University of Southern Queensland
Faculty of Engineering and Surveying

Options for the Replacement of Aging Bridges under Local Authority Control in Rural Areas of Queensland

A dissertation submitted by

Tyronne Meredith

In fulfilment of the requirements of

Courses ENG4111 and ENG4112 Research Project

Towards the degree of

Bachelor of Engineering (Civil)

Submitted: October 2011

Abstract

There are a significant amount of bridges under local government control currently in a state of severe degradation. To aid in rectifying this problem an analysis framework has been developed to enable rural local governments to determine appropriate bridge infrastructure replacement and repair options which satisfy the economic, social and environmental requirements of the organisation and of the community it serves.

The framework utilises a structured analysis process which enables both the most appropriate position for the crossing and the most appropriate form of the crossing to be determined. The analysis process uses a numerical system to rate the performance of several options relative to the performance of the existing situation. The performance of the option is determined by considering a set of criteria developed to assess the economic, social and environmental characteristics of the proposal. The relative importance of each criterion to the goals of the organisation is also taken into consideration in the performance appraisal. To enable a thorough analysis each option is considered through three numerical scores representing the economic, social and environmental performance.

Four case studies within the North Burnett Regional Council area have been developed to demonstrate the appropriate use of the framework within its intended environment. The framework developed provides an accurate analysis tool conducive to the time and resource constraints typical of rural local government engineering.

University of Southern Queensland

Faculty of Engineering and Surveying

ENG4111 Research Project Part 1 & ENG4112 Research Project Part 2

Limitations of Use

Professor Frank Bullen

Dean

Faculty of Engineering and Surveying

CERTIFICATION

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

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

Student Name Tyronne Meredith
Student Number: 0050086836

Signature

26th October 2011
Date

Acknowledgements

I would like to thank my supervisor Professor Ron Ayers for his guidance and help throughout the last year. I would also like to thank my family and friends for their help and support to finish this dissertation. I would also like to thank the staff of North Burnett Regional Council who gave their time and effort to provide me with assistance.

Contents

List of Figures

List of Tables

1 Introduction

There is an expectation in the current society that people should be able to travel safely, reliably and economically from their origin to their destination. It is the goal of any organisation tasked with controlling a transport network to meet this goal in an economically, environmentally and socially sustainable way. As bridges are an important component of any land transport network it is essential that any new or existing bridge does not compromise this fundamental goal. It is often difficult within the financial, time and personnel constraints of rural local governments to appropriately analyse the effects which a new or existing bridge has on this goal. This dissertation looks at developing a feasible procedure for this analysis through investigation of case studies within the North Burnett Regional Council area. A list of generic replacement and repair options commonly utilised has been generated. Each of these options has been assessed against criteria deemed necessary for meeting the goals of the organisation. The results of this assessment have been used to formulate a simple ranking system to establish the most appropriate option in each unique situation. It is envisaged that the procedure developed in this dissertation will provide a framework for rural local government authorities to undertake a thorough analysis of the replacement and repair options available to ensure an outcome is reached which satisfies the expectations of the community and the goals of the organisation. Appendix A provides an overview of the project specification.

1.1 North Burnett Regional Council

The North Burnett Region Council was formed in 2008 through the amalgamation of the six existing shires of Gayndah, Mundubbera, Eidsvold, Monto, Biggenden and Perry. As is shown by figure one the North Burnett Region is located slightly north of the densely populated South East corner of Queensland and slightly west of the east coast.

Figure 1

Figure one – Location of the North Burnett Region within Queensland (Department of Infrastructure and Planning 2009)

Figure two shows that the approximate council area of 19 700km^2 is enclosed between Gladstone Regional Council to the north, Banana Regional Council to the northwest, Western Downs Regional Council to the west, South Burnett Regional Council and Gympie Regional Council to the south, and Fraser Coast Regional Council and Bundaberg Regional Council to the east. The township of Gayndah, one of the largest population localities in the region is located approximately 300km north of Toowoomba and approximately 360km north west of Brisbane.

Figure 2

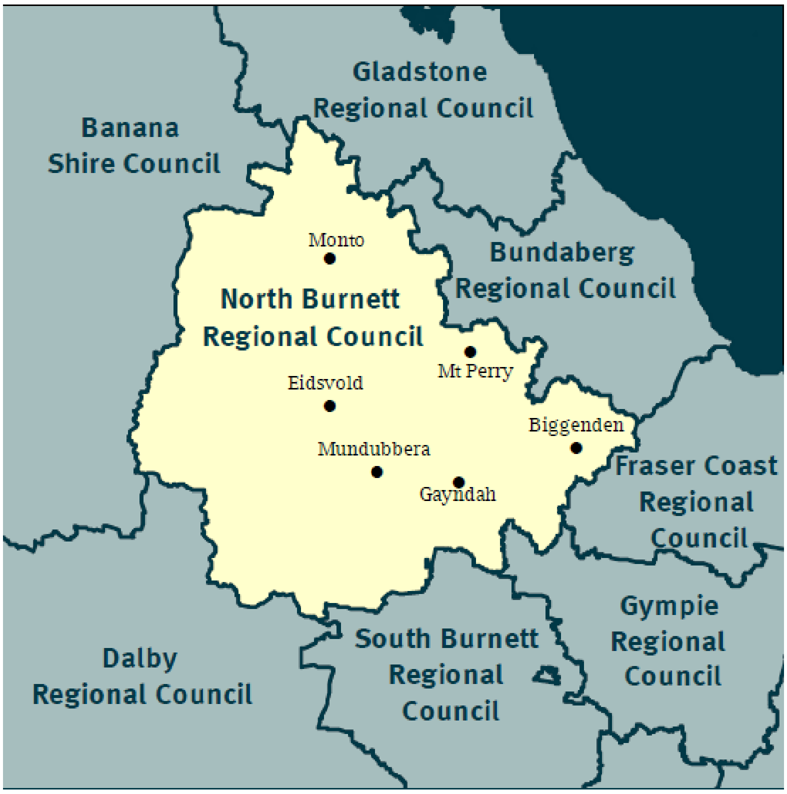


Figure two: North Burnett Regional Council and its surrounds (Department of Infrastructure and Planning 2009)

The main water catchment in the area is the Burnett Catchment with the predominant river system being the Burnett River. Figure three shows a detailed map of the Burnett Catchment.

Figure 3

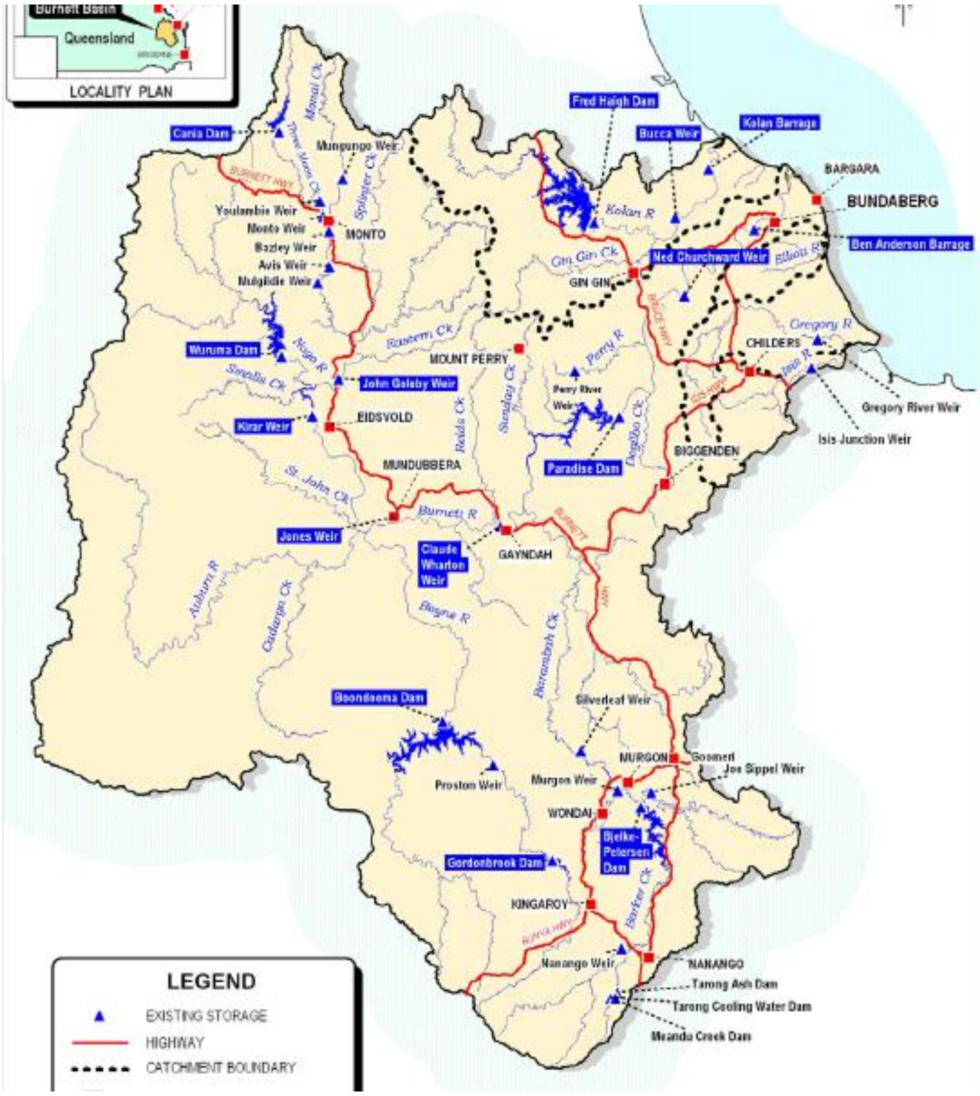


Figure Three: The Burnett Catchment (Department of Environment and Resource Management 2010)

As can be seen from figure three the main tributaries of the Burnett River are the Nogo, Boyne and Auburn Rivers as well as Three Moon, Reid and Barambah Creeks. The area is predominantly rural with beef cattle being the major industry across the region. Some of the other industries present within the area include citrus growing in the Gayndah and Mundubbera areas, mango and grapes in the Mundubbera area, dairying and broad acre cropping in the Biggenden and Monto areas, logging in the Eidsvold, Monto, Perry and Mundubbera areas and gold mining in the Perry region.

1.2 History of Bridges in Australia

When Australia was settled in 1788 bridges became an essential component of the transport network to allow settlement to continue further inland (Australian Academy of Technological Sciences and Engineering 1988). According to the South Australian Government (n.d), the first bridges built where directly square over the waterway and had sharp exit and entry points to minimise the span which in turn minimises the material and labour requirements of the job. According to Australian Academy of Technological Sciences and Engineering (1988) the unique flooding behaviour of Australian Rivers meant that traditional bridge designs had to be modified to successfully suit the conditions. Some of the initial designs utilised by Australian bridge builders included the use of masonry arches and cast iron. This particular Australian trend was not followed throughout Queensland however as O'Connor C (1985) suggests that the earliest Queensland bridges were made of timber. He suggests that the lack of stone and brick bridge infrastructure is a notable feature in the history of Queensland bridges. O'Connor (1985) also suggests that as well as the significant amount of timber girder and timber truss bridges, there was also some metal girder bridges built around the late 1800's and that Queensland is renowned for its use of concrete in early bridge building. Australian Academy of Technological Sciences and Engineering (1988) suggests that simple timber construction was heavily utilised due to quick and cheap construction and the readily available materials. According to Taplin & Fenwick (2009), simple timber construction, such as timber girder bridges, was the most common form of timber bridge constructed in Australia due mainly to it being a cheaper form of construction in comparison to wrought iron and steel, the large amounts of good timber available, the great durability of the species used and because of the local availability of the timber.

