12/kWh, would be about $92,000.

The analysis shows that the cost of pumping is greater than the cost savings from the power generated.

11.3 Opion-1: Hydro-power generation for a 200mm PVC pipeline

The following options have been considered for power generation:

Gravity flow rate, l/s	Head-loss, m/km	Total head-loss, m	Available head, m	Hydraulic Power Input, kW	Generator Power Output, kW
10	0.5	8.5	81.5	8.00	4.00
15	1	17	73	10.74	5.37
20	2	34	56	10.99	5.49
25	3	51	39	9.56	4.78
30	4	68	22	6.47	3.24

The above table shows that the most optimistic option for hydro-power generation is at gravity flow of 20 L/s which provides the highest power generation (about 5.5kW).

Utilising a 15kW rated hydro-generator for 15 hours (total peak hours), the maximum yearly (for 313 days) energy generation is 30112.5 kWh.

Cost Savings achieved

Based on local energy off-set the savings from this power generation, at the rate of $0.32/kWh, would be $9,636 per year.

Water pumping cost

In order to deliver 24 L/sec at 245m head, typically it would require installation of a 90kW (standard) rated motor. This motor typically must run for 7 hours to deliver required quantity water for gravity flow to the Hydro-generator. The annual energy cost for this transfer, assuming an off-peak rate of $0.12/kWh, would be $23,662.

The analysis shows that the cost of pumping is greater than the cost savings from the power generated.

11.4 Recommendation

A calculation and comparison of the energy cost shows that the cost to pump the water from Malpas to Guyra dam is more than the cost savings achieved from the power generation when gravitating from Guyra to Malpas dam. Hence the option of hydroelectric power generation does not have a cost benefit.

12 Appendix

Appendix A Reconnaissance Geotechnical Investigation

Guyra Water Supply Augmentation

Feasibility Studies for Water Supply Transfer Systems

Reconnaissance Geotechnical Investigation

Report Number: 17-GT38A

April 2017

Prepared for:

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Guyra Water Supply Augmentation
Feasibility Studies for Water Supply Transfer Systems

Reconnaissance Geotechnical Investigation

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Table of contents

Plates

Figures

Appendices

1 Introduction

The Armidale Regional Council area is located in the New England Region of New South Wales, and has three separate water supply schemes for Armidale, Guyra and Tingha. Guyra's town water is sourced from two small dams (referred in this report as Guyra Dam 1 and Guyra Dam 2) located on the Gara River. Hydrologic studies show that the dams are too small to guarantee supply during an extended drought. ARC is considering various options to augment Guyra's bulk water supply and provide water security.

The Armidale Regional Council commissioned the Public Works Advisory (PWA) to prepare an IWCM Strategy for the Guyra region. As part of this commission, the Specialist Services Section was engaged to undertake a reconnaissance geotechnical investigation for the various options of the feasibility studies.

It is understood that the options being considered for the augmentation of the Guyra bulk water supply include:

- Raising of Guyra Dam 2;
- Constructing an off-stream storage;
- Transferring water from the Malpas Dam; and,
- Effluent reuse for the Blush Tomato Farm to supplement the town water supply.

A desk top study was initially undertaken of readily available geoscience data and review of all prior work undertaken by our Section in the Guyra environs. This was followed by a site inspection on 11th and 12th of April, 2017. It also included test pit excavations at Off-stream Storage Site 1; and, limited laboratory testing program on samples recovered from these test pits.

For the bulk storage option, three alternate potential sites were also inspected in general vicinity and at the quarry site. For all other options involving pipeline construction, the alignments were not inspected in detail.

This report presents the outcomes of the site inspections and laboratory testing.

2 Regional Geology

The Dorrigo-Coffs Harbour 1:250,000 Geological Series Sheet SH56-10 & part SH56/11 (First Edition, 1971) and our prior experience in the area indicate that Guyra and its environs are located within Tertiary age tholeiitic and alkaline basalts with minor trachyte and dolerite.

3 Raising Guyra Dam 2

Guyra Dam 2 is located on the Gara River approximately 7.5km north of Guyra (see **Figure 1**). It is positioned immediately upstream of Dam 1 from which the town's water supply is sourced.

Dam 2 is of the concrete gravity type, approximately 7m high (max) and 120m long (see **Plate 1**). Massive basalt bedrock is exposed on the left abutment (see **Plate 2**). On the right abutment, large basalt boulders crop out on the slope; however, the bedrock is generally obscured by lush grass cover (see **Plate 3**). On the right abutment, to the south of the existing dam wall, variably weathered basalt is exposed in shallow cuttings along an access road (see **Plates 4** and **5**).

From inspection of the site, the existing dam appears to be keyed-in into basalt bedrock foundation in the bed of the river and in the abutments. Consequently, there appears to be no geotechnical constraints to the dam raising.

4 Off-Stream Storage – Site 1

4.1 Site Description

The inspected site is located within a private property (Lots 112 and 113, DP753660 and part of Lot 4, DP547509) on the northern periphery of Guyra and approximately 2km north of the town (see **Figure 2**). The site is bordered by Crystalbrook Road to the west and grassed paddocks to the north, south and east.

Broadly, the site is a shallow, grassed basin-type depression (see **Plates 9** and **10**) which collects the stormwater run-off from the north. The depression containing the proposed site is relatively flat with rising topography on all sides. Although not inspected closely, the southern side of the basin appears to have been blocked off by a low embankment. At the time of the inspection, the basin-depression contained some ponded water (see **Plate 10**) which typically was very shallow although it is interpreted that the depth of water varies with prevailing weather conditions.

4.2 Subsurface Conditions

Based on very limited test pit excavations, the site is located within Tertiary basalt. Basalt cobbles and small boulders (obscured by lush grass cover) are strewn on the western slope bordering the depression.

At discrete test pit locations, the subsurface profiles were found to be slightly variable. In each of the test pits, there is a 0.15m cover of friable, very soft, saturated clayey topsoil with fine roots.

The topsoil is underlain by dark grey (locally with red orange brown mottle) silty clay of high plasticity, visually classifying as CH in accordance with Australian Standard AS1726. The clay stratum extends to depth of between 0.4m and 0.45m, with thicknesses of 0.3m/0.25m. The clay is firm and at the time of fieldwork it was in a very moist to wet state.

The next stratigraphic succession is also silty clay of high plasticity, characterised by a light grey, light grey brown and yellow orange brown colour; however, the clay contains embedded basalt cobbles, gravel and small boulders. The concentrations of the embedded cobbles (refer to plates in **Appendix B**) vary in lenses and between the test pits with general trend being increasing content with depth. The materials, in lenses may be also described as basalt cobbles and boulders in a clayey matrix.

The strata extend for the full depth of excavation of 2.6m in test pit TP1. In test pits TP2 and TP3 it extends to depths of 1.3m and is underlain by moderately weathered, fractured basalt. Both test pits terminated upon reaching refusal of backhoe bucket at depths of 1.75m (TP2) and 1.75m to 1.9m (TP3).

Groundwater was only intersected in test pit TP1 at a depth of 2.4m. The inflow was low volume, steady seepage. After very short term monitoring period, the water level has risen to a depth of 2.4m.

Laboratory testing was carried out on samples recovered from test pits TP1 (1.0m to 1.2m) and TP2 (0.45m to 0.7m). However, it should be noted that any over-size fragments were excluded from the sample. The materials grading varied but both samples contained high clay contents of 57% and 47%. The clay is of very high plasticity with liquid limits of 100% and 107% at corresponding plasticity indices of 61% and 77%, thus classifying the materials as CH in accordance with AS1726. The moisture contents of the two samples (at the time of sampling) were also high with 56.3% (TP1) and 35.2% (TP2).

4.3 Discussion

The inspection and limited fieldwork identified a number of geotechnical constraints at the site if the storage is to be constructed in cut-and-fill. These include:

- Shallow depths to fractured basalt bedrock in two of the test pits.
- Shallow thicknesses of uniform silty clays.
- Variable distribution and concentrations of embedded cobbles and boulders within clay matrix.
- Potential groundwater issues.

The fill won from any excavation would be heterogeneous. At the current state, the clays are excessively wet and would be considered to be un-workable without significant drying back. Due to very high plasticity properties, the workability characteristics of these materials are assessed to be very poor.

The floor of the storage would require lining if fractured bedrock is exposed.

There is a potential for construction problems associated with groundwater if deep excavations are required to obtain the necessary fill volumes. However, the groundwater regime across the site is not clear based on limited fieldwork. At test pit TP1 location, it is plausible that a spring has been intersected given no groundwater was detected in the other two test pits. Nonetheless, it is likely that any groundwater would be confined within the fractured basal bedrock.

If the site is to be considered for the off-stream storage, then the best option would be to construct above ground storage with any stripping limited to the friable topsoil horizon and leaving the underlying clay stratum intact. For this option, fill would need to be imported.

Suitable borrow areas would need to be identified and investigated. Homogeneous embankments could be constructed if a suitable clay borrow area is identified. As an alternative, random fill from the quarry spoil could be considered; however, for this option the batters would require lining with geotextile clay liners such as Claymax or Bentofix to ensure a water-tight structure.

5 Alternate On-Creek Storage – Site 2

An alternate site, designated as Site 2, was inspected. The site is located on a minor creek/drainage gully that drains to Gara River, immediately to the north of the quarry (see **Figure 3**).

The site is located in cleared, grassed undulating land (see **Plates 11** and **12**) spanning different private properties. The gully is shallowly incised. Basalt boulders are strewn on the southern gully banks and on the slopes to the north. Bedrock is also exposed on the northern gully bank at its junction with Gara River, but downstream of any likely dam wall centreline. Close inspection of the outcrop was not possible; however, from a distance it appears that the bedrock's lithology may be other than basalt, possibly meta-siltstone.

Basalt bedrock is likely to be encountered at shallow depths within foundation areas of dam wall.

The inspection did not reveal any geotechnical constraints for constructing an on-stream storage at the alternate Site 2.

6 Alternate On-Creek Storage – Site 3

Another alternate site, designated as Site 3, was inspected. The site is located on Gara River, immediately to the south-east of the quarry (see **Figure 3**).

The site is within a narrow valley bordered by the quarry to the north-west (see **Plates 13** and **14**). However, there is an existing embankment extending from the quarry slope to close proximity of the river (see **Plates 13** and **15**). On the left abutment, the topography rises at moderate gradients to a ridge line. The lower slope is typically grassed with some scattered trees and outcrop of basalt bedrock (see **Plate 14**).

The existing embankment is approximately 10-12m in height with batter slopes in the order of 1(V) to 2.5 (H). It is understood that originally it has been intended to form a railway embankment and consequently, it is assumed that it was engineered. There is a cutting in the bank at the north-western extremity of the embankment (see **Plate 16**). It is interpreted that the cut has been made by the quarry operator to create a drainage course to divert stormwater run-off from the stockpile areas of the quarry. Limited exposure in the cut (see **Plates 16** and **17**) indicates that the fill materials generally comprise gravelly clayey silts with sand; however, the concentrations of the gravel-sized rock fragment do vary in pockets and lenses. Furthermore, towards the base of the cut there was an increase in concentration of embedded basalt cobbles. The consistency of the fill was assessed as very stiff which supports the earlier assumption that the fill has been engineered. Within the exposure, the fill contains sufficient fines which in a well compacted state would render the materials as being of very low permeability. However, it is not possible to comment as to any variations in material types throughout the embankment without further investigations.

In summary, the inspection did not identify any major geotechnical constraints to construction of a dam (incorporating the existing embankment) at this site. Basalt bedrock is expected to be at relatively shallow depth in the river bed and on the left abutment. Minor issues would be the need to provide suitable erosion protection for the existing embankment batter and slopes leading from the quarry site.

7 Quarry Site – Site 4

An additional storage at the existing quarry site was inspected (see **Figure 4**). General view of the quarry site is shown in **Plates 19** and **20**. The quarry currently holds water. Based on the discussions with the quarry operator, the quarry storage is being fed by a spring or springs from within the fractured basalt bedrock.

The quarry face batters are relatively steep and show signs of rutting erosion and localised minor instability/slumps (see **Plates 21** and **22**).

There are a number of geotechnical constraints at this site including permeability of cut batters in bedrock, groundwater issues, erosion and localised areas of instability of the batters. Consequently, based on on-site discussions, this option was therefore not considered further as a viable additional storage option.

8 Pipelines

It is understood that a number of pipeline options are being considered as detailed below.

- Transferring water from the Malpas Dam to the Guyra Water Treatment Plant
- Transferring water from the Malpas Dam to Blush Tomato farm
- Effluent reuse (from the Sewage Treatment Plant) for the Blush Tomato farm to supplement the town water supply.

Furthermore, for each option, a number of possible alignments have been suggested. The various options are shown on **Figures 4**, **5** and **6**. Please note that the following discussions would also be applicable to any other pipelines that may be required if any of the off-stream storage or on-stream dams are selected as the final strategy for the upgrading works.

Generally, all pipeline alignments would traverse undulating topography either through private properties or along services or road easements. The whole of this study area is located within Tertiary basalt which may be mantled by thin to thick residual deposits depending on topography.

The pipeline alignments have not been closely inspected; consequently, the following discussions are broad in nature and are based on our prior experience in Guyra environs (including geotechnical investigations at water treatment plant, sewage treatment plant, reticulation and rising mains and pumping stations sites within the town's boundaries), published data and bedrock exposures in road cuttings and the quarry.

Typically, the residual deposits will comprise silty clays and clayey silts of high plasticity, classifying either as CH or MH in accordance with AS1726. However, the soil cover is expected to be relatively thin, typically less than 1.5m or absent in areas of outcrop. Basalt boulders strewn on the slopes would be a common feature (see **Plate 24**).