2 Literature Review

2.1 Introduction

The purpose of this section is to review and analyse the findings and methodologies of researchers who have previously undertaken work in this field. The findings from this review will form the basis of the methodology for this investigation.

The focus of the review began with identifying the scope of the issue regarding aging bridge infrastructure in Australia. The focus then moved onto the current options available for the replacement and repair of the bridge infrastructure. From there the materials used in these methods were explored to gain a better understanding of the infrastructure. Finally, the focus then shifted to the forms of analysis used to select replacement and repair options and the criteria used within these analyses.

2.2 Aging bridge infrastructure

The current condition of Australia's bridge infrastructure is a topic area which is widely explored in both engineering and public media. A report published by the Institute of Public Works Engineering Australia in 2008 (The Sydney Morning Herald 2010) found that 27% of timber bridges in New South Wales were in a poor state and that another 52% were in a fair condition. An earlier survey through Australian Road Research Board (Giummarra, G(ed), 2000) showed that more 50% of Australian bridges under local control were in a fair or poor state. A report by the American Society of Civil Engineers (ABC News 2007) shows that the issue of aging bridges and resulting structural deficiency is not only an Australian problem with the data suggesting that 27% of America's bridges are either structurally deficient or functionally obsolete in the period 2000 -2003.

2.3 Bridge Management Systems

To deal with the aging issue many authorities are using a bridge management system. According to Giummarra(ed) (2000), 'the goal of a bridge asset management system is to minimise structural deterioration and optimise functional levels of service of the bridge stock within funding constraints.' Coe (n.d) supports this view while placing particular emphasis on the idea of levels of service. Coe (n.d) states that one purpose of the plan is to identify the required level of service by bringing together the vision of the local authority and the appropriate legislation. The author deepens his assessment of bridge management plans insisting that in addition to discussing the prevention of structural deterioration through maintenance, the bridge management plan should also discuss the competing demands on resources. Hearn et al (n.d) puts forth a broader view of bridge management systems mentioning that it is a combination of disciplines including structural engineering, operations research, economics, planning and information technology. Interestingly however, Hearn et al (n.d) does not mention the idea of pertaining bridge infrastructure to a defined level of service.

2.4 Bridge Replacement Options

There is currently a wide range of possible replacement options available for aging and deteriorating bridge infrastructure. In a comprehensive study conducted by Murray (n.d), he states that it is essential to first consider repair options before deciding on more drastic replacement options. In this form he has suggested that an analysis be undertaken considering the costs associated with repair of the relevant structures.

2.4.1 Repair

According to D Manderson (pers.comms,2011), the most common problems found in inspecting timber bridges is rotted or split members and members with large hollow pipes in the cross section. This generalised summary is in agreement with the findings of Murray's (n.d) investigation. D Manderson (pers.comms, 2011) goes onto suggest that currently within the North Burnett region these problems, when found in timber bridges, are rectified through either replacement of the member for members in the superstructure, splicing of piles, or through the application of a steel band over the member to prevent further splitting. He also suggests that timber members are generally used in the replacement. Murray (n.d) however suggests several other possible repair options. He suggests that instead of replacing the deck with a conventional timber deck, a cast in situ concrete deck could be used. Another different alternative suggested by Murray (n.d) is the use of fibre composite components to replace deteriorated girders and corbels. He also suggests that new concrete piers could be constructed adjacent to the bridge and steel beams used to transfer the load from the bridge to the pier.

2.4.2 Superstructure Replacement

The next level of repair suggested by Murray (n.d) is the replacement of the entire existing superstructure. For this form of repair to be undertaken it is imperative that the existing substructure be in an appropriate condition. The options put forward by Murray (n.d) in replacing the superstructure include the RTA Doolan Deck, the CSR Humes Humedeck, the Rocla M-Lock and a fibre composite bridge deck. Another option put forward by Carter (2009) for the replacement of a superstructure is a stress laminated timber deck.

2.4.2.1 Doolan Deck

According to Carter (2009), the Doolan Deck is a relatively recent form of a timber – concrete composite bridge superstructure. Steel plates and coach screws attached to the girder form a bond between the girder and the concrete deck which is pored over it. The girder is also cast into the concrete at the support. The concrete deck is then capable of preventing moisture ingress into the timber which is a typical cause of deterioration.

2.4.2.2 Humedeck

According to Humes (2010) the Humedeck is a reinforced concrete modular bridge deck. In this system the deck and girders are cast into one unit. A typical cross section of the unit is shown below in figure four. This form of cross section is consistent with what Carter 2009 would describe as a T – Beam system.

Figure 4

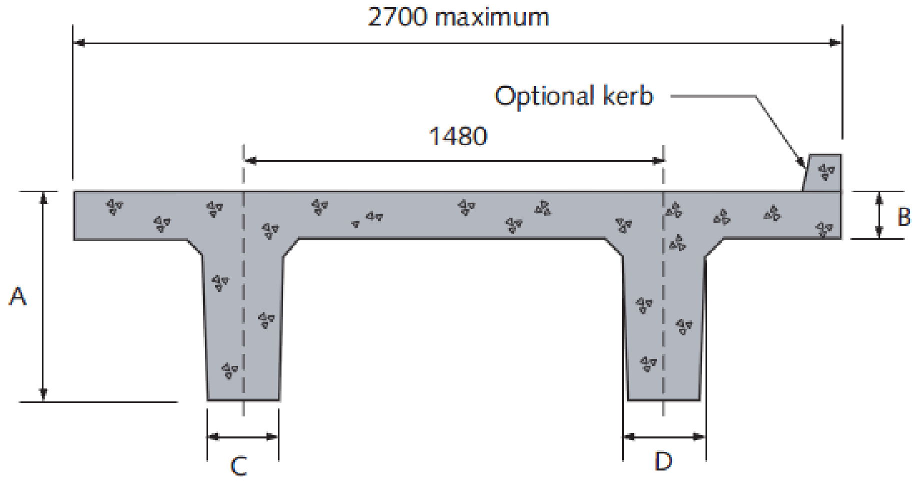


Figure 4: Typical cross section of a Humedeck. (Humes, 2010)

2.4.2.3 M – Lock

Similar to the Humedeck system, the M-Lock system is also a precast modular bridge deck. The M-Lock utilises planks in the form of inverted U-beams as described by Carter 2009. According to Rocla (2011), to allow for greater traffic movements the planks used to form the cross section can be transversely post tensioned. A typical M-Lock cross section is shown in figure five.

Figure 5

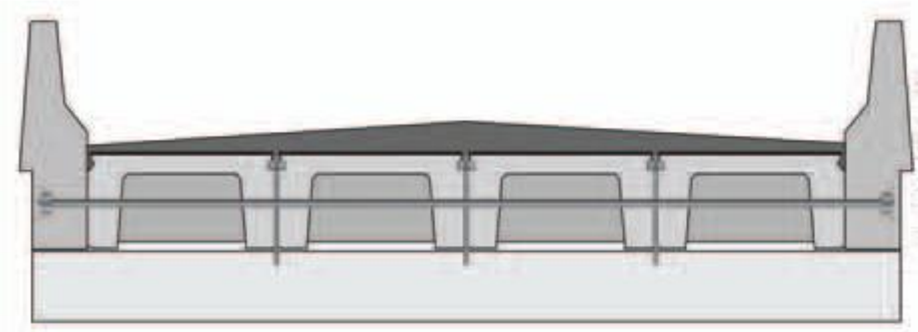


Figure 5: A typical M-Lock cross section complete with transverse post tensioning rod to allow for greater traffic flow. (Rocla, 2011)

2.4.3 Replacement

There are also a number of replacement alternatives which involve replacing the bridge with an entirely new structure. Murray (n.d) suggests that one possible alternative is to replace the bridge with a culvert system. He also suggests that whilst the substructure used depends on the geological conditions on site, some of the possible superstructure replacement components include the RTA Doolan Deck, the Humes Humedeck, the Rocla M – Lock, DMR Deck unit, Super Tee girders, Standard DMR I girders and fibre composite bridge decking. In a report commissioned by the now defunct Monto Shire Council (part of North Burnett Regional Council) to determine replacements for several timber bridges, Bell (2006) also suggests the majority of the systems put forth by Murray (n.d) as possible replacements. He also goes on to add that steel girder bridges with either concrete or plywood decking could also be considered as options. In addition to the idea of not replacing the existing bridge with a new bridge structure, Bell (2006) suggests that a low level floodway crossing be considered.

2.4.3.1 Culvert

Both Murray (n.d) and Bell (2006) suggest that both concrete and steel culverts should be considered as possible replacement options. According to Carter 2009, culverts are typically used where the waterway area is not sufficient to require a bridge, the road formation height above the natural surface is not sufficient to allow for a bridge and where a number of openings are required with a low flow height.

2.4.3.1.1 Concrete Culverts

The two types of concrete culverts which will be investigated are the concrete pipe culvert and the concrete box culvert. According to Humes (2010) box culverts are ideal in situations where wide flow and low hydraulic heads are prevalent. According to Rocla the largest culverts commonly available in Queensland have a flow area which is 3.6m wide by 3.6m high. However they also suggest that custom made culverts can be specially designed. They also suggest that linking slabs can be used between two adjacent culverts which reduces the number of culverts needed to span a crossing. Another suggestion is that precast headwalls can also be produced. Humes notes that 3.6m by 3.6m culverts are the largest of their range of culverts.

According to Rocla (2011) there are several different types of concrete pipe available. The ones considered for bridge replacement differ mainly in the connection detail. The two broad classifications are Rubber Ring Jointed pipes and Flush Joint pipes. According to Rocla (2011) the Flush Jointed pipes are convenient where an amount of infiltration and exfiltration has been allowed for and where significant ground movement is not expected. Humes (2010) recommends that this type of pipe, with an external band, be used in most culvert situations. Rocla (2011) suggests that the rubber ring jointed pipe allows for ground movement and also provides a watertight seal at the joint to minimise external water transfer. Humes (2010) suggests that this type of pipe should be used in situations where ground movement is expected and where the flow will have a large head and outlet conditions control. According to Rocla (2011) the largest size pipe in both categories which they commonly produce has an internal diameter of 3m. Humes however, produce larger pipes with an internal diameter of 3.6m in the same class as the Rocla 3m pipe.

2.4.3.1.2 Steel Culverts

The steel culverts being considered in this investigation include steel arches and steel pipes. According to Atlantic Civil (2011) corrugated steel pipes have great strength, flexibility and have good performance properties. They are also significantly lighter than similar sized concrete pipes. According to Humes (2010) the largest pipe which they commonly produce has a diameter of 5.1m. Both Humes (2010) and Atlantic Civil (2011) suggest that the pipes can be produced on site which reduces freighting costs and enables unique variations to be undertaken. Atlantic Civil (2011) also suggests that performance coatings can be added to steel culverts to increase their service life. The coatings which Atlantic Civil (2011) discussed include galvanised, aluminised type two and polymer laminated. Providing the in situ conditions are within certain limits, Atlantic Civil (2011) suggests that the galvanised coating, which is the standard coating, can provide a product with a service life of 50 years. With an aluminised type two coating this service life is expected to extend to 75 years and with a polymer laminate coating to 100+ years.

2.4.3.2 Humedeck and M-Lock

Both the Humedeck and the M-Lock system have been discussed previously in the context of replacing a superstructure. They can however also be used as a complete replacement system. Both Rocla (2011) and Humes (2010) suggest that precast headstock and abutment units are available which attach to concrete piles and provide a substructure for the system.

2.4.3.3 DMR Deck Units

According to Murray (n.d) the DMR Deck Units are a precast prestressed voided system. Murray (n.d) suggests that these units are placed adjacently to form the cross section and then either transversely stressed or has an in situ slab poured over them. Carter (2009) suggests that such units can also be tied together in short spans through the use of reinforcing steel. Carter (2009) also suggests that for shorter spans, solid precast prestressed systems can be used. A typical cross section of a precast prestressed voided system is shown below in figure six.

Figure 6

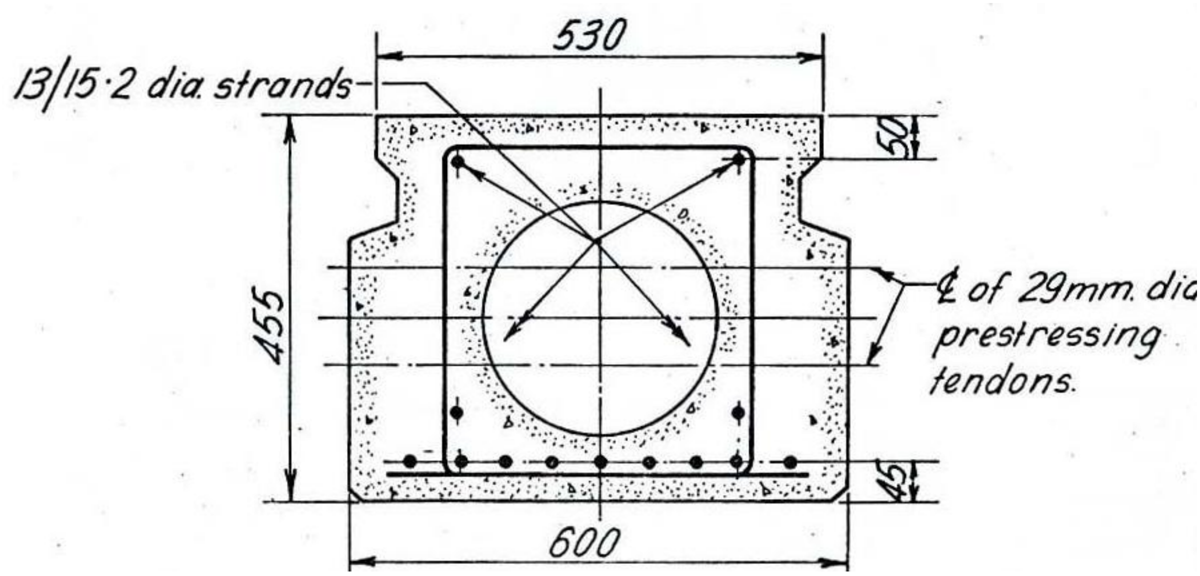


Figure six: A typical precast prestressed voided plank. The dimensions in this figure are specific to only one design. (Carter, 2009)

2.4.3.4 Super Tee Girder

According to Structural Concrete Industries (n.d) a Super Tee girder is a prestressed, pretensioned and precast concrete bridge girder. Structural Concrete Industries (n.d) also suggest that the sections come in depths between 750mm and 1800mm and are either open topped or closed topped. Murray (n.d) suggests that Super Tee girders are only economical for span of 25 to 35m. He suggests that these girders are generally used where central piers cannot be placed. Carter (2009) suggests that in situ concrete slabs are generally pored over the top flange of tee girders to form the deck. They also suggest that transverse beams can be used at regular centres.

2.4.3.5 I Girders

According to Carter (2009) concrete I girders are typically precast and pre tensioned members. However they also suggest that post tensioned members can be used. Murray (n.d) suggests that these girders are generally used for longer spans. This is reinforced by Carter (2009) who suggests that they are generally used to provide spans of between 20 – 35m. Carter (2009) also suggests that either an in situ concrete slab is poured over girders or precast slabs are used for a deck.

2.4.4 Timber Bridges

Although not generally currently considered as a viable replacement option, timber beam bridges form the majority of the bridge infrastructure of North Burnett Regional Council. It is therefore essential to review and understand the features of this form of construction.

2.4.4.1 Timber Beam Bridges

According to the Road Transport Authority of New South Wales (2008), timber beam bridges are one of the simplest forms of bridge structure. Figure seven below shows the typical features of a timber girder bridge in side section.

Figure 7

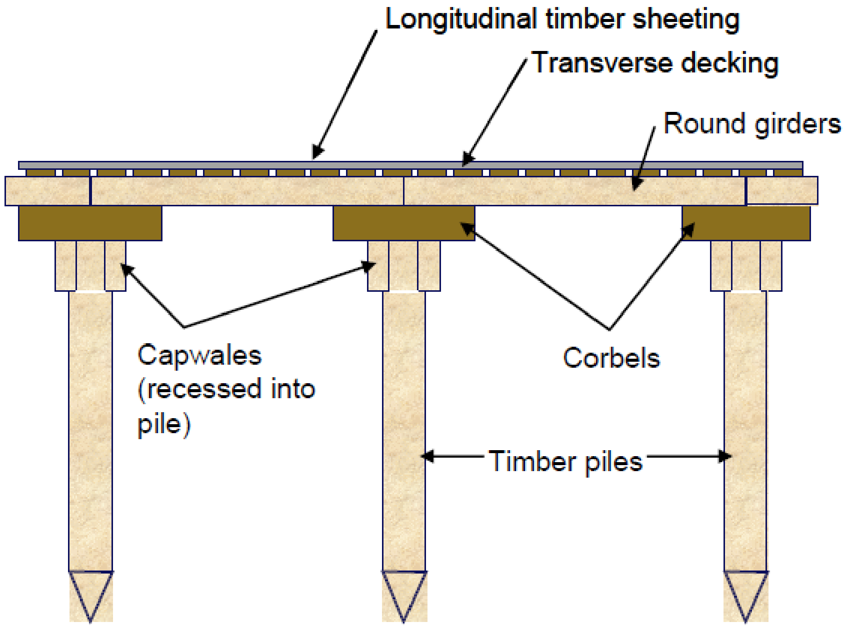


Figure 7: A typical side view of a timber beam bridge. (Carter 2009)

Components

Timber Sheeting

According to Road Transport Authority of New South Wales (2008) this is often the top layer usually consisting of 50-75mm boards running longitudinally. This is most often laid on timber decking.

Timber Decking

According to Road Transport Authority of New South Wales (2008) this is usually approximately 125mm deep by 200-250mm wide closely spaced timber planks laid in a transverse direction.

Timber Girders

According to Carter (2009) these members generally consist of round timber logs. Road Transport Authority of New South Wales (2008) suggests that girders are generally supported over the piers by other round timber members called corbels. Carter (2009) suggests that there are certain criteria which must be adhered to when selecting timber girders and corbels. Firstly there are limits on the defects allowable in the girder. These limits control knots, splits, straightness and taper of the timber.

The diameter is another important requirement with the nominal diameter generally being 450mm. The final criterion is the species, with only certain species meeting the required specifications. Carter (2009) suggests that the top and bottom of girders are generally faced to increase the bearing area for better load transition. Facing involves cutting the timber to create a horizontal surface. Figure eight shows how facing is applied in the cross section of the deck, girder, corbel and cap whale assembly.

Figure 8

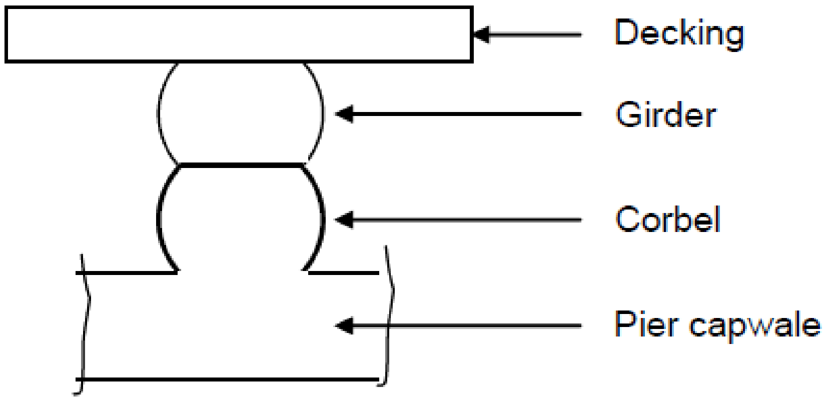


Figure eight: Typical facing of timber girders and corbels (Road Transport Authority of New South Wales, 2008).

Another important feature of timber girders are snipes. According to Carter (2009) snipes, or haunches, are sections cut from the girders to provide a consistent depth at the support. This action allows for the natural variability in the diameter of the timber log.

Bolting Planks

Another feature of the superstructure detailed by Carter (2009) is a longitudinal bolting plank. These longitudinal planks run between certain girders and allow for improved load distribution.

2.4.5 Materials

2.4.5.1 Timber

As was mentioned earlier, timber was used extensively in Australia due to the abundance of high quality timber. According to Crossman and Simm (2004), some of the other features of timber which see it used in river and coastal applications include its high tolerance of short duration loads, its attractive appearance, its high strength to weight ratio and its good workability. According to the Road Transport Authority of New South Wales (2008) some of the short comings of timber bridges include a low strength when considering modern traffic, high maintenance costs, design flaws enabling water penetration of members and the declining quality of replacement members.

According to Crossman and Simm (2004), some of the factors which can affect the service life of timber structures include the exposure level, the properties of the materials being used, the quality of the design and construction process and the monitoring and maintenance program implemented.

2.4.5.2 Concrete

According to Bridgeman (2000) some of the properties of concrete which make it ideal for bridge construction include:

- Ability to be made in any shape due to its workability in the plastic state
- High compressive strength
- Resistance to natural attacks
- High fatigue strength under heavy traffic loads
- Requires little maintenance considering appropriate design and construction

They also list the following disadvantages:

- Low tensile strength – this however can be combated with use of reinforcement rods and prestressing
- Dull surface – can show stains, irregular streaks and pores

As can be imagined one of the most important properties of concrete for bridge construction is durability. According to the Cement and Concrete Association of Australia (2002) the degradation of concrete is usually due to the following:

- Reinforcement corrosion – Concrete usually protects steel by covering it in an alkaline environment which prevents corrosion and by limiting the moisture and oxygen access to the steel. This can sometimes be overcome by carbonation which reduces alkalinity which enables corrosion more readily. Chlorides can also permeate concrete which more readily enables corrosion and which also accelerates the process
- Acid – Most common acids attack cement paste. Acidic water is not usually an issue as attack is only slight except in some circumstances, such as when concrete is exposed to running acidic water for an extended length of time, where more significant degradation can occur.
- Soft water – Soft water leaches out calcium bearing compounds from the paste. This leaves concrete with a lower strength
- Sulfate – The most common sulfate attack is from gypsum which can lead to disintegration of concrete
- Seawater – Not usually a great effect when fully immersed except when reinforcement corrodes. Partial immersion however can be damaging due to crystallisation of salts
- Abrasion resistance – In hydraulic structures wear is quite often due to abrasive materials in water
- Higher compressive strengths can generally mean greater resistance
- Freeze thaw resistance – Repeated freeze thaw cycles can cause disintegration

2.4.5.3 Steel

According to Ibrahim 2002, the primary benefits of steel as a structural building material include:

- High Strength
- Uniformity – constant properties throughout section

- Elasticity – adherence to Hooke's Law
- High ductility
- Good toughness

In addition to above general steel qualities the World Steel Association (n.d) presents some other benefits more specifically resulting from the use of steel in bridge works. These are discussed below:

- High strength to weight ratio – this allow easier transportation and other associated construction benefits.
- High Quality – prefabricated under controlled conditions resulting in high quality
- Speed of construction – allows for faster on site construction time due to prefabrication
- Versatile – can be implemented into a wide variety of construction processes
- Durable – Long life expectancy
- Aesthetics – Can be designed to have extensive aesthetic appeal

Ibrahim (2002) also suggests that some of the disadvantages of steel as a structural building material include:

- Maintenance cost – high maintenance requirements
- Buckling susceptibility – high susceptibility
- Fatigue – poor fatigue performance

2.4.6 Maintenance

2.4.6.1 General

McGuire (2009) suggests that the regular maintenance which should be undertaken on all bridges include:

- Clearing obstructions to view
- Localised road surface repair
- Cleaning of drainage components
- Tightening of deck components
- Cleaning vent, weepholes and wing walls

- Removing possible fire fuel from on and around the bridge
- Filling scour holes

They also suggest that the following routine maintenance tasks be undertaken:

- Sealing concrete cracks
- Application of protective components
- Cleaning of steel or iron surfaces not cleaned by rain
- Maintenance of protective coating

2.4.6.2 Timber

McGuire (2009) suggests that in addition to the regime discussed above timber bridges should be inspected on a yearly basis and defective components should be repaired and bolts tightened.