Below any uniform clay cover, the dominant underlying stratum is expected to comprise gravel, cobble and boulders in a clayey matrix. The cobbles/boulders are remnants of weathering of parent basalt bedrock with the clayey zones representing the weathered material along former joints. The sizes of cobbles and boulders would depend on the defect spacing in the bedrock. The cobble/bouldery profile is not expected to be deeply developed but can extend to depths in excess of 2m. The excavation characteristics of this bouldery zone would depend on whether the boulders are tightly packed with only minor clay infill. A typical view of such a zone is shown in **Plate 23**.

Basalt bedrock is expected to underlie the bouldery zone. However, the bedrock can be expected to vary in degree of weathering, rock substance strength and defect spacing. The defect spacing can range from very closely spaced to very widely spaced. Typical outcrop and exposures in the cuttings within the study area are shown on **Plates 23** to **30**. Best illustration of likely conditions that may be expected along the ridge lines is shown in the exposure at the quarry (see **Plate 30**).

In general, residual deposits and bouldery zone are expected to be excavatable using a backhoe or a hydraulic excavator. Hard digging conditions for a backhoe would be expected in areas where the cobbles/boulders are tightly packed.

Excavation in basalt bedrock will depend on defect spacing and degree of weathering. Moderately weathered bedrock with closely spaced defects is expected to be excavatable using a large hydraulic excavator (say 20 tonne capacity). Depths in the order of 2-3m are likely to be achievable using this equipment along major part of any alignment.

However, in parts of the alignments, the excavations to these depths may encounter more massive beds (see **Plate 26**) or very large embedded boulders. If the boulders are massive and slightly weathered then it is envisaged that some "popping" using expandable mortar will be required. Some assistance from a rock breaker is likely to be required in bedrock where joints are tight and widely spaced.

The extent of any difficult excavation could not be ascertained based on this limited study.

Generally, for the likely depths of any excavation, construction difficulties associated with permanent water table are envisaged. Some dewatering may be required at any drainage line crossings and any stormwater infiltration during periods of inclement weather. Furthermore, locally, some springs may be intersected.

PLATES

Plate 1: Guyra Dam 2.

Plate 2: Guyra Dam 2 - View of the left abutment.

Plate 3: Guyra Dam 2 - General view of the right abutment.

Plate 4: Guyra Dam 2 - View of the right abutment showing weathered basalt in the cut and basalt boulders on the ridge line.


Plate 5: Guyra Dam 2 - Close up view of basalt exposure in the right abutment.


Plate 6: Guyra Dam 2 - Downstream view of the right river bank.


Plate 7: Guyra Dam 2 - Upstream view of the right river bank.


Plate 8: Guyra Dam 2 - View of the Gara River upstream of the dam.

Plate 9: Off - Stream Storage - Site 1 - General view looking north-east and location of Test Pit 1 (TP1).

Plate 10: Off - Stream Storage - Site 1 - General view looking south-east and location of Test Pit 3 (TP3). Note ponded water in the depression.

Plate 11: Alternative Site 2 Dam - View along the dam wall, looking north from the quarry.

Plate 12: Alternative Site 2 Dam - View of the area downstream of the dam wall.

Plate 13: Alternative Site 3 Dam - General view of the site and left abutment looking south-east from the quarry.

Plate 14: Alternative Site 3 Dam - Close up view of the left abutment showing basalt outcrop on the river bank.

Plate 15: Alternative Site 3 Dam - General view of existing right embankment.

Plate 16: Alternative Site 3 Dam - View of the cutting at the north-western end of the existing right abutment.

Plate 17: Alternative Site 3 Dam - Close up view of the fill profile in the above cutting.

Plate 18: Alternative Site 3 Dam - Upstream view, looking north-west from the existing embankment.


Plate 19: Alternative Site 4- Quarry Site - General view of the site looking west.


Plate 20: Alternative Site 4- Quarry Site - General view of the eastern extremity of the site.

Plate 21: Alternative Site 4- Quarry Site - Close up view of the quarry face showing rutting erosion and minor instability (slumping).

Plate 22: Alternative Site 4- Quarry Site - Another view of the southern face of the quarry.

Plate 23: View of the cutting on the right bank at Guyra Dam 2, showing shallow residual boulder basalt profile overlying more deeply weathered bedrock.

Plate 24: General view of the paddock on the right bank at Guyra Dam 2, showing scattered boulders on the slope.

Plate 25: View of the rock cutting along the New England Highway, showing shallow residual profile.

Plate 26: Another view of the above cutting showing variably weathered basalt. Note variable defect spacing with more massive outcrop in the centre.

Plate 27: View of the cutting along the access road to Malpas Dam, showing highly to moderately weathered, highly fractured basalt.

Plate 28: General view of basalt outcrop on the slope to the west of the access road to Malpas Dam.

Plate 29: General view of the right bank, downstream from Guyra Dam 1, showing basalt outcrop and slopes littered with basalt boulders.

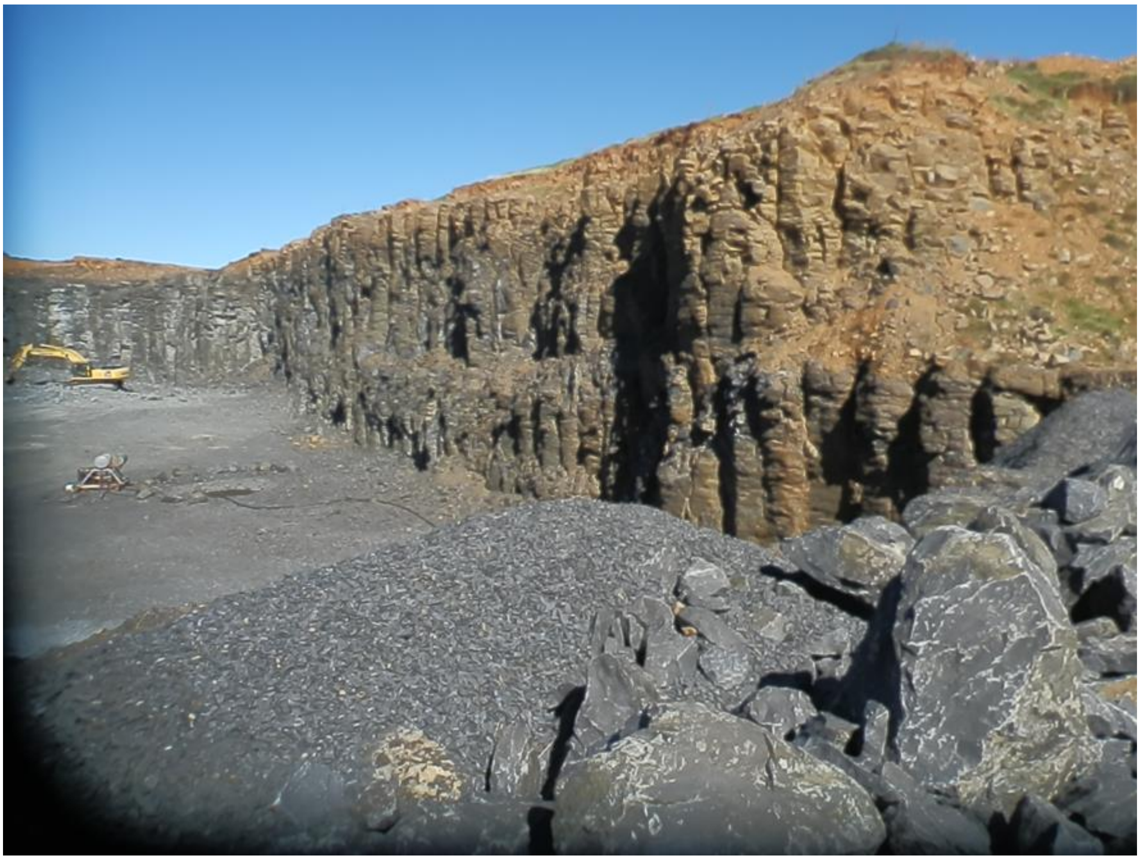
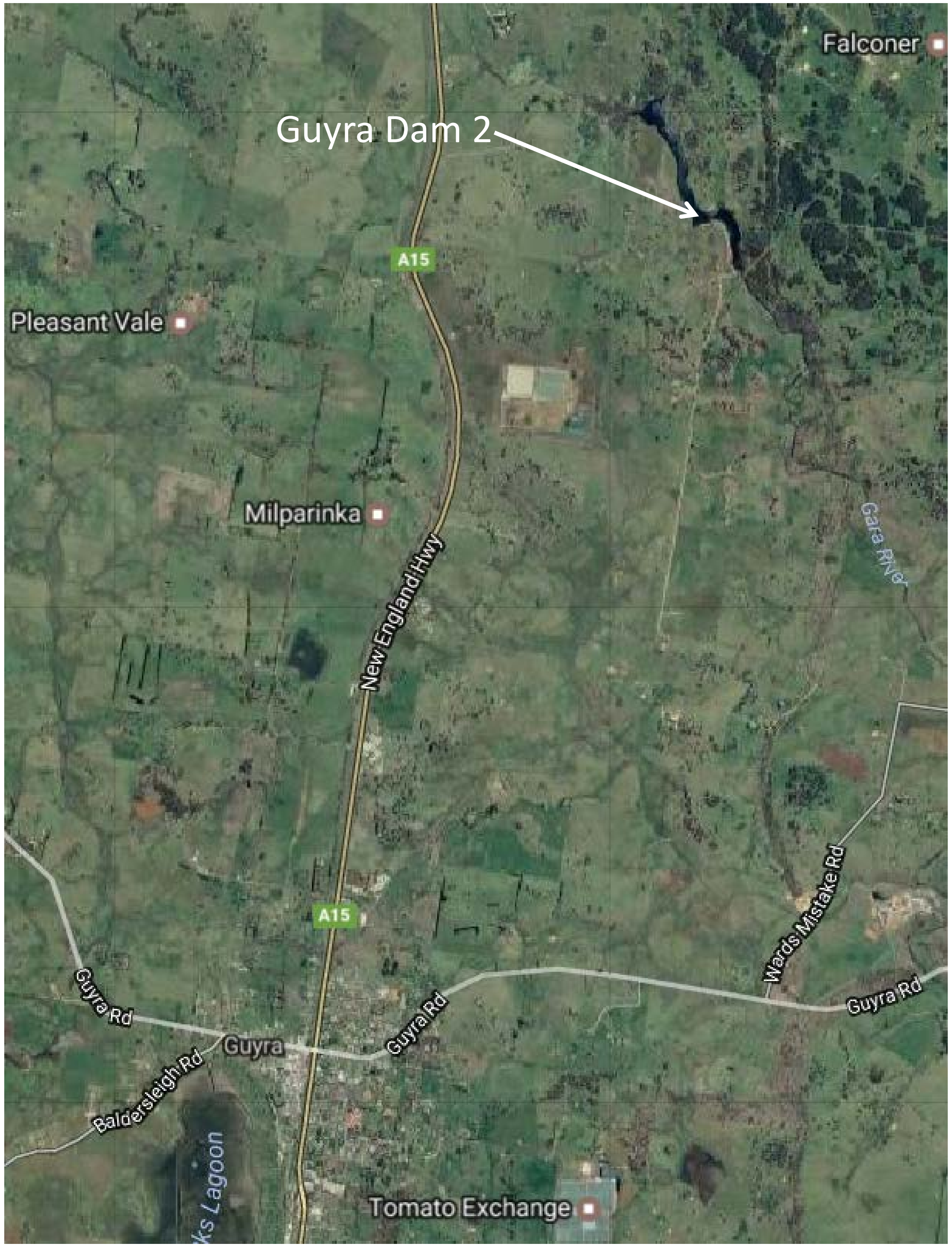


Plate 30: General view of the quarry face (Site 4) showing shallow residual, bouldery profile overlying more competent basalt.

FIGURES



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GUYRA WATER SUPPLY

Guyra Dam 2 - Locality Plan

GT38A

FIGURE 1

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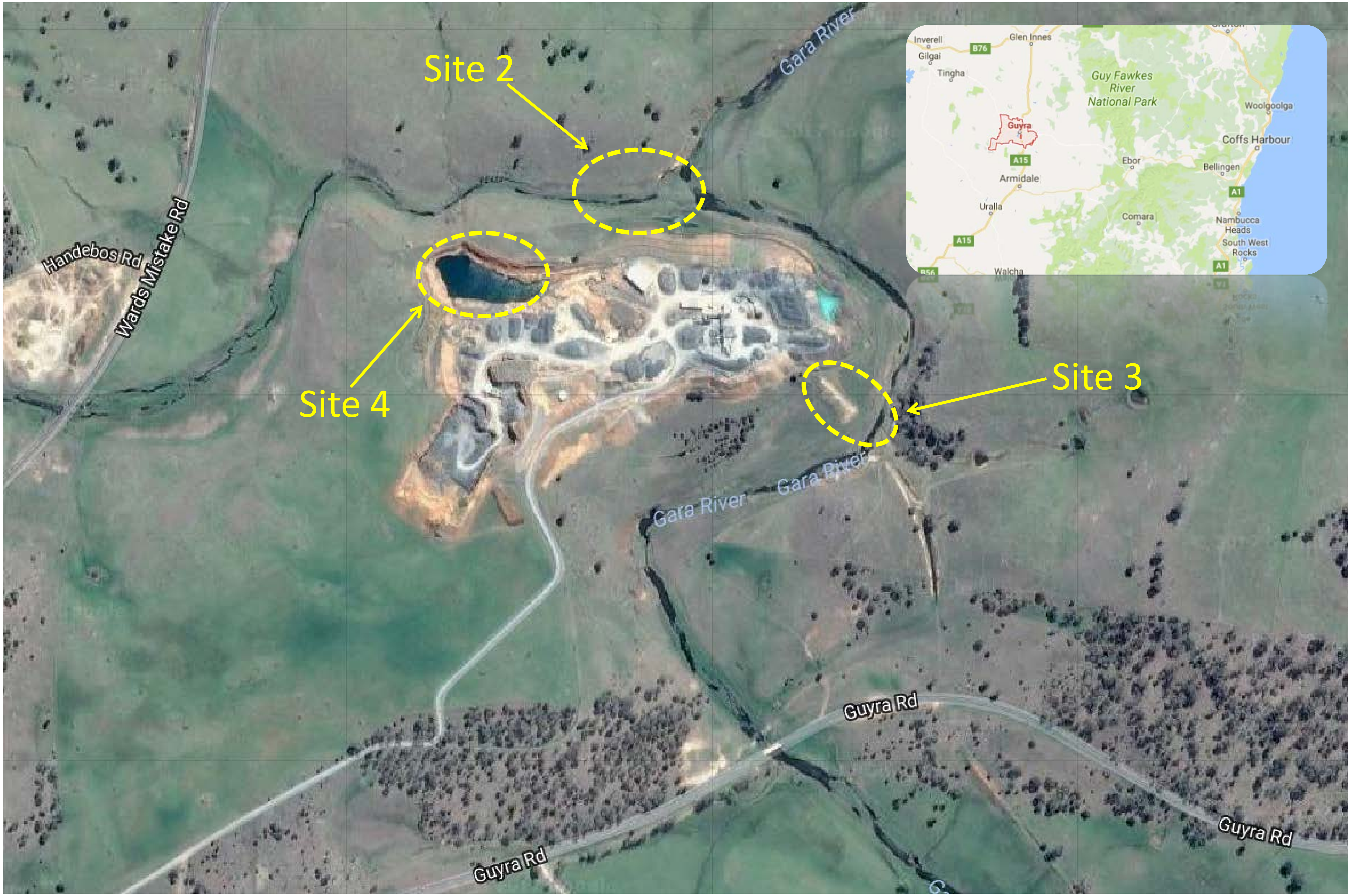
GUYRA WATER SUPPLY

Off Stream Storage - Site 1: Locality Plan and Approximate Test Pit Locations

GT38A

FIGURE 2



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GUYRA WATER SUPPLY

Alternative Sites - 2,3,4 Locality Plan

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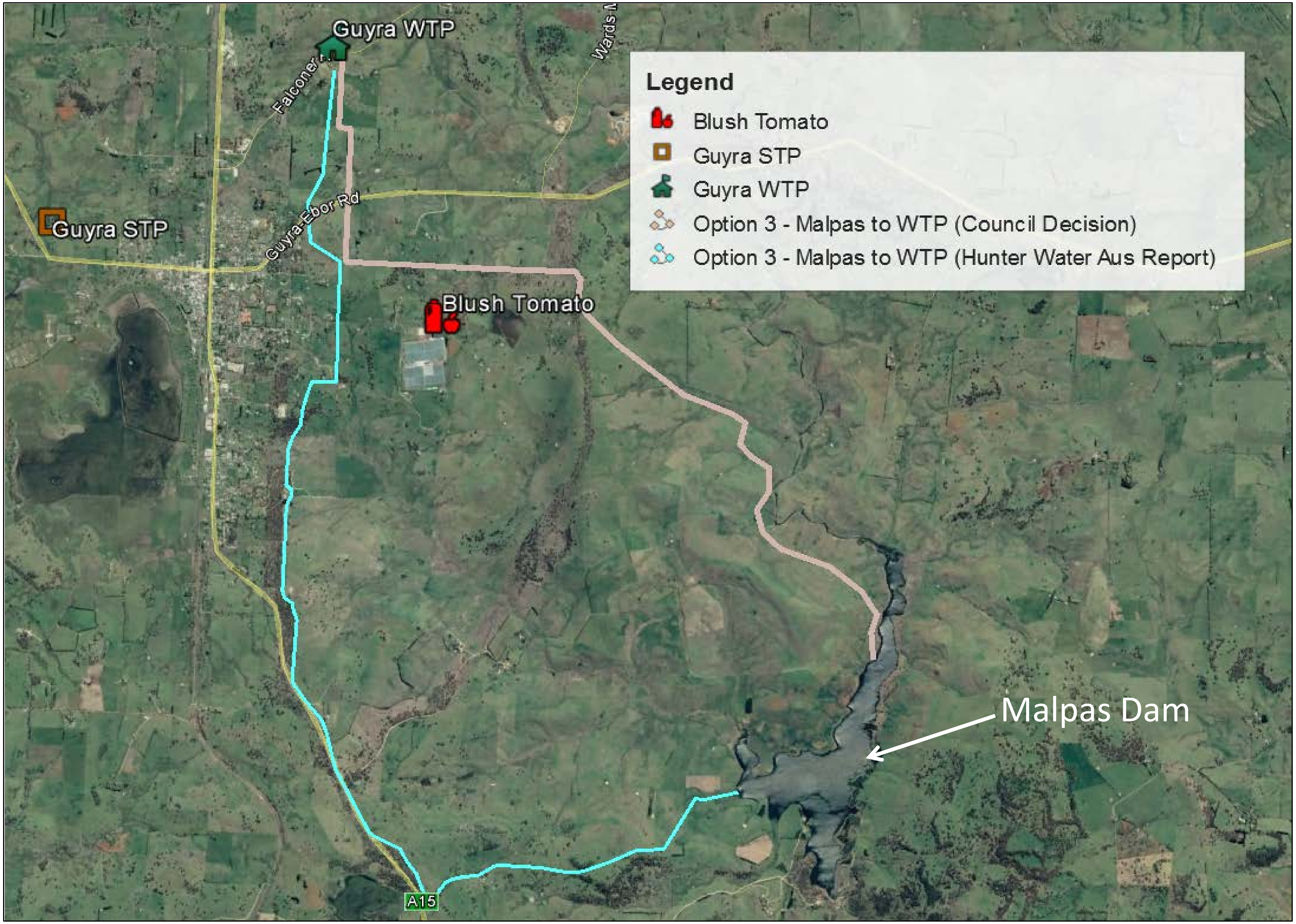
FIGURE 3



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GUYRA WATER SUPPLY

Malpas Dam to Guyra Water Treatment Plant Pipeline - Locality Plan

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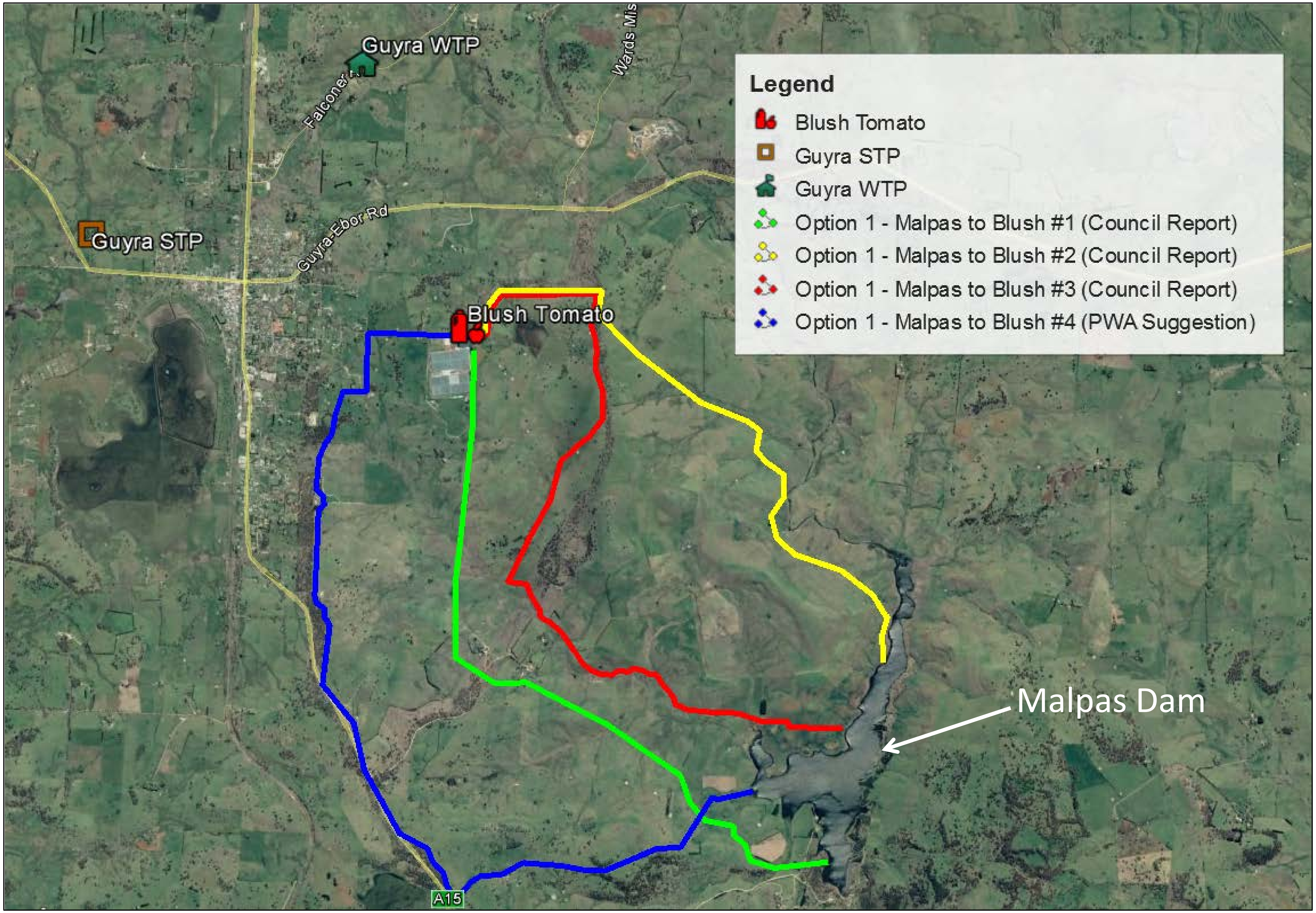
FIGURE 4



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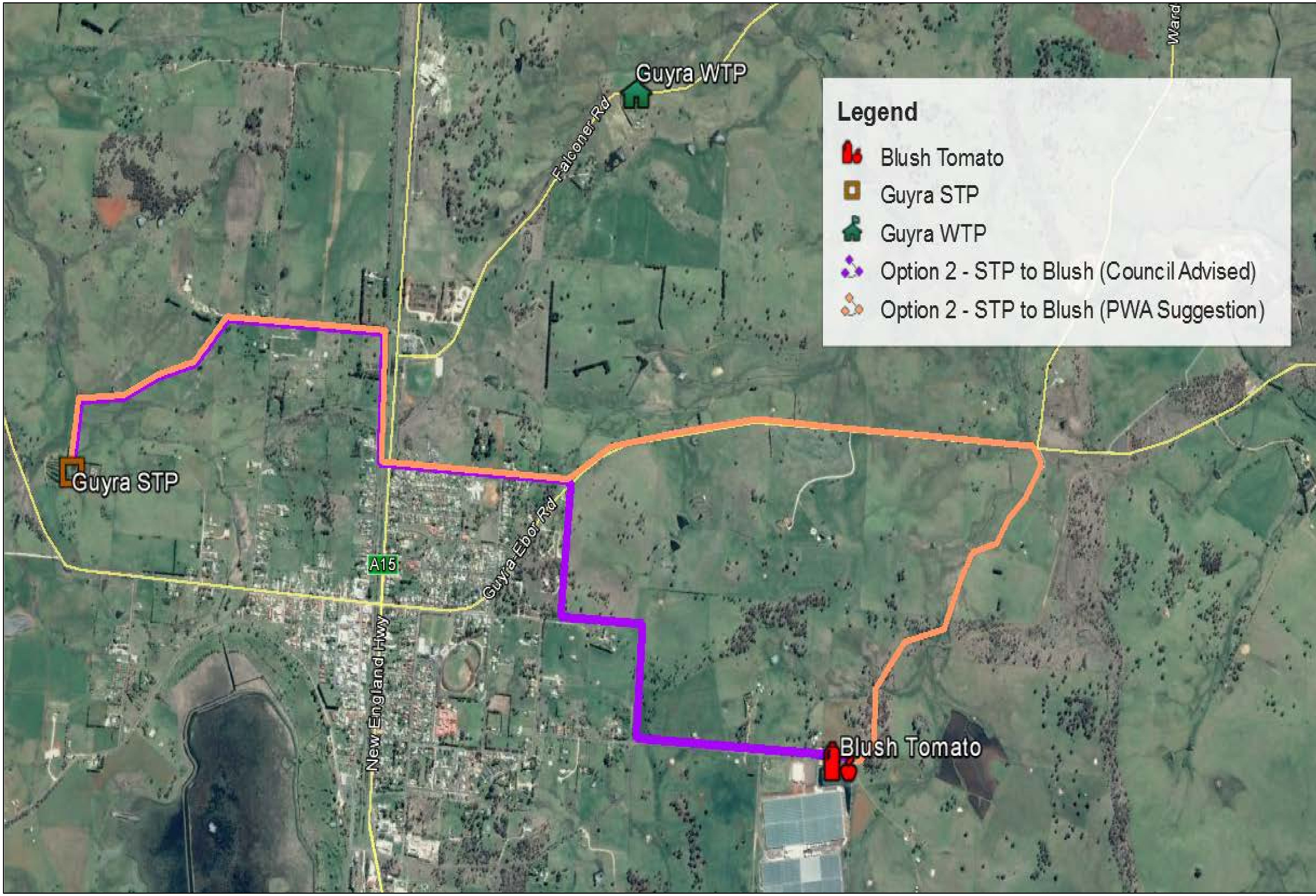
GUYRA WATER SUPPLY

Malpas Dam to Blush Tomato Farm Pipeline - Locality Plan

GT38A

FIGURE 5



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GUYRA WATER SUPPLY

Sewage Treatment Plant to Blush Tomato Farm Pipeline - Locality Plan

GT38A

FIGURE 6

APPENDIX A

Geotechnical Terminology and Technical Aids

CHARACTERISATION OF GEOTECHNICAL DATA

Geotechnical data generally fall into the categories of fact, interpretation and opinion, as defined by the Institution of Engineers, Australia, 1987 - Guidelines for the Provision of Geotechnical Information in Construction Contracts.