2.4.6.3 Concrete

McGuire (2009) suggests that the most common issue affecting the durability of concrete is the corrosion of reinforcing steel. They also suggest that where a concrete substructure has been utilised the following should be inspected in addition to the general inspection mentioned above:

- Check for scour or erosion around piers
- Check for any settlement

2.4.6.4 Steel

McGuire (2009) suggests that a steel bridge should especially be inspected for the following:

- Corrosion
- Cracks
- Buckles
- Kinks
- Yielding

2.5 Project Evaluation

There are a variety of different methods available for assessing potential bridge replacement and repair options. One common strategy determined from the literature is comparing the option of maintaining the current bridge to several replacement options. The techniques of analysis differ between researchers. Coe (n.d) bases the analysis on risk analysis which he translates to an overall bridge score. The overall bridge score is then used to determine the effective life span of the bridge after repairs are undertaken. The annual depreciation costs of the repaired bridge and a new structure can then be calculated. Giummarra(ed) (2000) also incorporates risk analysis into the evaluation process. They do however also employ three other quantitative approaches into the analysis. These are basic cost estimation, Net Present Value of capital and operating costs and a benefit cost analysis. Austroads (1996) suggests that some of the economic analysis techniques which can be used in the evaluation include net present value, net present value per dollar investment, internal rate of return, first year rate of return and benefit cost ratio. They include these techniques under the title of cost benefit analysis. They also suggest that the benefit cost ratio is usually the most preferred technique when considering road projects. This would suggest it would also be an appropriate technique when considering bridge replacements in rural shires. Graham (2007) has utilised a far more in depth process when evaluating options for a particular major bridge replacement. After developing a series of available options, including repairing the existing structure, they have discarded several options on the basis of community impacts as well as on the basis of some of the basic economic analysis techniques described above including benefit – cost analysis and net present value. After this initial analysis Graham (2007) then selected a set of criteria with which to evaluate the rest of the options against. This set of criteria included relative travel efficiency, safety and access, construction impacts, aesthetics, social amenity impacts, severance impacts, local business impacts, environmental impacts, cultural heritage impacts. An obvious exclusion from this set of criteria is the economic analysis on behalf of road authority. This may be due to previous economic evaluations being undertaken. This general in depth approach is supported by

Giummarra(ed) (2000) which suggests that the general risk analysis, cost benefit analysis, net present value and cost estimation analysis which they described should be used in conjunction with a qualitative approach which includes an assessment of community impacts of each option. This suggests that the criteria suggested by Graham (2007) could be changed depending on the community expectations. This particular set of criteria was set by local residents and other key project stakeholders such as special interest groups, government representatives. The different criteria utilised by Graham (2007) are consistent with what many other sources state as being essential in project evaluation. Tsolakis et al (2005) suggests that the three most important dimensions which must be incorporated into a project evaluation are economic considerations, social considerations and environmental considerations. This view is supported by Nicolas and Journard (2010) in which they add that project reversibility is another key component in evaluation for sustainable projects. From the above review of the literature it can be seen that three of the most important criteria to consider assessing alternative bridge options are economic criteria, social criteria and environmental criteria. Therefore these three components will be explored in more detail in the following sections.

2.5.1 Alternative Projects

The first step in any cost benefit analysis is to determine a list of alternative projects. Boardman et al (2006) states that whilst there are often many possible variations of projects it is essential that a list of no more than six be selected at one time. This is due to the cognitive inability of people responsible for the project analysis to effectively focus on a large amount of options simultaneously.

In developing the set of alternatives it is essential that base case scenario be included. According to Austroads (1996) the base case can be described as maintaining the service standard of the authority. This generally means the option of not completing any new project but maintaining the asset to the accepted standard of the relevant authority. This is the project which all other options are compared against with respect to change in benefits and costs. The American Association of State Highway and Transportation Officials (2003) also support this consensus by stating that the base case scenario should be a representation of what the world will be like without the project. Boardman et al (2006) has a slightly different view on this idea of a base case scenario. They suggest that this base case scenario, which they call the counter factual, should be the case which a specific alternative will replace if deemed appropriate. Whilst they comment that this is generally the status quo suggested by Austroads (1996), there are some situations where the base case option is not a continuance of the current situation. Such a situation would arise when there is no feasible way of maintaining the current asset.

According to Austroads (1996) the list of possible projects is created by assessing the objectives at hand and formulating ideas on how to meet them. The objectives set for a particular project are generally set in terms of particular shortcomings and should reflect the higher objectives of the authority.

2.5.2 Economic Project Evaluation

As can be seen from above, the process of determining the appropriate strategy for raising the level of service of a bridge relies greatly on economic evaluation. According to Hendrickson (1998), the major steps in the process of economic evaluation in a construction project are determining different options for consideration, establishing a timeframe for analysis, estimating cash flow, specifying minimum attractive rate of return, determining the criteria for rejection or acceptance, sensitivity analysis and finally accepting or rejecting each project. University of Southern Queensland (2011) adds some important points to this description adding that any feasibility study, of which economic project evaluation is part of, must be made from the point of view of whoever owns the project. Another important point in which they add is that all potential cost and benefits in the long range forecast be included and not just those in the shorter term. Tsolakis et al (2005) suggests that the criteria which must be considered are the project costs, benefit cost analysis as well as further economic impacts.

2.5.2.1 Cost Benefit Analysis

As is suggested by Austroads (1996) many of the above economic evaluation techniques can be put under the banner of a cost benefit analysis. Boardman et al (2006) and Austroads (1996) concur that the basic methodology of completing a cost benefit analysis includes:

- Setting out a list of alternative projects
- Determining the costs and benefits of each option
- Determining the present value of each of the options
- Select and use a criteria to compare each option
- Perform a sensitivity analysis
- Make a recommendation

It can be seen that this approach is similar to the general process set out above by Hendrickson (1998).

2.5.2.2 Benefits and Costs

According to Boardman et al (2006) the first step in considering the costs and benefits of a particular project is to determine who has a standing in the issue. This requires determining whose costs and benefits should be included in the analysis. Austroads (1996) suggests that the people with standing in road projects are the users of the asset. It suggests that impacts on non users are difficult to accurately measure and therefore should be excluded from the analysis. This approach is supported by the Department of Transport and Regional Services (2007) who in a case study consider the cost and benefits of the people who actually use the asset. The fact that both Austroads (1996) and the above mentioned case study focus on road infrastructure projects suggests that this is a common approach in this field. Hendrickson (1998) expands this idea to other projects by stating that all parties whose welfare is affected should be included in the investigation.

Another important point to note by Boardman et al (2006) is that there must be a cause and effect relationship between the project and the impact before it can be used in the evaluation.

Austroads (1996) suggest that the benefits of a project which should be considered in the analysis include the reduction of travel time, the reduction in vehicle operating costs and the reduction of accidents. American Association of State Highway and Transportation Officials (2003) agree with the benefits laid down by Austroads (1996) and add that the increase in consumer surplus must also be considered in the analysis. Hendrickson (1998) also suggests that consumer surplus must be considered in the analysis and states that it is at times the only benefit of a project run by a public agency. They also define the consumer surplus as the excess of private benefits over the costs of a facility for the user. Boardman et al (2006) also agrees with the general consensus of what constitutes a benefit on a road infrastructure project and adds that value of the highway at the end of the evaluation period as well as the reduction of congestion on other routes must also be considered. The idea of including the value of the asset at the end of the evaluation period is also brought forward by Austroads (1996). The basis of this is to enable a fair comparison of options over the one evaluation period even though they have varying project life expectancies. Hendrickson (1998) also adds that another potential benefit of a project run by a public authority is the increase in profit and employment for private contractors.

As can be seen above, the general consensus is that most of benefits to be considered come from all users of the project, as was discussed in the previous section. Giummarra(ed) (2000) however suggests that when measuring the benefits of the project, they should only be measured in terms of how they benefit heavy vehicle operators. This approach relates directly to cost benefit analysis in local bridges and is not as generalised on road infrastructure as the other sources mentioned.

Throughout their analysis, Austroads (1996) suggest that the costs which are to be taken into account in the analysis are the cost incurred by the responsible road authority. This includes the costs of design, construction and maintenance etc. American Association of State Highway and Transportation Officials (2003) once again concur with most of Austroads (1996) suggestions and also go onto suggest that the costs of travel delay during construction as well as the costs associated with financing the project must also be considered in the cost analysis. Boardman et al (2006) agrees with the general consensus on the costs to be considered.

2.5.2.3 Discount Rate

Austroads (1996), Boardman et al (2006) and American Association of State Highway and Transportation Officials (2003) agree that there is a need to determine the present value of the benefits and costs of a project which accrue over the evaluation period of the project. The need for this process is due to the preference to consume benefits now more so than in the future. However the process of selecting an appropriate discount rate differs between sources. American Association of State Highway and Transportation Officials (2003) suggests that the basic premise of selecting a discount rate is to account for foregone economic opportunities which could have been utilised with the capital invested in the selected project. They also suggest that the rate decision should be based off the risks involved in the project. If there is a certainty that the expected benefits and cost will be a result of the project than a discount rate equivalent to the riskless interest rate which is used in the private market. However if there is considerable risk that the predicted benefits and costs of a project option will not come to fruition then the discount rate should be chosen so that the present value is less than when there is no risk. American Association of State Highway and Transportation Officials (2003) then go onto suggest that when inflation is removed from the cost and benefits a discount rate of 3% can be used. If inflation is incorporated into the calculations then a discount rate of 3% plus the inflation rate used can be considered for the discount rate. Boardman et al (2006) however suggests a different criterion for selecting an appropriate discount rate. They suggest that it could be based on the predicted life cycle of the project. If the project is intra generational then a discount rate of between 3-5% should be implemented. However if it is predicted that the project will be intergeneration then a time varying rate could be appropriate. Austroads suggests that a much higher rate of 7% be used. This is considerably greater than what Boardman et al (2006) and American Association of State Highway and Transportation Officials (2003) recommend, however it should be noted that Austroads (1996) is the only Australian publication out of the three above mentioned sources.