Facts are defined as the materials, statistics and properties which may be seen, measured or identified by means of accepted and preferably standardised criteria, classifications and tests. Examples of facts include: exploration locations, outcrop locations, samples and drill core, lithological names/descriptions of soils and rocks, measured water levels, laboratory test results and seismic time/distance plots.

Interpretative data is defined as information derived from competently made interpretation of facts using accepted and proven techniques, or reasonable judgement exercised in the knowledge of geological conditions or processes evident at the site. Examples of interpretative data are: borehole and test pit logs, inferred stratigraphy and correlations between boreholes or test pits, material and rock mass properties used in analysis (e.g. permeability), and seismic interpretation (yielding velocity and layer depths).

Opinion is derived from consideration of relevant available facts, interpretations and analysis and/or the exercise of judgement. Examples of opinions based on geotechnical/geological interpretations include bearing capacity and foundation suitability, need for foundation treatment, settlements, potential for grouting, excavation stability, ease of excavation, and suitability of construction materials.

SOIL DESCRIPTION

The methods of description and classification of soils are based on Australian Standard 1726, the SAA Site Investigation Code. The description of a soil is based on particle size distribution and plasticity as shown in the "GUIDE TO THE DESCRIPTION, IDENTIFICATION AND CLASSIFICATION OF SOILS".

SOIL CLASSIFICATION

The basic soil types and their subdivisions are defined by their particle sizes:

MAJOR SOIL CATEGORIES

Soil Classification	Particle Size
Boulders	Greater than 200mm
Cobbles	63 - 200mm
Gravel	2.36 - 63mm
Sand	0.075 - 2.36mm
Silt	0.002 - 0.075mm
Clay	Less than 0.002mm

MINOR SOIL CONSTITUENTS

As most natural soils are combinations of various constituents, the primary soil is further described and modified by its minor components:

Coarse grained soils		**Fine grained soils**	
% Fines	**Modifier**	**% Coarse**	**Modifier**
≤ 5	Omit, or use 'trace'	≤ 15	Omit, or use 'trace'
> 5 ≤ 12	Describe as 'with clay/silt', as applicable	> 15 ≤ 30	Describe as 'with sand/gravel', as applicable
> 12	Prefix soil as 'silty/clayey', as applicable	> 30	Prefix soil as 'sand/gravelly', as applicable

COHESIVE SOILS

Clay and silt may be described according to their plasticity:

Descriptive Term	**Range of liquid limit (percent)**
Of low plasticity	≤ 35
Of medium plasticity	> 35 ≤ 50
Of high plasticity	> 50

MOISTURE CONDITION

Term	Description
Dry (D)	Cohesive soils; hard and friable or powdery, well dry of plastic limit. Granular soils; cohesionless and free-running.
Moist (M)	Soil feels cool, darkened in colour. Cohesive soils can be moulded. Granular soils tend to cohere.
Wet (W)	Soil feels cool, darkened in colour. Cohesive soils usually weakened and free water forms on hands when handling. Granular soils tend to cohere.

CONSISTENCY - NON-COHESIVE SOILS

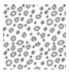
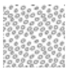
Term	Density index %		SPT "N" value
Very loose		≤ 15	< 5
Loose	> 15	≤ 35	5 - 10
Medium dense	> 35	≤ 65	10 - 30
Dense	> 65	≤ 85	30 - 50
Very dense	> 85		> 50

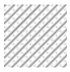
CONSISTENCY - COHESIVE SOILS

Term	Undrained shear strength (kPa)		Field guide to consistency	SPT "N" value
Very soft		≤ 12	Exudes between the fingers when squeezed in hand.	< 2
Soft	> 12	≤ 25	Can be moulded by light finger pressure.	2 - 4
Firm	> 25	≤ 50	Can be moulded by strong finger pressure.	4 - 8
Stiff	> 50	≤ 100	Cannot be moulded by fingers; can be indented by thumb	8 - 16
Very stiff	> 100	≤ 200	Can be indented by thumb nail.	16 - 32
Hard	> 200		Can be indented with difficulty by thumb nail.	> 32

GRAPHICAL SYMBOLS USED FOR GEOTECHNICAL BOREHOLE AND TEST PIT LOGS

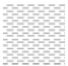
SOIL - COARSE GRAINED

 GW
 GP
 GM
 GC

 SW
 SP
 SM
 SC

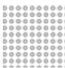
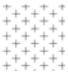
SOIL - FINE GRAINED

 CH
 CI
 CL

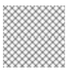
 MH
 ML

 OH
 OL
 Pt

ROCK

 Sedimentary rock
 Igneous rock
 Metamorphic rock

FILL MATERIAL

 Fill

GROUNDWATER

 Level
 Inflow

NGE No Groundwater Encountered

SOIL HORIZON BOUNDARIES

——— Boundary measured or determined from drilling conditions

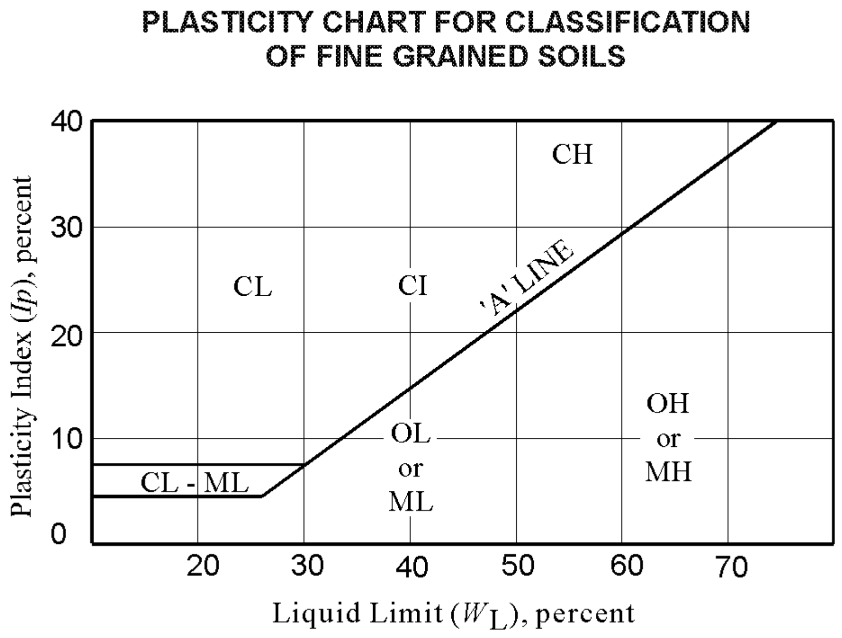
.... Diffuse or uncertain boundary

GUIDE TO THE DESCRIPTION IDENTIFICATION AND CLASSIFICATION OF SOILS

Major Divisions		Particle Size (mm)	Group Symbol	Typical Names	Field Identification Sand and Gravels	Laboratory Classification					
							% < 0.06mm (see note 2)	Plasticity of Fine Fraction	$C_u = \frac{D_{50}}{D_{10}}$	$C_c = \frac{(D_{30})^2}{D_{10}D_{60}}$	Notes
COARSE GRAINED SOILS (more than half of material less than 63 mm is larger than 0.075 mm)	**BOULDERS**	200				Use the gradation curve of material passing 63mm for classification of fractions according to the criteria given in "Major Divisions"	—	—	—	—	
	COBBLES	63					—	—	—	—	
	GRAVELS (more than half of coarse fraction is larger than 2.36mm)	coarse 20	GW	Well-graded gravels, gravel-sand mixtures, little or no fines	Wide range in grain size and substantial amounts of all intermediate sizes, not enough fines to bind coarse grains, no dry strength		0-5	—	> 4	between 1 and 3	1. Identify lines by the method given for fine grained soils.
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines, uniform gravels	Predominantly one size or range of sizes with some intermediate sizes missing, not enough fines to bind coarse grains, no dry strength		0-5	—	Fails to comply with above	—	
		medium 6	GM	Silty gravels, gravel-sand-silt mixtures	'Dirty' materials with excess of non-plastic fines, zero to medium dry strength		12-50	Below 'A' line or $I_p < 4$	—	—	2. Borderline classifications occur when the percentage of fines (fraction smaller than 0.06mm size) is greater than 5% and less than 12%.
		fine 2.36	GC	Clayey gravels, gravel-sand-clay mixtures	'Dirty' materials with excess of plastic fines, medium to high dry strength		12-50	Above 'A' line or $I_p > 7$	—	—	Borderline classifications require the use of dual symbols e.g. SP-SM, GW-GC
	SANDS (more than half of coarse fraction is smaller than 2.36mm)	coarse 0.6	SW	Well graded sands, gravelly sands, little or no fines	Wide range in grain size and substantial amounts of all intermediate sizes, not enough fines to bind coarse grains, no dry strength		0-5	—	> 6	between 1 and 3	3. I_p = Plasticity Index
			SP	Poorly graded sands and gravelly sands; little or no fines	Predominantly one size or range of sizes with some intermediate sizes missing, not enough fines to bind coarse grains, no dry strength		0-5	—	Fails to comply with above	Fails to comply with above	
		medium 0.2	SM	Silty sands, sand-silt mixtures	'Dirty' materials with excess of non-plastic fines, zero to medium dry strength		12-50	Below 'A' line or $I_p < 4$	—	—	
		fine 0.075	SC	Clayey sands, sand-clay mixtures	'Dirty' materials with excess of plastic fines, medium to high dry strength		12-50	Above 'A' line or $I_p > 7$	—	—	

GUIDE TO THE DESCRIPTION, IDENTIFICATION AND CLASSIFICATION OF SOILS (CONT.)

Major Divisions		Particle Size (mm)	Group Symbol	Typical Names	Field Identification: Dry* Strength	Field Identification: Dilatancy†	Field Identification: Toughness ‡	Laboratory Classification		Plasticity of Fine Fraction	Notes
FINE GRAINED SOILS (more than half of material less than 63 mm is smaller than 0.075 mm)	SILTS & CLAYS (liquid limit < 50%)	<0.075	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	None to low	Quick to slow	None	Use the gradation curve of material passing 63mm for classification of fractions according to the criteria given in "Major Divisions"	More than 50% passing 0.06 mm	Below 'A' line	
			CL, CI	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Medium to high	None to very slow	Medium			Above 'A' line	
			OL ⌖	Organic silts and organic silty clays of low plasticity	Low to medium	Slow	Low			Below 'A' line	
	SILTS & CLAYS (liquid limit > 50%)		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, clastic silts	Low to medium	Slow to none	Low to medium			Below 'A' line	
			CH	Inorganic clays of high plasticity, fat clays	High to very high	None	High			Above 'A' line	
			OH ⌖	Organic clays of medium to high plasticity, organic silts	Medium to high	None to very slow	Low to medium			Below 'A' line	
	HIGHLY ORGANIC SOILS		Pt ⌖	Peat and other highly organic soils	Identified by colour, odour, spongy feel and generally by fibrous texture					—	⌖ Effervesces with H_2O_2



FIELD IDENTIFICATION PROCEDURE FOR FINE GRAINED SOILS OR FRACTIONS

THESE PROCEDURES ARE TO BE PERFORMED ON THE MINUS 0.2MM SIZE PARTICLES. FOR FIELD CLASSIFICATION PURPOSES, SCREENING IS NOT INTENDED, SIMPLY REMOVE BY HAND THE COARSE PARTICLES THAT INTERFERE WITH THE TESTS.

*** Dry strength (Crushing characteristics)**

After removing particles larger than 0.2mm size, mould a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun or air drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity. High dry strength is characteristic for clays of the CH group.

A typical inorganic silt possesses only very slight dry strength.

Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

† Dilatancy (Reaction to shaking)

After removing particles larger than 0.2mm size, prepare a pat of moist soil with a volume of 10 cm³. Add enough water if necessary to make the soil soft but not sticky.

Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens, and finally it cracks or crumbles.

The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.

Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, shows a moderately quick reaction.

‡ Toughness (Consistency near plastic limit)

After removing particles larger than 0.2mm size, a specimen of soil about 10cm³ in size is moulded to the consistency of putty. If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. The specimen is then rolled out by hand on a smooth surface or between the palms into a thread about 3mm in diameter. The thread is then folded and re-rolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.

After the thread crumbles, the pieces should be lumped together with a slight kneading action continued until the lump crumbles. The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil.

Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line. Highly organic clays have a very weak and spongy feel at the plastic limit.

EXPLANATION OF LOGGING TERMS FOR ENGINEERING GEOLOGY BOREHOLE LOGGING

ROCK SUBSTANCE WEATHERING CLASSIFICATION		ESTIMATED STRENGTH CLASSIFICATION	
RS	Residual soil	EW	Extremely weak
EW	Extremely weathered	VW	Very weak
HW	Highly weathered	W	Weak
MW	Moderately weathered	MS	Medium strong
SW	Slightly weathered	S	Strong
F(s)	Fresh (stained defects)	VS	Very strong
F	Fresh	ES	Extremely strong

DEFECTS

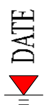
Defects include all joints, bedding planes, fracture zones, seams, veins and cleavage partings.

RQD

Rock quality designation:

$$RQD = \frac{\text{length of core in pieces 100mm or longer}}{\text{length of run}} \times 100\%$$

WATER



Water table, with date


Water inflow


Partial drilling water loss


Complete drilling water loss

Angles of joint inclination (and other geological features and drill holes) are angles between the feature and a horizontal plane. In core, angles of joints (and other geological structures) are angles between the structure and the plane normal to the axis of the core. In vertical holes these angles are then the true inclination (dip) of the structure.

DEFINITIONS OF ENGINEERING GEOLOGICAL TERMS

This classification system provides a standard terminology for the engineering description of rock.

DEGREE OF WEATHERING [1]

TERM	SYMBOL	DEFINITION
Residual Soil	RS	Rock is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.
Extremely Weathered	EW	Rock substance affected by weathering to the extent that the rock exhibits soil properties - i.e. it can be remoulded and can be classified according to the Unified Classification System, but the texture of the original rock is still evident.
Highly Weathered	HW	Rock substance affected by weathering to the extent that limonite staining or bleaching affects the whole of the rock substance, and other signs of chemical or physical decomposition are evident. Porosity and strength may be increased or decreased compared to the fresh rock, usually as a result of iron bleaching or deposition. The colour and strength of the original substance is no longer recognisable.
Moderately Weathered	MW	Rock substance affected by weathering to the extent that staining extends throughout the whole of the rock substance, and the original colour of the fresh rock is no longer recognisable.
Slightly Weathered	SW	Rock substance affected by weathering to the extent that partial staining or discolouration of the rock substance, usually by limonite has taken place. The colour and texture of the fresh rock is recognisable.
Fresh (stained)	F_S	Rock substance unaffected by weathering. Weathering is limited to the surface of major discontinuities, for example an iron-stained joint.
Fresh	F	Rock substance unaffected by weathering.

ROCK STRENGTH [2]

Rock strength is defined by the Point Load Strength Index (Is (50)), and refers to the strength of the rock substance in the direction normal to the bedding.

TERM	Is (50)	FIELD GUIDE	APPROX. qu MPa *
Extremely Weak (EW)		Easily remoulded by hand to a material with soil properties.	
	0.03		0.7
Very weak (VW)		May be crumbled in the hand. Sandstone is "sugary" and friable.	
	0.1		2.4
Weak (W)		A piece of core 150mm long x 50mm dia. may be broken by hand and easily scored with a knife. Sharp edges of core may be friable and break during handling.	
	0.3		7
Medium Strong (MS)		A piece of core 150mm long x 50mm dia. may be broken by hand with considerable difficulty. Readily scored with a knife.	
	1		24
Strong (S)		A piece of core 150mm long x 50mm dia. cannot be broken by unaided hands, may be slightly scratched or scored with knife.	
	3		70
Very Strong (VS)		A piece of core 150mm long x 50mm dia. may be broken readily with hand held hammer. Cannot be scratched with pen knife.	
	10		240
Extremely Strong (ES)		A piece of core 150mm long x 50mm dia. is difficult to break with hand held hammer. Rings when struck with hammer.	

* The approximate unconfined compressive strength (qu) shown in the table is based on an assumed ratio to the point load index of 24:1. This ratio may vary widely and should be calibrated on site.

STRATIFICATION SPACING [2]

TERM	SEPARATION OF STRATIFICATION PLANES
Thinly laminated	< 6mm
Laminated	6mm - 20mm
Very thinly bedded	20mm - 60mm
Thinly bedded	60mm - 200mm
Medium bedded	200mm - 600mm
Thickly bedded	600mm - 2m
Very thickly bedded	> 2m

DISCONTINUITY SPACING [3]

TERM	SPACING
Very widely spaced	> 2m
Widely spaced	600mm - 2m
Moderately widely spaced	200mm 600mm
Closely spaced	60mm - 200mm
Very closely spaced	20mm - 60mm
Extremely closely spaced	< 20mm

APERTURE OF DISCONTINUITY SURFACES [4]

The degree to which a discontinuity is open, or to which the faces of the discontinuity have been separated and the space subsequently infilled (such as in a vein, fault or joint).

TERM	APERTURE THICKNESS (Discontinuities, veins, faults, joints)
Wide	> 200mm
Moderately wide	60mm - 200mm
Moderately narrow	20mm - 60mm
Narrow	6mm - 20mm
Very narrow	2mm - 6mm
Extremely narrow	> 0 - 2 mm
Tight	Zero

BLOCK SHAPE AND SIZE [4]

The following descriptive terms define shape:

Blocky	- approximately equidimensional.
Tabular	- one dimension considerably shorter than the other two.
Columnar	- one dimension considerably larger than the other two.

Block sizes are defined by the following descriptive terms:

TERM	BLOCK SIZE	EQUIVALENT DISCONTINUITY SPACINGS IN BLOCKY ROCK
Very large	$> 8m^3$	Extremely wide
Large	$> 0.2m^3 - 8m^3$	Very wide
Medium	$> 0.008m^3 - 0.2m^3$	Wide
Small	$> 0.0002m^3 - 0.008m^3$	Moderately wide
Very small	$\leq 0.0002m^3$	Less than moderately wide

REFERENCES

1. Modifications of:

   (a) McMahon, B.K., Douglas, D.J., & Burgess, P.J., 1975. Engineering classification of sedimentary rocks in the Sydney area. Australian Geomechanics Journal, G5 (1), 51-53.

   (b) Geological Society Engineering Group Working Party, 1977. The description of rock masses for engineering purposes. Quarterly Jour. Engg. Geology, 10 (4), 355-388.

2. McMahon, B.K., Douglas , D.J., & Burgess, P. J., 1975. Engineering classification of sedimentary rocks in the Sydney area. Australian Geomechanics Journal, G5 (1), 51 -53.

3. ISRM Commission on Standardisation of Laboratory and Field Tests, 1978. Suggested methods for the quantitative description of discontinuities in rock masses. J1. Rock Mechanics Min. Sci. and Geomech. Abstra., 15, 319-368.

4. Geological Society Engineering Group Working Party, 1977. The description of rock masses for engineering purposes. Quarterly Journ. Engg Geology, 10 (4), 355-388.

APPENDIX B

Test Pit Logs and Photos

Public Works
NSW Water Solutions

GEOTECHNICAL & ENVIRONMENTAL

TEST PIT No. **TP1**

PROJECT: GUYRA WATER SUPPLY
LOCATION: SITE 1
CONTRACTOR: COUNCIL
SITE SUPERVISOR: C. KARWAJ
EQUIPMENT: KOMATSU HB93R
PROJECT COORDINATOR: C. KARWAJ
DATE: 11/04/2017
SURFACE RL: AHD
EASTING:
NORTHING:

DEPTH (m)	RL (m)	GRAPHIC LOG	SOIL GROUP	MATERIAL DESCRIPTION Soil type, colour, consistency, grainsize, moisture, remarks	SAMPLE or TEST	WATER	METHOD
0.00–0.15			CH	TOPSOIL - CLAYEY SILT with fine roots; dark grey; soft; very moist to wet.			Backhoe
0.15–0.45			CH (v)	SILTY CLAY; red-orange-brown and dark grey mottled; firm; very moist.			
0.45–0.80			CH (v)	SILTY CLAY with some rounded basalt cobbles and gravel to 200mm size; mottled dark grey and red-brown; firm; very moist to wet.	D (0.5–0.7)		
0.80–1.50			CH (v)	SILTY CLAY with occasional embedded cobbles; yellow-orange-brown and light grey mottled; firm to stiff; very moist.	D (1.0–1.2)		
1.50–2.40			CH (v)	High concentration of embedded basalt cobbles and boulders to 350mm size below 1.5m depth.		2.2m (water table)	
2.40–2.60			CI (v)	CLAYEY SILT with some fine ironstone gravel; yellow-brown, grey, grey-brown; firm; wet.	D (2.4–2.6)	2.4m (water inflow)	
2.60				Hole Terminated at 2.60 m			

v : visual
I : laboratory

SAMPLE OR TEST
Undisturbed: U
Disturbed: D
Bulk: B
Standard Penetration Test: SPT

GROUNDWATER
Water Table
Water Inflow

PROJECT No.:

SHEET: 1 OF 1

NSWPW LIB 1.03.GLB Log NSW PW BOREHOLE GUYRA WATER SUPPLY-TP LOGS.GPJ <<DrawingFile>> 21/04/2017 14:13 8.30.004 Datgel Lab and In Situ Tool

Test Pit TP1 - Profile.

Test Pit TP1 - Stockpile.

Public Works NSW Water Solutions

GEOTECHNICAL & ENVIRONMENTAL

TEST PIT No. **TP2**

PROJECT: GUYRA WATER SUPPLY
LOCATION: SITE 1
CONTRACTOR: COUNCIL
SITE SUPERVISOR: C. KARWAJ
EQUIPMENT: KOMATSU HB93R
PROJECT COORDINATOR: C. KARWAJ
DATE: 11/04/2017
SURFACE RL: AHD
EASTING:
NORTHING:

DEPTH (m)	RL (m)	GRAPHIC LOG	SOIL GROUP	MATERIAL DESCRIPTION Soil type, colour, consistency, grainsize, moisture, remarks	SAMPLE or TEST	WATER	METHOD
0.00–0.15			CH	TOPSOIL - SILTY CLAY/ CLAYEY SILT with fine roots; dark grey; friable; soft; very moist.		Not Encountered	Backhoe
0.15–0.40			CH (v)	SILTY CLAY, trace of rounded basalt gravel; dark grey, minor red-brown mottle; firm; very moist.			
0.40–1.30			CH (v)	SILTY CLAY, trace of gravel; with some embedded basalt cobbles and boulders; grey-brown, grey, some red-brown mottle; firm; moist.	D		
1.30–1.75			ROCK (v)	BASALT; fresh; strong to very strong; highly fractured; minor clay infill along joints; dark grey/ black.			
1.75				NOTE: Backhoe refusal at 1.75m depth. Hole Terminated at 1.75 m			

v : visual
I : laboratory

SAMPLE OR TEST
Undisturbed: U
Disturbed: D
Bulk: B
Standard Penetration Test: SPT

GROUNDWATER
Water Table
Water Inflow

PROJECT No.:

SHEET: 1 OF 1

NSWPW LIB 1.03.GLB Log NSW PW BOREHOLE GUYRA WATER SUPPLY-TP LOGS.GPJ <<DrawingFile>> 21/04/2017 14:13 8.30.004 Datgel Lab and In Situ Tool


Test Pit TP2 - Profile.


Test Pit TP2 - Stockpile.

Public Works
NSW Water Solutions

GEOTECHNICAL & ENVIRONMENTAL

TEST PIT No. **TP3**

PROJECT: GUYRA WATER SUPPLY
LOCATION: SITE 1
CONTRACTOR: COUNCIL
SITE SUPERVISOR: C. KARWAJ
EQUIPMENT: KOMATSU HB93R
PROJECT COORDINATOR: C. KARWAJ
DATE: 11/04/2017
SURFACE RL: AHD
EASTING:
NORTHING:

DEPTH (m)	RL (m)	GRAPHIC LOG	SOIL GROUP	MATERIAL DESCRIPTION Soil type, colour, consistency, grainsize, moisture, remarks	SAMPLE or TEST	WATER	METHOD
0.00–0.15			CH	TOPSOIL - CLAYEY SILT with fine roots; dark grey; friable; soft; wet.		Not Encountered	Backhoe
0.15–0.40			CH (v)	SILTY CLAY; orange-red-brown and dark grey mottled; firm; very moist to wet.			
0.40–0.90			CH (v)	SILTY CLAY, with embedded basalt cobbles and boulders; light grey; firm to stiff; very moist.			
0.90–1.30			CH (v)	SILTY CLAY, with some gravel; mottled grey-brown, light grey and red-brown; stiff; very moist.	D		
1.30–1.90			ROCK (v)	BASALT; fractured; joints infilled with clay; moderately weathered to fresh; strong to very strong.			
1.90				NOTE: Backhoe refusal at 1.7m to 1.9m depth along trench length. Hole Terminated at 1.90 m			

v : visual
I : laboratory

SAMPLE OR TEST
Undisturbed: U
Disturbed: D
Bulk: B
Standard Penetration Test: SPT

GROUNDWATER
Water Table
Water Inflow

PROJECT No.:

SHEET: 1 OF 1

NSWPW LIB 1.03.GLB Log NSW PW BOREHOLE GUYRA WATER SUPPLY-TP LOGS.GPJ <<DrawingFile>> 21/04/2017 14:13 8.30.004 Datgel Lab and In Situ Tool

Test Pit TP3 - Profile.

Test Pit TP3 - Stockpile.

APPENDIX C

Geotechnical Test Results

Geotechnical Centre
110B King Street, Manly Vale, NSW 2093
Telephone 02- 9949 0253

NSW GOVERNMENT | Public Works Advisory

CLIENT:	GEOTECHNICAL & ENVIRONMENTAL	BATCH No:	17010
SOIL SUMMARY SHEET			
PROJECT:	GUYRA WATER SUPPLY	COMPILED BY:	MA
LOCATION:	SITE 1	DATE:	27/04/2017

General Information Note: All test methods are as indicated on accompanying test reports.