2.5.3 Environmental Project Evaluation

In 2011 the North Burnett Regional Council drafted an Environmental Management Plan for use by the Technical Services department under whose control the management and replacement of bridges lay. This EMP outlines the following criteria for consideration for any project:

- Erosion and sedimentation
- Topsoil management and stockpiles
- Waterways including fauna movement
- Water quality and flooding
- Vegetation preservation
- Pest management
- Fauna
- Noise
- Vibration
- Site working area
- Air quality
- Contaminated sites
- Incident management
- Cultural heritage
- Protected estates and Environmentally Significant areas
- Threatened Species and Regional Ecosystems

With regards to flora, Strategic Environmental Management (2001) adds that the impacts on indigenous species and grasslands as well as the trees removed must be assessed. Nicolas and Journard (2010) also add that the biodiversity present at the site should be maintained and that protected flora and fauna should be especially considered.

With regards to cultural heritage, Strategic Environmental Management (2001) suggests that the impact on both Aboriginal cultural sites as well as RAMSAR wetlands should be considered. Nicholas and Journard (2010) adds a more global perspective to the cultural impacts by suggesting that man made heritages should also be considered.

Another interesting point which Nicholas and Journard (2010) suggest is the need for considering the indirect effects, such as increased trips, in the analysis.

One of the most vital environmental concerns when considering bridge works is maintaining connectivity. According to the Environmental Protection Agency (n.d) the ecological value of a stretch of river is linked to the connectivity of certain components upstream and downstream. One important component of this connectivity is the movement of fish species both upstream and downstream. The Department of Employment, Economic Development and Innovation (2010) have set out self assessable guidelines regarding the requirements under the Sustainable Planning Act and the Fisheries Act which both temporary and permanent barrier works, such as culvert installation, must adhere to. The Tasmanian Government (2003) has also set out some advisory guidelines for limiting environmental disruption in waterway construction works. Their set of guidelines for bridge construction includes:

- Designing the bridge for all flow conditions – This is an important hydrologic consideration of bridges. This suggests that the bridge should be designed for all level of flows. The Texan Government suggests that for predominantly economic reasons, bridges should be designed to handle only certain levels of flooding dependent upon their classification within the transport network.
- Orienting bridge perpendicular to waterway – The Texan Government also agrees that where possible the bridge should be orientated perpendicular to the waterway.
- The natural hydraulic regime should be maintained where possible – avoid constrictions where possible. This is due to the potential for scour which is discussed in more detail later.

- Where piers must be placed in channel, ensure they are oriented with direction of flow – The New York State Government also agree that it is ideal to align bridge substructure components with the waterway.
- Rock beaching of batters usually necessary to avoid undermining the abutments
- Avoid steep approaches to bridges
- Keep roadside drains at least 20m away from bridge

Another important environmental consideration which Marek (n.d) has alluded to is scour. According to Kattell and Eriksson (1998), 'scour is the removal of bank or streambed material from bridge foundations due to flowing water.' Applied University Research (n.d) suggests that bridge scour is comprised of three different scouring actions: natural scour, local scour and general scour. They suggest that local scour is what is generally found around substructure components. Mareck (n.d) suggests that this form of scour can be caused by the additional local turbulence and vortices which are created around piers. They also suggest that another form of scour is constriction scour which is due to the change in velocity of the flow as it is constricted by the bridge. They therefore suggest that the bridge velocity be used as a sizing criterion when considering a new structure.

Another environmental consideration brought to attention by Mareck (n.d) is that the waterway bed should be examined for meanders. They suggest that meandering generally migrates downstream and that this migration is accompanied by an increase in amplitude.

The Tasmanian Government (2003) has also set out guidelines for culvert installation:

- Design culvert for peak flow conditions
- Where possible use open bottom culverts and do not break the substrate of the bed and ensure sufficient size to not constrict flow or debris movement
- The minimum amount of constriction is best in the channel therefore one large culvert is better than multiple smaller culverts

- If multiple culverts are used, concentrate small flows into a smaller culvert to allow fish passage
- Culverts should be oriented perpendicular to flow to minimize constriction in channel and aid fish passage
- The gradient of the culvert should be similar to the channel gradient
- Installation of culverts should not create untypical discontinuities in stream bed such as ponding (unless ponding is typical)
- If there is a possibility of fish being present in the stream, and open bottom culverts are not used, a portion of the culvert should be buried
- The culvert should be designed so that the velocity and other hydraulic properties are relatively consistent upstream and downstream
- To allow sufficient light for fish movement, at least 600mm of space should be allowed for above typical base flows
- Roughening of the base should be implemented to aid fish travel
- The culvert should be designed with sufficient velocity to prevent silting up
- Any fill which is used below the high water mark should be free of fines, sediment, soil, pollutants, toxic material and other waste materials
- Roadside drains should be kept at least 20m from the crossing

The self assessable code reinforces some of the above guidelines including the need to align the culverts perpendicular to the flow, the need for the gradient of the culvert to be no greater than that of the bed and the need to allow at least 600mm between base flow and the invert of the culvert. There is however some differences between the self assessable code and the above guidelines. These focus mainly on the allowances for fish passage. Whereas the guidelines specify the need for burial of all open culverts for fish passage, the guidelines suggest that only one cell needs to be provided especially for fish passage. This particular cell needs to be buried at least 300mm for a box culvert with a base and 40% of the diameter of a pipe culvert.

Some of the other criteria for this culvert include:

- The bed within the cell must match the existing bed
- The cell must be at least 1200 x 900mm (box) or 1800mm diameter (pipe)

- The obvert of the fish passage cell must have the same RL as the obverts of the other cells
- The cell must be aligned with the low flow channel
- The sides of the cell must be roughened

Some of the other general requirements which the self assessable code adds to the Tasmanian Government (2003) guidelines include:

- Roughening the outer walls of the outer cells within the array
- The apron of the culvert must be buried, roughened, at a gradient no greater than that of the bed and extend a maximum of 3m in the upstream and downstream direction
- The joint between the cells and the apron must be flush
- The height of the deck above the obvert must be no greater than the minimum specified value or 750mm, whichever is less
- The total width of the culvert cells in the direction of traffic flow must be a minimum of 75% of the natural bank full width and 100% of the low flow channel width
- The maximum length of the culvert in the upstream/ downstream direction is 15m
- The culverts must not be placed on bends or meandering sections or in riffle or rapid sections
- The waterway width on site must be more than 20m in a non tidal area

According to the Tasmanian Government (2003) some of the potential environmental concerns of bridges include the reduction of stability due to disturbance of natural bank material, degradation of water quality after construction due to disturbance of sedimentation as well as scouring around piers and the introduction of road runoff, the destruction of natural bank vegetation due to limited light and the constriction of animal movements.

2.5.4 Social Project Evaluation

Tsolakis et al (2005) suggest that some of the social impacts which must be considered are the aesthetics of the new infrastructure as well as the equitability of access to services. Nicolas and Journard (2010) also reinforce the need for considering the equitability of access to services and employment and add that distribution of impacts such as local pollution and noise should also be considered.

2.5.5 Types of Evaluation

The only method of evaluation thoroughly discussed thus far in the review has been the cost benefit analysis. Boardman et al (2006) suggests that non monetary benefits can have a financial value attributed to them to allow for accurate comparison. Tsolakis et al (2005) suggests that a form of analysis for impacts which cannot be monetised is the multi criteria analysis.

2.5.5.1 Multi – Criteria Analysis

Argyrous (n.d) suggests that a multi criteria analysis can be used in conjunction with a cost benefit analysis or that a cost benefit analysis can be performed as part of a multi criteria analysis or that a multi criteria analysis can be used to narrow down the options before a full cost benefit analysis is undertaken. Different sources employ the different relationships between the cost benefit analysis and the multi criteria analysis. Tsolakis et al (2005) suggests that the MCA should be used in conjunction with the CBA. This view is supported by Arup (2009) as shown by the example mentioned previously. Nicolas and Journard (2010) however suggest that the CBA should be used as only one component of the CBA. Graham 2007 utilise a different approach whereby they use only a multi criteria analysis and do not undertake a cost benefit analysis.

Argyrous (n.d) also suggests that the general procedure for analysis includes the following:

- Establishing the decision context
- Establishing the criteria
- Assessing each project alternative against the selected criteria
- Establish a weighting for each criteria relative to the other criteria
- Combine the scores and weights
- Examine and review the results
- Conduct a sensitivity analysis

This general procedure is supported by other sources such as Arup (2009) however they did not detail the review of the results nor the sensitivity analysis. Nicolas and Journard (2010) add a differing point when considering the combination of the different scores and weightings for each dimension. They suggest that the scores of each dimensions should not be simply added together to determine an overall score as this means that a short coming in one area could be over looked due to extra benefits in another section. Therefore they suggest that scores of each dimension should be analysed individually and compared against similar criteria from the other project alternatives.

3 Methodology

3.1 Introduction

The aim of this investigation is develop a framework for the assessment of rural local government bridge infrastructure projects. The development of this framework involved the selection of several case studies within the North Burnett Regional Council area, the development of an assessment methodology and the criteria associated with the assessment and the development of a selection methodology to determine the most appropriate replacement or repair option.

3.2 Selection of Case Studies

The first process in undertaking the investigation was to determine appropriate case studies. It is essential to the relevance of this investigation that a number of bridges with varying constraints be selected. This allows for a more thorough cross section of the issues faced to be discussed. It is also essential that each case study selected has been identified by qualified bridge inspectors as being in need of significant repair or upgrade. To achieve this, the following process was undertaken:

1. A brief investigation of all bridge assets on the North Burnett Regional Council Asset Register was conducted and from level two inspection reports the bridges which have been nominated for replacement within the near future were determined.
2. A further investigation was then undertaken to determine a series of unique bridges. Some of the differences used include:
    - Road classification – low volume, high volume, Local Road of Regional Significance (LRRS)
    - Waterway type – River, creek
    - Waterway Flood Duration – several weeks, localised
    - Width - one lane, two lane
    - Length – single span, multiple span
    - Area usage – different industries
    - Amount of residents it services

- Condition of existing structure
- Proximity to population centre
- Flow height

3.3 Analysis

After selecting the case studies, the next step in the investigation is to undertake an assessment on the options available for replacing or repairing the bridge. An overview of the process is shown in figure nine. The assessment process adopted involves three analyses used to determine the most appropriate bridge replacement option. The first two analyses are used to determine the most appropriate physical position of the bridge. The first analysis focuses on the effect of shifting the bridge vertically or horizontally from the perspective of the local area. The second analysis determines the effect of changes to the bridge from the perspective of the greater transport network in the area. Upon completion of the first two analyses a process is undertaken to determine the position of the bridge. The third analysis is then undertaken to assess the advantages and disadvantages of each individual replacement and repair option**.** To be consistent with the literature the criteria used in the assessment has been grouped into economic, environmental and social criteria.