Sample No.	**7641**	**7643**				
Bore/Reference	TP 1	TP 2				
Depth (m)	1.00 - 1.20	0.45 - 0.70				
Sample Type	D	D				
Soil Colour & Description (v) indicates visual classification	Orange Brown and Grey Sandy Silty Clay	Dark Grey Gravelly Sandy Clay trace Silt				
Classification	CH	CH				

Moisture Content & Density

Field Moisture Content (%)	56.3	35.2				
Field Wet Density (t/m³)						
Field Dry Density (t/m³)						
Soil Particle Density (t/m³)						

Particle Size Distribution

Cobble Size (%)						
Gravel Size (%)	0	21				
Sand Size (%)	16	24				
Silt Size (%)	27	8				
Clay Size (%)	57	47				
Effective Size (mm)						
Uniformity Coefficient						
Curvature Coefficient						

Plasticity

Liquid Limit (%)	100	107				
Plastic Limit (%)	39	30				
Plasticity Index (%)	61	77				
Linear Shrinkage (%)						

Dispersion

Dispersal Index						
Percent Dispersion (%)						
Emerson Class No.	2	7				

Compaction

Compaction Type						
Optimum Moisture Content (%)						
Maximum Dry Density (t/m³)						

California Bearing Ratio

Placement Moisture Content (%)						
Placement Dry Density (t/m³)						
Swell under 4.5kg Surcharge (%)						
C.B.R. at 2.5 mm Penetration (%)						
C.B.R. at 5.0 mm Penetration (%)						

Shrink-Swell Index

Shrink Strain (%)						
Swell Strain (%)						
Shrink-Swell Index (Iss)						

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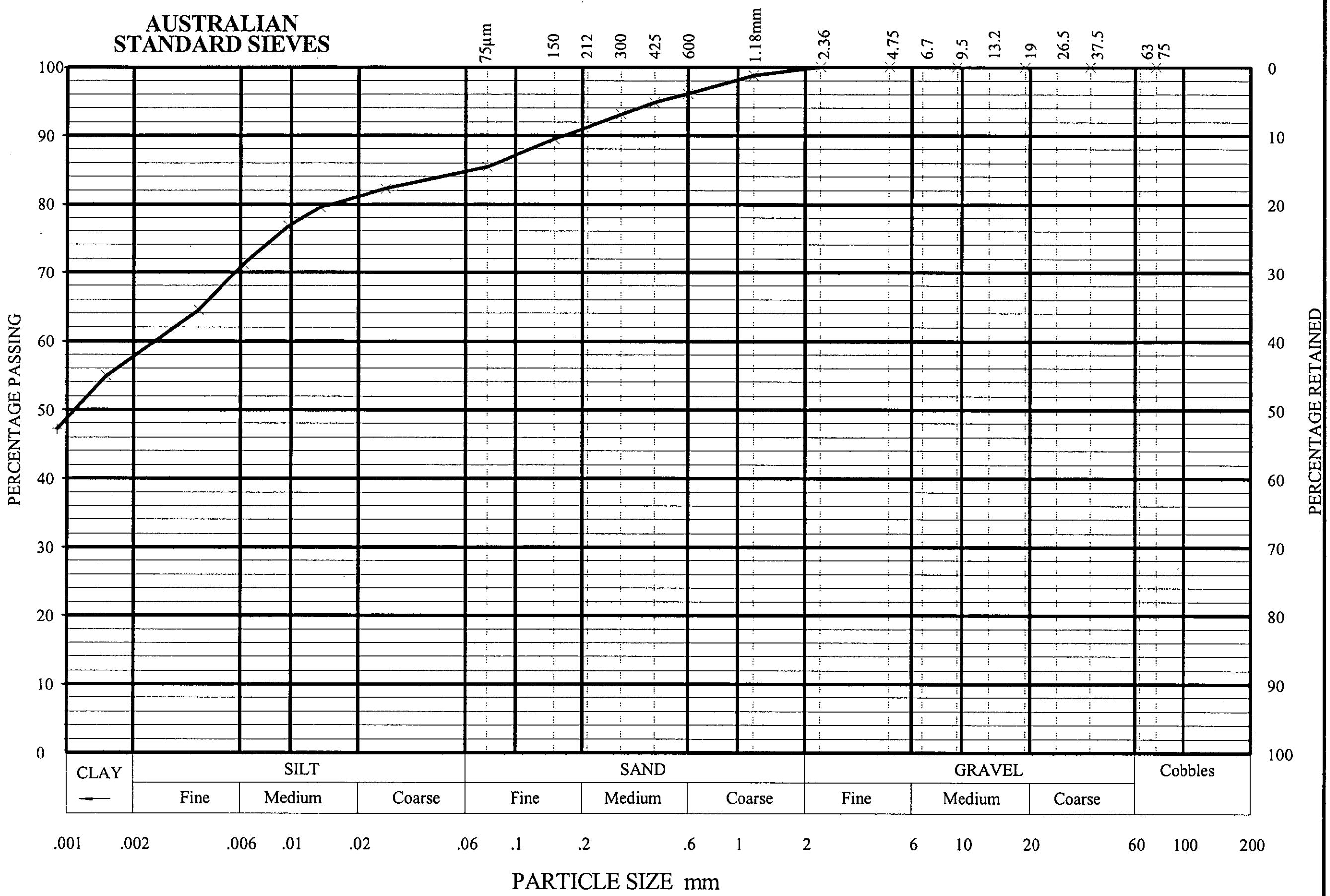
Telephone 02 9949 0253
NATA Accreditation Number: 13380

NSW GOVERNMENT | Public Works Advisory

CLIENT: GEOTECHNICAL & ENVIRONMENTAL		REPORT No: 17010/7641/R1119
PARTICLE SIZE DISTRIBUTION		
PROJECT: GUYRA WATER SUPPLY		SAMPLE No: 7641
LOCATION: SITE 1	HOLE No: TP1	DEPTH (m): 1.00



SIZE DISTRIBUTION	
COBBLES	0 %
GRAVEL	0 %
SAND	16 %
SILT	27 %
CLAY	57 %
SIZE D50:	-
EFFECTIVE SIZE D10:	-
UNIFORMITY COEFFICIENT D60/D10(Cu):	-
CURVATURE COEFFICIENT $D30^2/(D60 \times D10)$ (Cc):	-

Soil Particle Density: 2.65 t/m^3 (estimated for analysis)

Method of dispersion: End-over-end shaking

Hydrometer: ASTM 152H

Dispersion chemical: Sodium hexametaphosphate + Anhydrous sodium carbonate

Notes on Test: Tested as received

Loss in pre-treatment: 0 %

Test Methods:
DPWS GM 9: Determination of the Particle Size Distribution of a Soil

PARTICLE SIZE DISTRIBUTION R1119 (ISSUE 4, 2005)

NATA Accredited for compliance with ISO/IEC 17025 - Testing

Tested By: MA | Date Tested: 24/04/2017

APPROVED SIGNATORY

M. Ashover

Mark Ashover 27/04/2017

Geotechnical Centre

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Telephone 02 9949 0253
NATA Accreditation Number: 13380

NSW GOVERNMENT | Public Works Advisory

CLIENT: GEOTECHNICAL & ENVIRONMENTAL		REPORT No: 17010/7641/R1115
SOIL INDEX PROPERTIES		
PROJECT: GUYRA WATER SUPPLY		SAMPLE No: 7641
LOCATION: SITE 1	HOLE No: TP1	DEPTH (m): 1.00

SOIL INDEX PROPERTIES	RESULT	TEST METHOD
Moisture Content (as received)	: 56.3 %	AS 1289.2.1.1
Liquid Limit	: 100 %	AS 1289.3.1.1
Plastic Limit	: 39 %	AS 1289.3.2.1
Plasticity Index	: 61 %	AS 1289.3.3.1
Linear Shrinkage	: -	AS 1289.3.4.1
Soil Particle Density	: -	GM 8
Classification	: CH	AS 1726

Sample History: ☐ Natural State ☒ Air Dried ☐ Oven Dried

Method of Preparation: ☐ Wet Sieved ☒ Dry Sieved

Linear Shrinkage Sample: ☐ Curling ☐ Crumbling ☐ No Deformation

Notes on test: Sample tested as received from client.

ATTERBERG LIMITS R1115 (ISSUE 4, 2005)

NATA Accredited for compliance with ISO/IEC 17025 - Testing

Tested By: MA   Date Tested: 26/04/2017

APPROVED SIGNATORY   M. Ashover

Mark Ashover 27/04/2017

Geotechnical Centre

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Telephone 02 9949 0253
NATA Accreditation Number: 13380

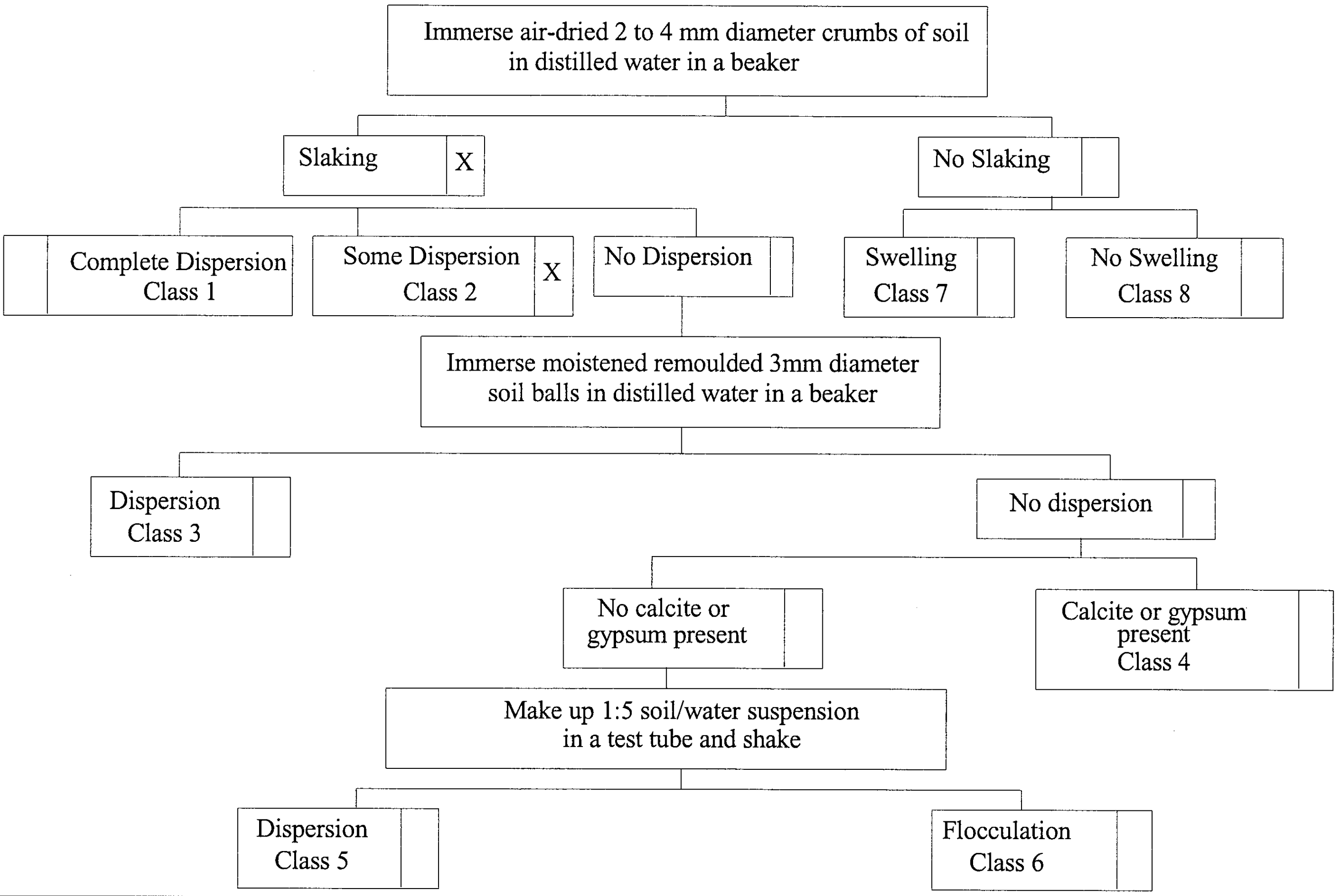
NSW GOVERNMENT | Public Works Advisory

CLIENT: GEOTECHNICAL & ENVIRONMENTAL	REPORT No: 17010/7641/R1118

DISPERSION TESTS

PROJECT: GUYRA WATER SUPPLY		SAMPLE No: 7641
LOCATION: SITE 1	HOLE No: TP1	DEPTH (m): 1.00

Determination of the Emerson Class Number of a soil



Emerson Class Number	(AS 1289.3.8.1)	2
Percent Dispersion	(AS 1289.3.8.2)**	No Test
Dispersal Index	(DPWS GM 15)	No Test

Sample Description: Yellow Brown and Grey Sandy Silty Clay

Type and temperature of water: Distilled, 20.2 ° C

Notes on test: Sample tested as received from client.