Figure 9

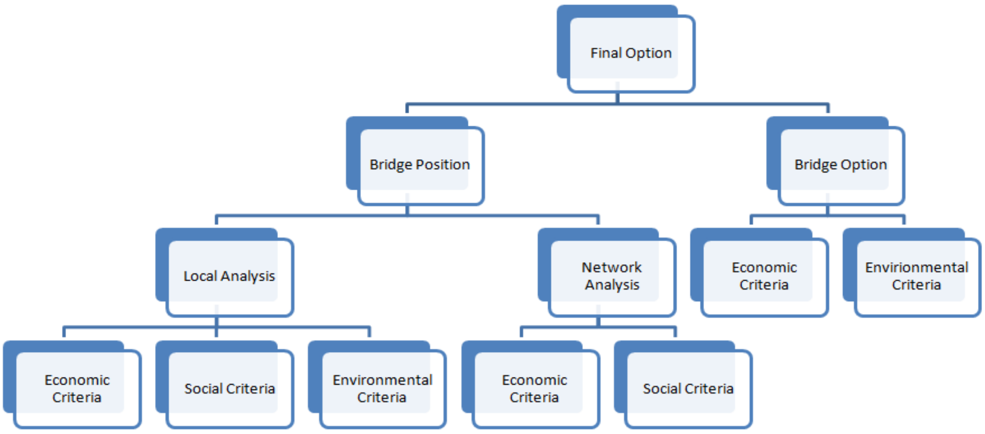


Figure nine: Overview of assessment process

3.3.1 Positional Shift Criteria Selection

The positional shift analysis is the collective term given to the two separate analyses used to determine the most appropriate position of the bridge. The first analysis is undertaken from the perspective of the local area and the second analysis is undertaken from the perspective of the greater transport network and region.

3.3.1.1 Local Analysis

This analysis is undertaken to determine if the crossing should be raised, lowered, shifted up or down stream, a combination of the above or kept in the existing position. Although the option of moving a crossing point could be directly related to the type of structure constructed, the two analyses have been kept separate as for practical reasons it is expected that this is how the analysis would be undertaken in an industry situation.

3.3.1.1.2 Criteria

The following set of criteria and methods of data collection were devised for the local analysis.

Economic Criteria

Capital Costs

- Relative change in deck area compared to base case scenario – determining the expected change in deck area which would result from changing the position of the bridge compared to the current deck area. Determined from preliminary plans.
- Approach works – determining the approximate costs of any works involved in reconstructing the approach from the existing road to the location of the bridge. Determined from preliminary plans.
- Property purchase – determining the approximate costs of purchasing land for the bridge or approach road to be constructed on. Determined from plans and by considering land use and size.

Economic status of area

- The amount of days the immediate area is isolated – determined from anecdotal advice and where possible from flood data
- The value of production lost or gained – determined by considering the land use of the area
- Potential for new industry – determined from investigation

Environmental Criteria

Scour Potential

- Current presence and future potential of scour – determined through site inspection and by considering current structure
- Possible changes to potential of scour – determined by considering preliminary plans of option

Meanders

- Current presence and future potential of meanders in waterway – determined from aerial photograph
- Possible future potential for meanders in proposed location – determined from aerial photograph

Bank Stability

- Current rating of bank stability – determined through site inspection

- Current rating of bank stability in proposed location – determined through site inspection
- Effect of proposal on bank stability – determined by considering preliminary plans of option

Disturbance to Waterway

- Affect to fish passage – determined by considering preliminary plans of option
- Affect to terrestrial passage – determined by considering preliminary plans of option
- Change to natural waterway – determined by considering preliminary plans of option

Destruction of Habitat

- Type of habitat cleared – determined from site inspection
- Amount of habitat cleared – determined from preliminary plans

Social Criteria

Isolation

- Approximate days isolated every year – determined from anecdotal evidence
- Average length of isolation – determined from anecdotal evidence
- Size of community isolated – determined from road inspections

Safety

- Vertical and horizontal alignment of the approach road – determined by considering preliminary plans
- Condition of approach road – determined from site inspection
- Sight distance to bridge – determined from site inspection

Effect on Nearby Properties

- Distance to nearby houses – determined by considering preliminary plans
- Amount of land required to be purchased – determined by considering preliminary plans
- Current use of land required to be purchased – determined from site inspection

3.3.1.2 Network Analysis Criteria and Network Selection

The aim of this analysis is to determine the most appropriate vertical and horizontal alignment of the bridge by considering its effect on the transport network of the area.

3.3.1.2.1 Network Selection

An arbitrary traffic network is determined by taking into consideration the major roads in the vicinity of the bridge.

3.3.1.2.2 Criteria Selection

Economic Criteria

Travel Distance

- Change in travel distance – determined from road inspections

Capital Costs

- Upgrades required – determined from road inspection
- Use of upgrade – determined from investigation

Economic Benefit

- Effect on economic status of local area and region – determined from investigation
- Effect on economic status of extended region – determined from investigation

Social Criteria

Isolation

- Average time isolated every year – determined from flood height data
- Average length of time isolated in each occurrence – determined from flood height data
- Effect of isolation – determined from investigation

Safety

- Alignment and condition of alternative routes – determined from road inspection

3.3.1.2.2 Scenario Selection

A series of scenarios were detailed to assess the effect which each bridge has on its network. The scenarios were selected to represent real life situations which could potentially occur.

3.3.2 Option Analysis Criteria Selection

The aim of this analysis is to assess each of the possible replacement options. This analysis is undertaken following the previous analysis as the results of that analysis influence the design of the alternative replacement options.

3.3.2.1 Criteria Selection

Economic Criteria

Capital Cost

- Cost of materials – determined by considering the preliminary plans
- Cost of earth works – determined by considering the preliminary plans
- Cost of labour – determined by considering type of labour and length of construction
- Expected life span of structure

Maintenance Cost

- Materials used – determined by considering the preliminary plans
- Type of maintenance required – determined by investigation
- Ease of maintenance – determined by considering the preliminary plans

Day Labour

- Construction processes – determined by considering the preliminary plans
- Day labour ability – determined through investigation

Construction Ease

- Construction processes – determined by considering the preliminary plans
- Disruption to traffic – determined by considering the preliminary plans

Economic Status of Area

- Weight restrictions – determined by considering the preliminary plans

- Land use of area – determined through road inspection

Environmental Criteria

Scour Potential

- The change in potential of local scour – determined by considering the preliminary plans
- The change in potential of constriction scour – determined by considering the preliminary plans

Disturbance to Waterway

- Change in fish passage – determined by considering the preliminary plans
- Change in terrestrial animal passage – determined by considering the preliminary plans

3.4 Analysis Methodology

Each of the three analyses is undertaken using the same assessment methodology. The first phase involves determining the relative importance of each criterion. Each criterion is ranked between one and five with one being of limited importance and five being of the highest importance. The assignment of each rating is based on previous experience and the findings from the literature. Each proposal is then given a score for each criterion. The score given is based on the performance of the option relative to the existing, or base case, situation. The scores range from -5 to 5 with -5 representing a significantly worse performance and 5 representing a significantly better performance. The product of the criteria rating and the option score is then found. The product of the option score and criteria rating for each of the three categories, environmental, social and economical, is then summed. A simplified example of this process is shown in figure 10**.** The scores of each category of the first two analyses are considered together to determine the position of the bridge. This process utilises engineering judgment and a process of elimination to determine the most appropriate position. This process is discussed and demonstrated in further detail in the discussion section. A visual description of this process is shown in figure 11. Once the position of the bridge is chosen the options analysis is undertaken. A similar process is used to analyse the results of this assessment. This process is shown visually in figure 12.

Figure 10

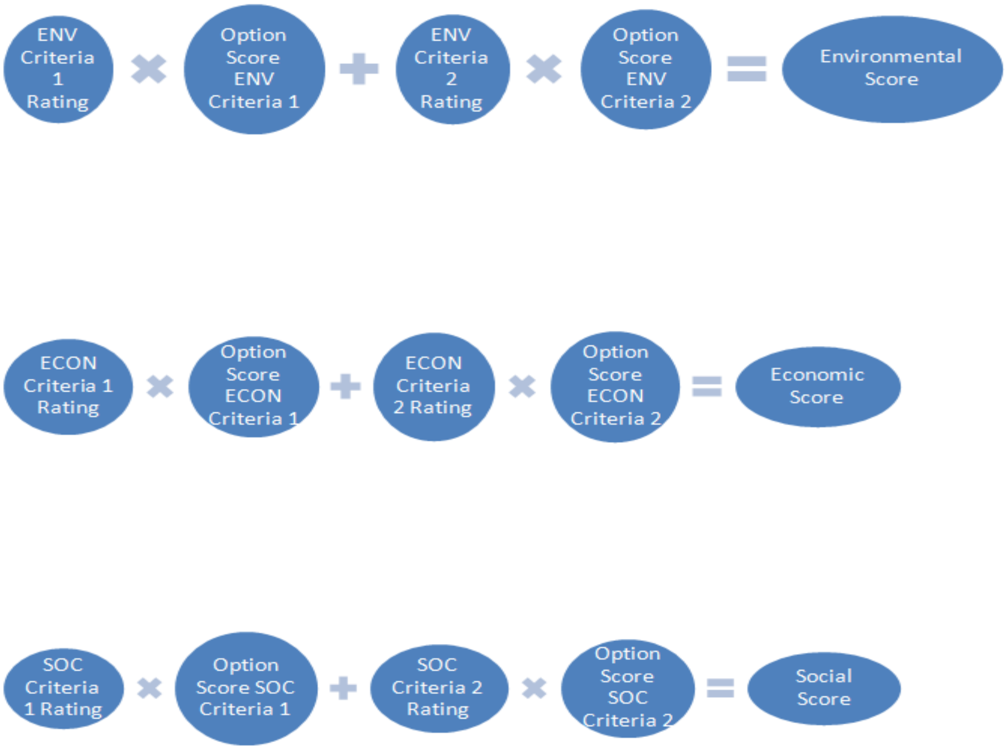


Figure 10: Assessment Methodology description

Figure 11

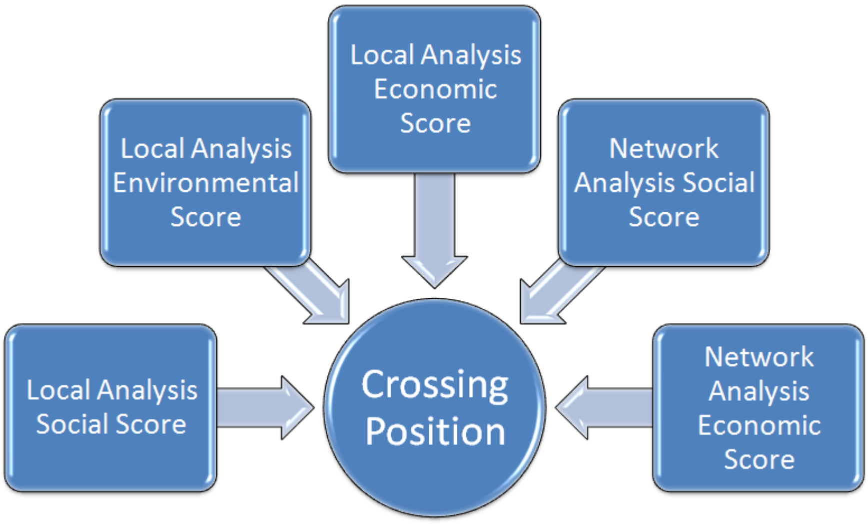


Figure 11: The process used to determine the crossing position

Figure 12

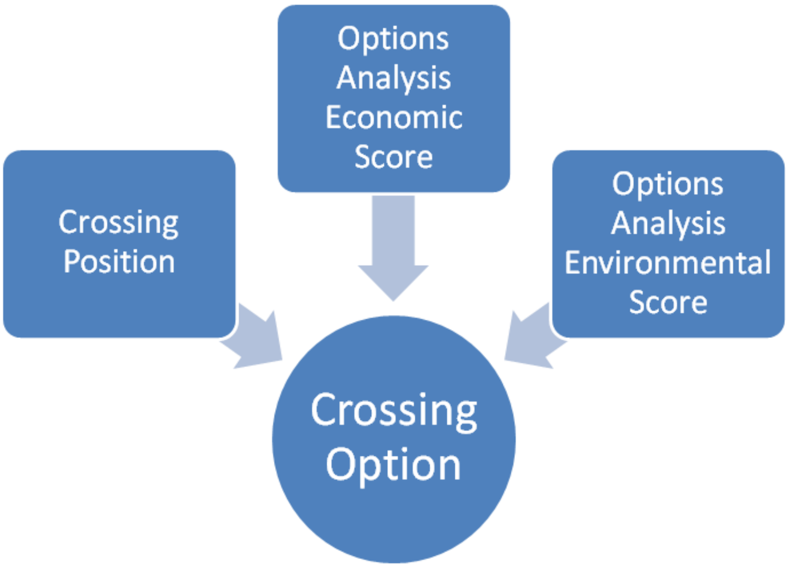


Figure 12: The process used to determine the crossing option used.