** 0.05mm size interpolated from hydrometer readings taken after 21min, 1hour and 2 hours.

Tested By: MA	Date Tested: 24/04/2017

NATA Accredited for compliance with ISO/IEC 17025 - Testing

APPROVED SIGNATORY M. Ashover

Mark Ashover 27/04/2017

Geotechnical Centre
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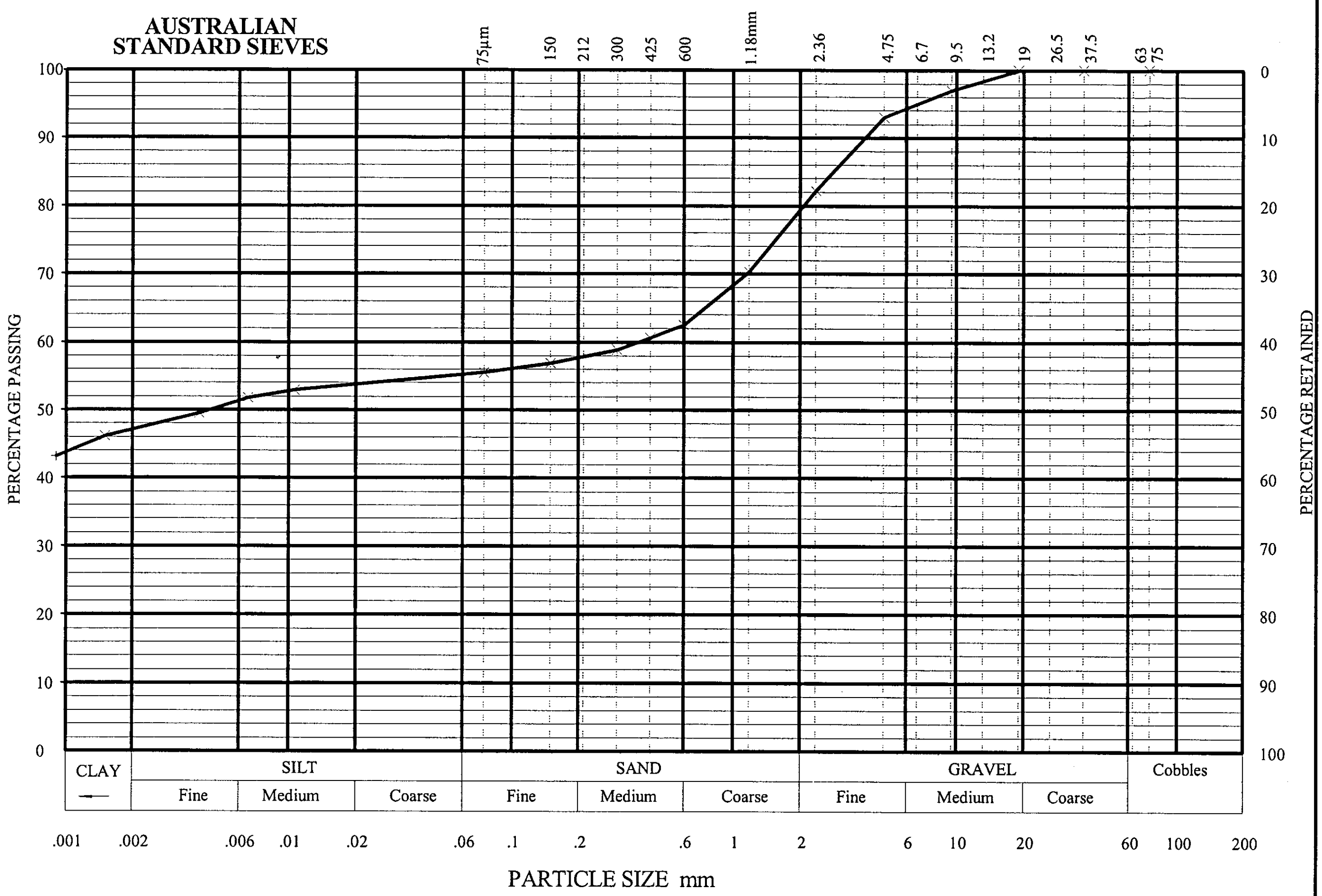
Telephone 02 9949 0253
NATA Accreditation Number: 13380

NSW GOVERNMENT | Public Works Advisory

CLIENT: GEOTECHNICAL & ENVIRONMENTAL	REPORT No: 17010/7643/R1119

PARTICLE SIZE DISTRIBUTION

PROJECT: GUYRA WATER SUPPLY		SAMPLE No: 7643
LOCATION: SITE 1	HOLE No: TP2	DEPTH (m): 0.45



SIZE DISTRIBUTION

COBBLES	0 %
GRAVEL	21 %
SAND	24 %
SILT	8 %
CLAY	47 %
SIZE D50:	0.004 mm
EFFECTIVE SIZE D10:	-
UNIFORMITY COEFFICIENT D60/D10(Cu):	-
CURVATURE COEFFICIENT $D30^2$ /(D60 x D10) (Cc):	-

Soil Particle Density: 2.65 t/m³ (estimated for analysis)

Method of dispersion: End-over-end shaking

Hydrometer: ASTM 152H

Dispersion chemical: Sodium hexametaphosphate + Anhydrous sodium carbonate

Notes on Test: Tested as received

Loss in pre-treatment: 0 %

Test Methods:
DPWS GM 9: Determination of the Particle Size Distribution of a Soil

PARTICLE SIZE DISTRIBUTION R1119 (ISSUE 4, 2005)

NATA Accredited for compliance with ISO/IEC 17025 - Testing

Tested By: MA

Date Tested: 24/04/2017

APPROVED SIGNATORY

Mark Ashover 27/04/2017

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Telephone 02 9949 0253
NATA Accreditation Number: 13380

NSW GOVERNMENT | Public Works Advisory

CLIENT: GEOTECHNICAL & ENVIRONMENTAL	REPORT No: 17010/7643/R1115

SOIL INDEX PROPERTIES

PROJECT: GUYRA WATER SUPPLY		SAMPLE No: 7643
LOCATION: SITE 1	HOLE No: TP2	DEPTH (m): 0.45

SOIL INDEX PROPERTIES	RESULT	TEST METHOD
Moisture Content (as received)	: 35.2 %	AS 1289.2.1.1
Liquid Limit	: 107 %	AS 1289.3.1.1
Plastic Limit	: 30 %	AS 1289.3.2.1
Plasticity Index	: 77 %	AS 1289.3.3.1
Linear Shrinkage	: -	AS 1289.3.4.1
Soil Particle Density	: -	GM 8
Classification	: CH	AS 1726

Sample History: ☐ Natural State ☒ Air Dried ☐ Oven Dried

Method of Preparation: ☐ Wet Sieved ☒ Dry Sieved

Linear Shrinkage Sample: ☐ Curling ☐ Crumbling ☐ No Deformation

Notes on test: Sample tested as received from client.

ATTERBERG LIMITS R1115 (ISSUE 4, 2005)

NATA Accredited for compliance with ISO/IEC 17025 - Testing

Tested By: MA | Date Tested: 26/04/2017

APPROVED SIGNATORY

Mark Ashover 27/04/2017

Geotechnical Centre

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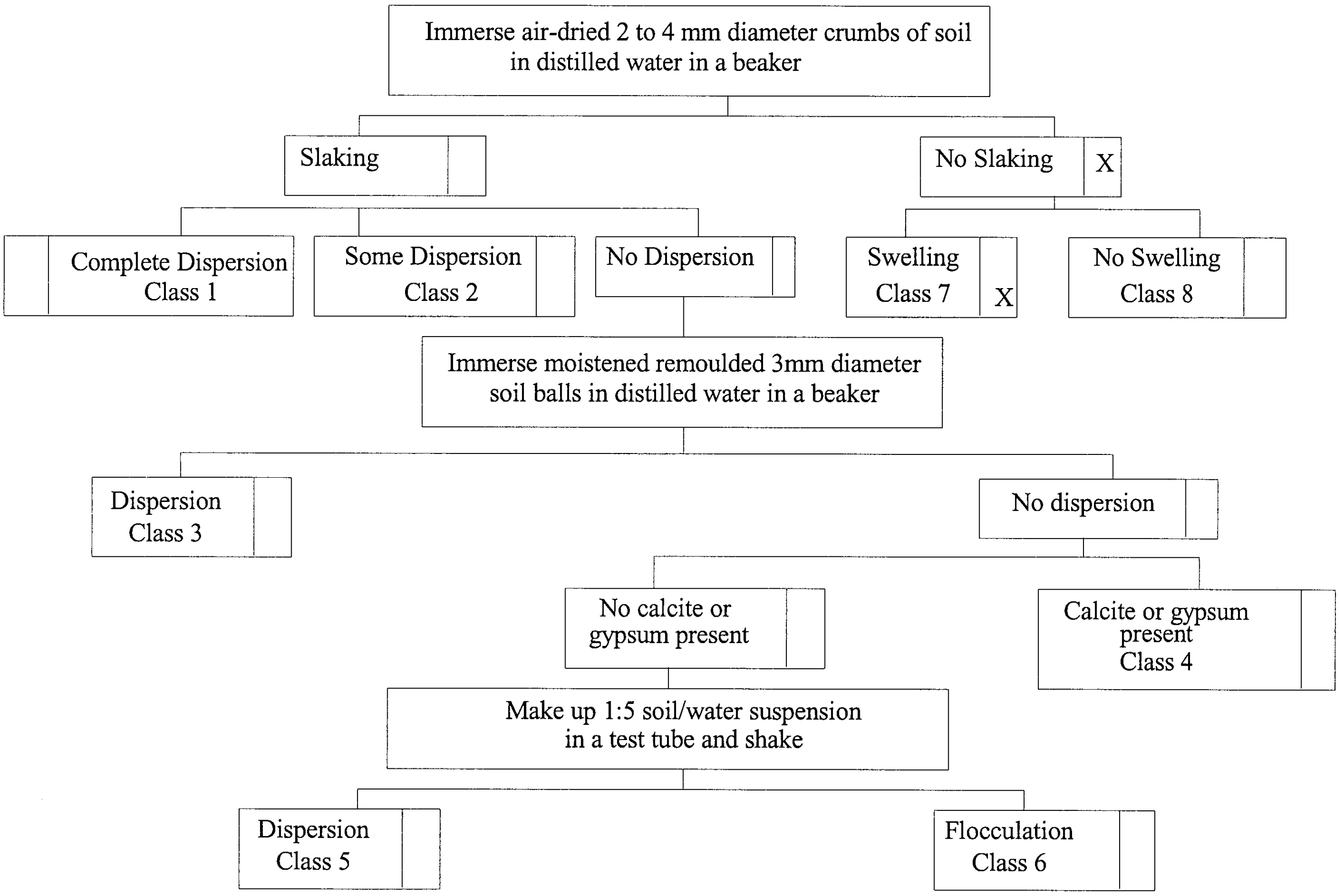
Telephone 02 9949 0253
NATA Accreditation Number: 13380

NSW GOVERNMENT | Public Works Advisory

CLIENT: GEOTECHNICAL & ENVIRONMENTAL			REPORT No: 17010/7643/R1118
DISPERSION TESTS			
PROJECT: GUYRA WATER SUPPLY			SAMPLE No: 7643
LOCATION: SITE 1		HOLE No: TP2	DEPTH (m): 0.45

Determination of the Emerson Class Number of a soil



Emerson Class Number	(AS 1289.3.8.1)	7
Percent Dispersion	(AS 1289.3.8.2)**	No Test
Dispersal Index	(DPWS GM 15)	No Test

Sample Description: Dark Grey Sandy Silty Clay trace Gravel
Type and temperature of water: Distilled, 20.2 ° C

Notes on test: Sample tested as received from client.
** 0.05mm size interpolated from hydrometer readings taken after 21min, 1hour and 2 hours.

NATA **Accredited for compliance with ISO/IEC 17025 - Testing**

Tested By: MA   Date Tested: 24/04/2017

APPROVED SIGNATORY

Mark Ashover 27/04/2017

Appendix B Environmental Impacts

B.1 Aboriginal Heritage

Aboriginal Heritage Registered Sites				
Site ID	Site name	Location (Co-ordinates) Easting	Northing	Site Feature
21-1-0097	DF 8	376170	6656260	Artefact : 7, Shell : 1
21-1-0098	DF 4	375610	6655710	Modified Tree (Carved or Scarred) : 2
21-1-0099	DF 3	375830	6655300	Artefact : 1
21-1-0100	DF TSR 2	374940	6655530	Artefact : 50
21-1-0101	Daisy Flat 7	376410	6656300	Modified Tree (Carved or Scarred) : 1
21-1-0106	DF 5	375680	6655690	Artefact : 2
21-1-0107	DF 6	376340	6655540	Modified Tree (Carved or Scarred) : 1
21-1-0111	DF 1	375070	6655900	Modified Tree (Carved or Scarred) : 1
21-1-0089	MDL1	370890	6655490	Modified Tree (Carved or Scarred) : 2

B.2 European Heritage

European Heritage				
Item	Description	Co-ordinates	HeritageListing Status	Location
Guyra Railway Precinct	Railway Platform/ Station	30°13'53.52"S, 151°40'15.51"E	Heritage Act - s.170 NSW State agency heritage register	7 Lagoon Rd Guyra
Office - Former W.A. Robert's Drapery	Commercial Office/Building	30°13'3.60"S, 151°40'18.09"E	Local Government	100 Bradley Street Guyra
Former Coach Road	Fomer roadway		Local Government (Item I097)	East of Guyra town ship

B.3 Threatened Flora and Fauna

OEH Search					
Species	Type	Number of Sightings in Area	TSC Act	EPBC Act	Approximate Co-ordinates
Yellow Spotted Tree Frog (*Litoria castanea)*	Amphibian	19	Critically Endangered	Endangered	30°11'0.91"S, 151°41'13.21"E 30°13'25.33"S, 151°39'18.08"E 30°16'58.73"S, 151°40'58.89"E 30°17'50.32"S, 151°39'55.05"E
Magpie Goose (*Anseranas semipalmata*)	Bird	1	Vulnerable		30°17'0.48"S, 151°41'5.10"
Brolga (*Grus rubicunda*)	Bird	1	Vulnerable		30°13'40.04"S, 151°39'57.27"E
Brown Treecreeper (eastern subspecies) (*Climacteris picumnus victoriae*)	Bird	1	Vulnerable		30° 9'49.72"S, 151°40'5.84"E
Australian Painted Snipe (*Rostratula australis)*	Bird	4	Endangered	Endangered	30°14'15.07"S, 151°39'43.73"E 30°13'24.66"S, 151°39'56.36"E 30°13'3.99"S, 151°39'50.24"E
Spotted-tailed Quoll	Mammal	1	Vulneralbe	Endanagered	30°11'14.01"S, 151°40'44.75"E

OEH Search					
Species	**Type**	**Number of Sightings in Area**	**TSC Act**	**EPBC Act**	**Approximate Co-ordinates**
(*Dasyurus maculatus*)					
Koala (*Phascolarctos cinereus*)	Mammal	2	Vulnerable	Vulneralbe	30° 9'55.61"S, 151°41'8.50"E 30°16'56.98"S, 151°39'27.41"E
Callistemon pungens	Plant	2		Vulneralbe	30°12'55.25"S, 151°40'2.87"E
Small Snake Orchid (^*Diuris pedunculata*)	Plant	12	Endangered	Endangered	30°12'6.66"S, 151°41'59.31"E
Bluegrass (*Dichanthium setosum*)	Plant	1	Vulnerable	Vulnerable	30°12'55.25"S, 151°40'2.87"E
Australian Toadflax (*Thesium australe*)	Plant	1	Vulnerable	Vulnerable	30°16'55.42"S, 151°41'4.21"E

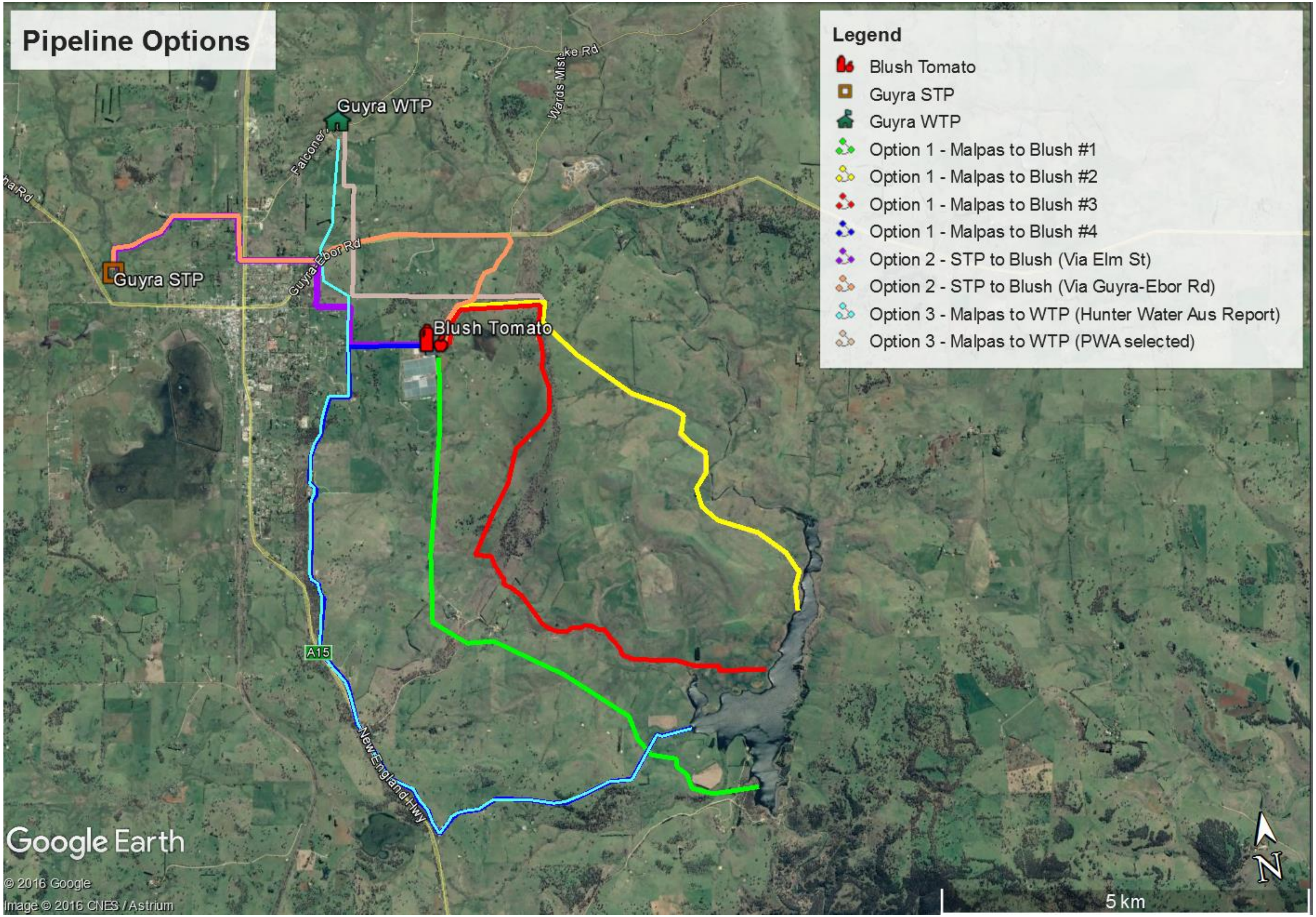
TSC Act = Threatened Species Conservation Act 1995

EPBC Act - Environment Protection and Biodiversity Conservation Act 1999

EPBC Act Protected Matters Search					
Species	**Type**	**Number of Sightings in Area**	**TSC Act**	**EPBC Act**	**Type of Presence**
Regent Honeyeater (*Anthochaera phrygia*)	Bird	n/a	Critically Endangered	Critically Endangered	Foraging, feeding or related behaviour may occur within area
Curlew Sandpiper (*Calidris ferruginea*)	Bird	n/a	Endangered	Critically Endangered	Species or species habitat known to occur within area
Red Goshawk (*Erythrotriorchis radiatus*)	Bird	n/a	Critically Endangered	Vulnerable	Species or species habitat may occur within area
Painted Honeyeater (*Grantiella picta)*	Bird	n/a	Vulnerable	Vulnerable	Species or species habitat may occur within area
Swift Parrot (*Lathamus discolor*)	Bird	n/a	Endangered	Critically Endangered	Species or species habitat may occur within area
Murray Cod (*Maccullochella peelii*)	Fish	n/a		Vulnerable	Species or species habitat may occur within area
Booroolong Frog (*Litoria booroolongensis*)	Frog	n/a	Endangered	Endangered	Species or species habitat may occur within area

EPBC Act Protected Matters Search					
Species	**Type**	**Number of Sightings in Area**	**TSC Act**	**EPBC Act**	**Type of Presence**
Corben's Long-eared Bat, South-eastern Long-eared bat (*Nyctophilus corbeni)*	Mammal	n/a	Vulnerable	Vulnerable	Species or species habitat may occur within area
Large-eared Pied Bat, Large Pied Bat (*Chalinolobus dwyeri*)	Mammal	n/a	Vulnerable	Vulnerable	Species or species habitat likely to occur within area
Grey-headed Flying-fox (*Pteropus poliocephalus*)	Mammal	n/a	Vulnerable	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Greater Glider (*Petauroides volans)*	Mammal	n/a		Vulneralbe	Species or species habitat may occur in area
Brush-tailed Rock-wallaby (*Petrogale penicillata)*	Mammal	n/a	Endangered	Vulnerable	Species or species habitat may occur within area
Narrow-leaved Peppermint, Narrow-leaved Black Peppermint (*Eucalyptus nicholii*)	Plant	n/a	Vulnerable	Vulnerable	Species or species habitat likely to occur within area
Blackbutt Candlebark (*Eucalyptus rubida subsp. Barbigerorum*)	Plant	n/a	Vulnerable	Vulnerable	Species or species habitat likely to occur within area
Tall Velvet Sea-berry (*Haloragis exalata subsp. Velutina)*	Plant	n/a	Vulnerable	Vulnerable	Species or species habitat may occur within area
Omeo Stork's-bill (*Pelargonium sp. Striatellum)*	Plant	n/a	Endangered	Endangered	Species or species habitat may occur within area
Tarengo Leek Orchid (*Prasophyllum petilum)*	Plant	n/a	Endangered	Endangered	Species or species habitat may occur within area
a leek-orchid (*Prasophyllum sp. Wybong)*	Plant	n/a		Critically Endangered	Species or species habitat may occur within area

Appendix C Pipeline Route Options



Appendix Figure C.1: Guyra Pipeline Summary

Level 13 McKell Building
2-24 Rawson Place
Sydney NSW 2000

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Appendix B Cost Benefit Analysis Details

Cost Benefit Analysis – 'Water Transfer from Malpas Dam to Guyra WTP' Option

	COSTS			BENEFITS					
Year	Capital Cost	Additional OMA Cost	Total Costs	Water Security/ Avoided Water restrictions	Flow-on economic benefit	Additional Water Resource availability	Residual value of Assets	Total Benefits	Net benefits
2017	9,482,519	-	9,482,519					-	- 9,482,519
2018		50,091	50,091	528,822	1,223,800	23,200		1,775,822	1,725,731
2019		50,091	50,091	531,501	1,223,800	23,200		1,778,501	1,728,410
2020		50,091	50,091	534,180	1,223,800	23,200		1,781,180	1,731,089
2021		50,091	50,091	536,859	1,223,800	23,200		1,783,859	1,733,769
2022		50,091	50,091	539,538	1,223,800	23,200		1,786,538	1,736,448
2023		140,051	140,051	658,162	1,223,800	23,200		1,905,162	1,765,111
2024		140,856	140,856	661,202	1,223,800	23,200		1,908,202	1,767,346
2025		141,661	141,661	664,242	1,223,800	23,200		1,911,242	1,769,580
2026		142,467	142,467	667,282	1,223,800	23,200		1,914,282	1,771,815
2027		143,272	143,272	670,322	1,223,800	23,200		1,917,322	1,774,050
2028		50,091	50,091	555,613	1,223,800	23,200		1,802,613	1,752,522
2029		50,091	50,091	558,292	1,223,800	23,200		1,805,292	1,755,201
2030		50,091	50,091	560,971	1,223,800	23,200		1,807,971	1,757,880
2031		50,091	50,091	563,650	1,223,800	23,200		1,810,650	1,760,559
2032		50,091	50,091	566,329	1,223,800	23,200		1,813,329	1,763,238
2033		148,104	148,104	688,562	1,223,800	23,200		1,935,562	1,787,459
2034		148,909	148,909	691,602	1,223,800	23,200		1,938,602	1,789,693
2035		149,714	149,714	694,642	1,223,800	23,200		1,941,642	1,791,928
2036		150,519	150,519	697,682	1,223,800	23,200		1,944,682	1,794,163
2037		151,325	151,325	700,722	1,223,800	23,200	5,689,511	7,637,234	7,485,909
							BCR	IRR	NPV/I
	PV of Costs @ 7% p.a.		$10,428,448	PV of Benefits @ 7% p.a.		$21,010,602	2.01	18.1%	$1.90
	PV of Costs @ 4% p.a.		$10,744,209	PV of Benefits @ 4% p.a.		$27,753,541	2.58		$3.05
	PV of Costs @ 10% p.a.		$10,214,415	PV of Benefits @ 10% p.a.		$16,496,255	1.61		$1.13

Cost Benefit Analysis – 'Business As Usual/ Do Nothing' Option

	COSTS				BENEFITS				
Year	Capital Cost	Loss of amenity due to water restrictions	Import of Water to meet dry year demand	Total Costs	Opportunity cost of avoided capital works	Additional Water Resource availability	Residual value of Assets	Total Benefits	Net benefits
2017				-	9,482,519			9,482,519	9,482,519
2018		528,822	-	528,822				-	- 528,822
2019		531,501	-	531,501				-	- 531,501
2020		534,180	-	534,180				-	- 534,180
2021		536,859	-	536,859				-	- 536,859
2022		539,538	-	539,538				-	- 539,538
2023		658,162	487,269	1,145,430				-	- 1,145,430
2024		661,202	491,631	1,152,832				-	- 1,152,832
2025		664,242	495,992	1,160,234				-	- 1,160,234
2026		667,282	500,354	1,167,636				-	- 1,167,636
2027		670,322	504,716	1,175,038				-	- 1,175,038
2028		555,613	-	555,613				-	- 555,613
2029		558,292	-	558,292				-	- 558,292
2030		560,971	-	560,971				-	- 560,971
2031		563,650	-	563,650				-	- 563,650
2032		566,329	-	566,329				-	- 566,329
2033		688,562	530,887	1,219,449				-	- 1,219,449
2034		691,602	535,249	1,226,851				-	- 1,226,851
2035		694,642	539,611	1,234,253				-	- 1,234,253
2036		697,682	543,973	1,241,655				-	- 1,241,655
2037		700,722	548,334	1,249,057			-	-	- 1,249,057
								BCR	IRR
	PV of Costs @ 7% p.a.		$8,578,882		PV of Benefits @ 7% p.a.		$9,482,519	1.11	5.9%
	PV of Costs @ 4% p.a.		$11,356,447		PV of Benefits @ 4% p.a.		$9,482,519	0.83	
	PV of Costs @ 10% p.a.		$6,688,575		PV of Benefits @ 10% p.a.		$9,482,519	1.42	

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