3.5 Data Collection

To undertake an accurate assessment of each option it was necessary to collect relevant information regarding the individual bridge, the area the bridge is in and the region in general. The relevant information was collected through an onsite inspection as well as through a desk top analysis.

To provide an accurate representation of the existing bridge the following information was collected:

Bridge and span dimensions – This involved measuring the bridge in both the span direction and road way width. Due to most of the bridges still being in current operation, for safety reasons this had to be done quickly and hence the measurements were stepped out instead of using more accurate methods such as a measuring wheel.

Waterway area – This is the approximate area in which water can flow under the bridge. This was determined using the length of each span and by estimating the height between the waterway bed and the base of the girders. This was taken from the natural waterway bed and not the depression commonly found directly underneath a bridge. This height had to be estimated due to the safety implications of measuring from the bridge deck and due to the presence of water in the waterways.

Orientation of bridge – This is visually measured relative to the river bed and is an indication of the skew of the bridge. The measurements taken are only estimates as the non linearity of the waterway creates difficulties in determining more accurate angles.

Location of bridge in river bed – This determines if the bridge is on a straight section or bend of a river bed. This was determined by viewing the bridge from a high point of the waterway bank where a clear view upstream and downstream could be achieved.

Bridge description – This was to determine the category in to which the existing bridge was classified. This was determined by comparing the construction materials and form used with the descriptions found in the literature.

Flora – The flora species, both aquatic and terrestrial, were noted as well as their relative density. This inspection will be undertaken immediately upstream and downstream of site. Any species not recognised were photographed for further analysis

Fauna – Any animals encountered on site were recorded as well as any animal markings found which could be identified.

Upstream and downstream conditions – This involved scouting the waterway for approximately 100m in both the upstream and downstream directions. The bank conditions, waterway conditions, density of flora and geometry of bed as well as any anomalies were recorded.

Approach road conditions – This was a visual description of the vertical and horizontal alignment of the approach road as well as its formation width and current condition.

Condition of existing bridge – Level Two inspection reports have been found for each existing structure. From these reports a list of defects has been generated.

Prior crash history – A list and description of any serious vehicle accident which have occurred in the vicinity of each bridge has been found from council records.

Bridge submersion information – A description of the flood events of the bridge has been documented. This includes anecdotal evidence of flood frequency and heights as well as, where possible, documented river flood heights.

To provide an accurate representation of the area in which the bridge is located the following information was collected:

Road Description – This is a basic description of the road category and where it is located.

Type of industry present – This was a brief inspection of the properties whose predominant access to the nearest population centre involves traversing the bridge. It is generally possible to determine from a roadside inspection the main activities undertaken on a property.

Other waterway crossings – This determined the location of other waterway crossings which could possibly disrupt the network link in times of flood. The waterway and relative height of the crossing was also determined.

Potential for future development – This was determined by considering the characteristics of the area. Characteristics taken into consideration include current industry and development, water availability and road conditions. Any pending development applications have been taken into consideration for the affected area however the details of these developments cannot be publicly discussed.

Amount of residents affected by bridge – This is a relative estimate of the traffic usage of the bridge. This was determined by considering the amount and type of properties affected as well as, where possible, traffic counts of the roads.

Waterway description – Certain characteristics of the waterway have been determined. This includes, approximate distance from headwaters, location of nearby weirs and flood description.

The following information relates to the entire region:

Regional ecosystems – The possibility of the presence of any of concern or endangered regional ecosystems have been identified through a search of the Department of Environment and Natural Resources database.

Cultural Heritage – The location of any Native Title claims in vicinity of the bridges was determined through inspection of a Queensland Claim Map from the Department of Environment and Natural Resources.

3.5.1 Surveys

To aid in determining the rating of criteria for the analyses a survey was developed to gauge the opinion of local government employees with extensive experience in the management of bridge replacement and repair. To aid in participation the questions on the survey are of a general nature. The survey form is shown in Appendix B.

The pre-requisite of the participants was that they have experience in the management of bridge repair or replacement.

4 Results

4.1 Case Studies

Table one provides the basic characteristics of the case studies chosen.

Table 1

	Bridge Name			
	Jack Parr	**Flagstone**	**Derrabungy**	**Waratah**
Region	Mundubbera	Mundubbera	Mundubbera	Monto
Road	Coonambula Rd	Hawkwood Rd	Beeron Rd	Cahalane Rd
Road Class	LRRS	LRRS	Minor Distributor	Distributor
Bridge Length	83m	54m	-	28m
Bridge Type	Timber Beam	Timber Beam – Concrete Piers	Steel Truss	Timber Beam
Waterway	Burnett River	Auburn River	Derrabungy Creek	Monal Creek

4.2 Data Collection

4.2.1 Survey Results

The results of the survey are shown in table two.

Table 2

Question	**Answers**	**Average Score**
In evaluating each alternative how would you rank the relative importance of each of the following considerations?	Economic Considerations	1
	Social Considerations	1.83
	Environmental Considerations	2.5
	Political Consideration	3.17
In evaluating the economical considerations how would you rank the relative importance of the following factors?	Capital Cost	1
	Maintenance Cost	1.5
	Industry Benefits	1.67
	Use of Day labour	3
In evaluating the social considerations how would you rank the relative importance of the following factors?	Delay for User	2.83
	Size of Affected Community	2.17
	Flood Immunity	1.83
	Aesthetics	3.5
In evaluating the environmental considerations how would you rank the relative importance of the following factors?	Complying with Legislation	1.33
	Minimizing Waterway Disruption	2.17
	Maintaining Fish Passage	2.5

4.2.2 Local Analysis Criteria Rating

Table 3

Criterion	Option Score
Capital Cost	**5**
Flood Immunity	**4**
Scour Potential	**2**
Potential for Meanders	**5**
Bank Stability	**3**
Disturbance to Waterway	**5**
Destruction of Habitat	**5**
Isolation	**3**
Safety	**5**
Effect on Nearby Residents	**2**

4.2.3 Network Analysis Criteria Rating

Table 4

Criteria	Option Score
Travel Distance	3
Capital Cost	5
Economic Benefit	4
Safety	5
Isolation	3

4.2.4 Options Analysis Criteria Rating

Table 5

Criteria	**Option Score**
Capital Cost	5
Maintenance Cost	4
Day Labour	2
Construction Ease	4
Economic Status of Area	2
Scour Potential	4
Disturbance to Waterway	5

The most recent level two bridge inspections for Jack Parr Bridge and Flagstone Bridge are shown in Appendix C.

The data collected from inspections undertaken at the site of the four case study bridges is shown in Appendix D.

The data collected from office based inspections of the four case study bridges is shown in Appendix E.

The data found which is specific to the entire region is shown in Appendix F.

4.3 Local Analysis Options Selection

4.3.1 Jack Parr Bridge

4.3.1.1 Option One (Base Case) – Maintaining Current Alignment

Description

This option involves maintaining the current bridge position and therefore no horizontal or vertical shifts in the road. An approximation of the current cross section of the bridge is provided in figure 13. In this diagram the current roadway is shown as well as the waterway profile in green.

Figure 13

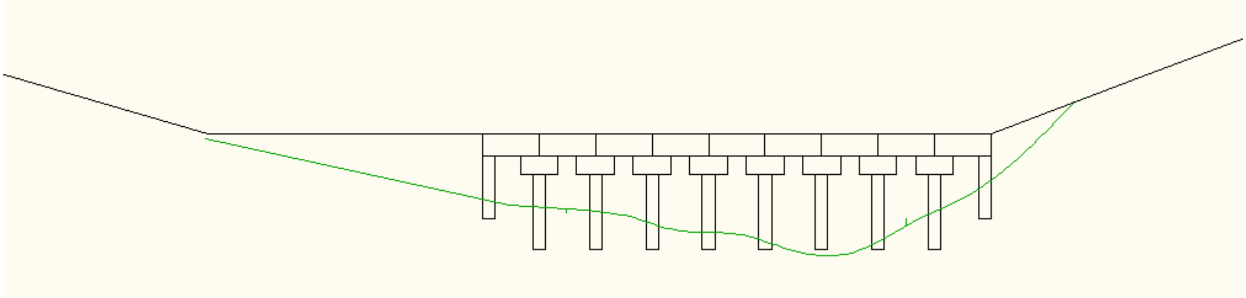


Figure 13: Current alignment vertical alignment of Jack Parr Bridge and the waterway profile of the Burnett River in the vicinity of the bridge.

The existing horizontal alignment is shown below in figure 14.

Figure 14

Figure 14: The current horizontal alignment of Jack Parr Bridge.

4.3.1.2 Option Two – Current horizontal alignment and raising the bridge deck by one metre.

The proposed cross section of this option is provided in figure 15 below.

Figure 15

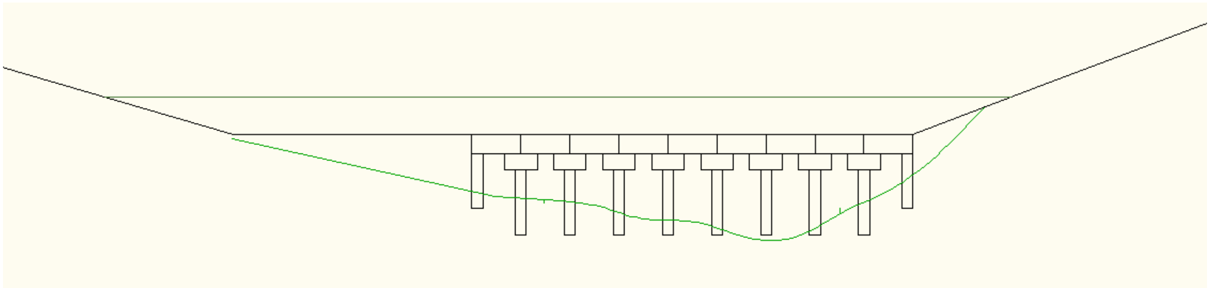


Figure 15: Proposed cross section of the second option for Jack Parr Bridge Replacement.

Description

There are two separate ways which this option could be undertaken. Firstly the embankment on the Coonambula approach could be raised by one meter and the start of the bridge remain in the same location. The bridge would be extended on the Mundubbera approach. The second option is to remove the embankment and increase the length of the bridge. Both options will be discussed and analysed in tandem.

4.3.1.3 Option Three – Lowering the deck height of the bridge

The proposed cross section of this option is shown graphically in figure 16 below.

Figure 16

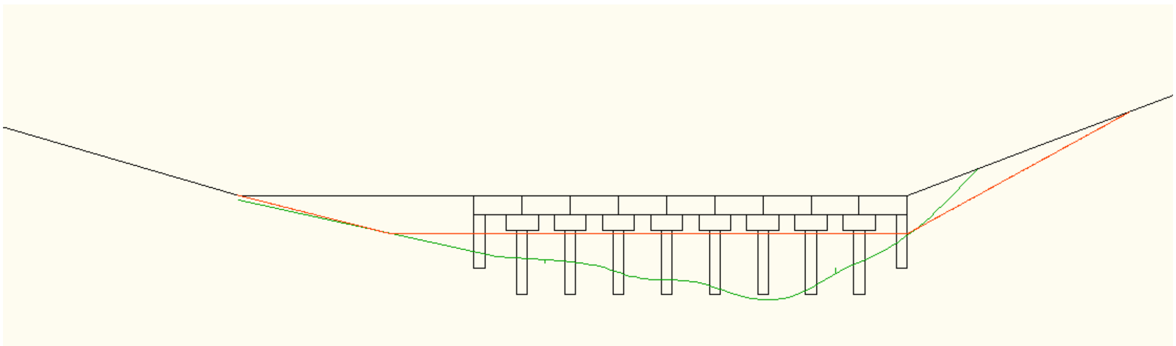


Figure 16: The proposed cross section of Jack Parr Bridge Option Three – lowering bridge deck height.

Description

This option involves lowering the height of the bridge deck by one metre. This would involve removal of a significant proportion of the embankment and an increase in length of the embankment from the Coonambula side. It would also require significant earthworks in reconstructing the approach road to meet the bridge.

4.3.1.4 Option Four – Moving Upstream

Description

This option involves moving the bridge approximately 200m upstream of the existing crossing location. The proposal is depicted graphically by the red line in figure 17 below. For the comparison to be accurate, the bridge deck height in this option is assumed to be the same as the existing bridge.

Figure 17

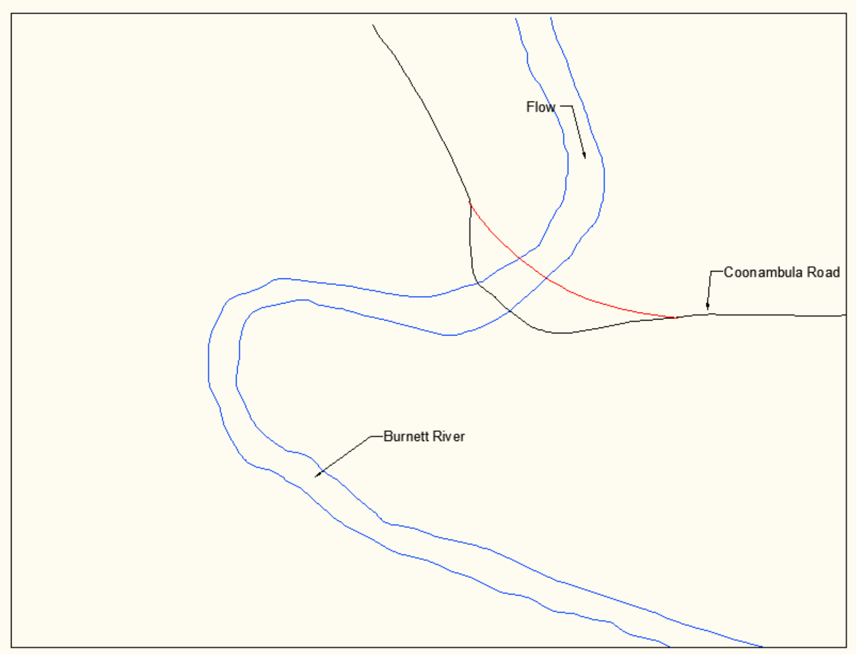


Figure 17: Proposal four for Jack Parr Bridge

4.3.1.5 Option 5 – Moving Downstream

Description

This option involves moving the bridge approximately 200m downstream of the existing location. As with option four it is assumed that the deck height will remain the same as the existing bridge. This option is seen in figure 18 below.

Figure 18

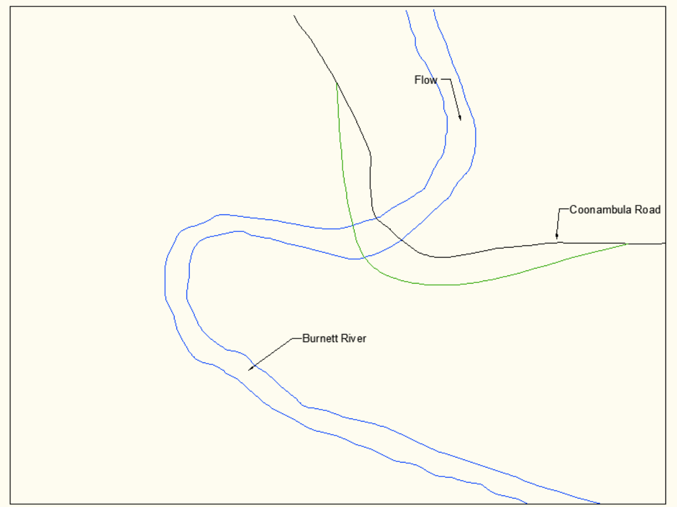


Figure 18: Proposal five for Jack Parr Bridge

4.3.2 Flagstone Bridge

4.3.2.1 Option One – Maintaining current horizontal and vertical alignment

Description

As before, the base case scenario on which to compare all other alternative options is to retain the existing alignment of the approach road and bridge and to maintain the current deck height. An approximate cross section is shown below in figure 19.

Figure 19

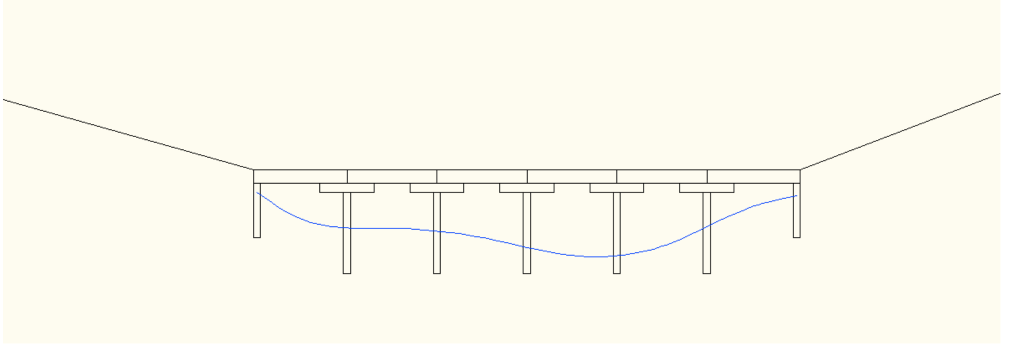


Figure 19: An approximate cross section of the existing Flagstone Bridge.

Figure 20 shows the existing horizontal alignment of Flagstone Bridge.

Figure 20

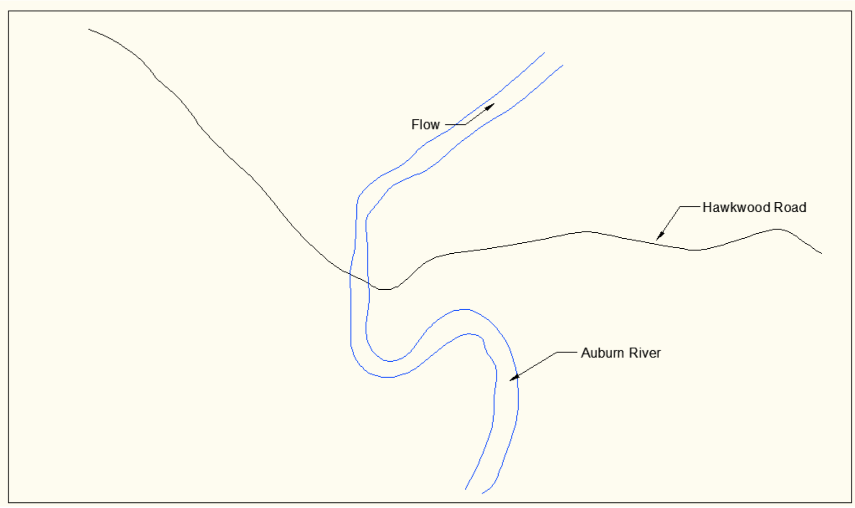


Figure 20: Plan view of the existing alignment of Flagstone Bridge

4.3.2.2 Option Two – Increase deck height

Description

This option involves a direct increase in height of deck by one metre. It is suggested that increase in height will not be achieved by the use of an embankment as before. An approximate cross section of this proposal is shown in figure 21.

Figure 21

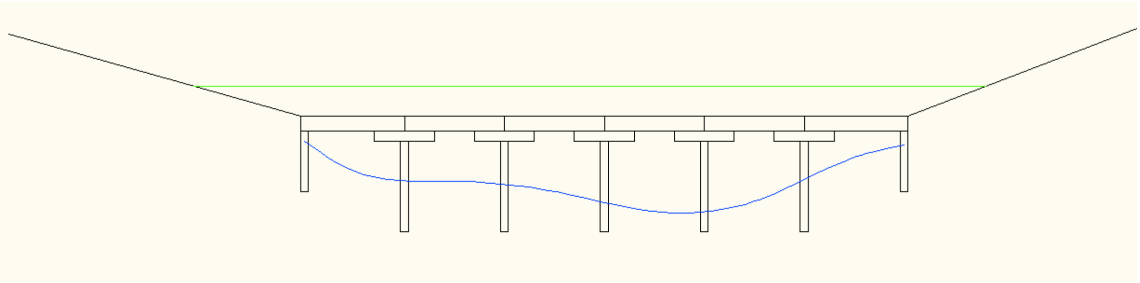


Figure 21: Cross section of proposal two for Flagstone Bridge

4.3.2.3 Option Three – Lower deck height

This option involves a direct decrease in deck height by one metre. An approximate cross section of this proposal is shown in figure 22.

Figure 22

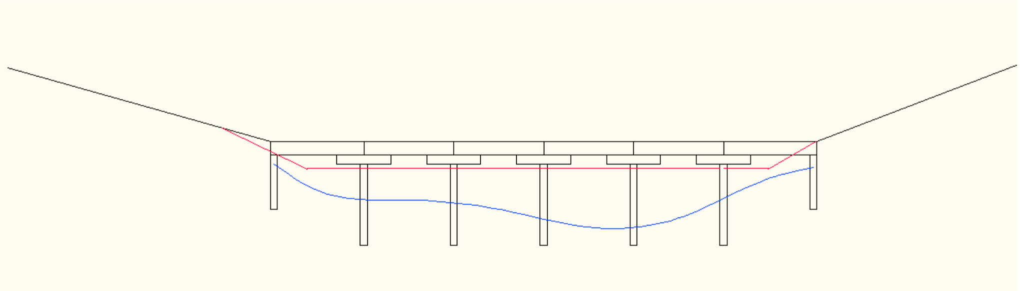


Figure 22: Cross section of proposal three for Flagstone Bridge

4.3.2.4 Option Four – Move downstream

Description

This option involves moving the bridge downstream by approximately 100 metres but maintaining the current deck height. The plan view of this proposal is shown in figure 23.

Figure 23

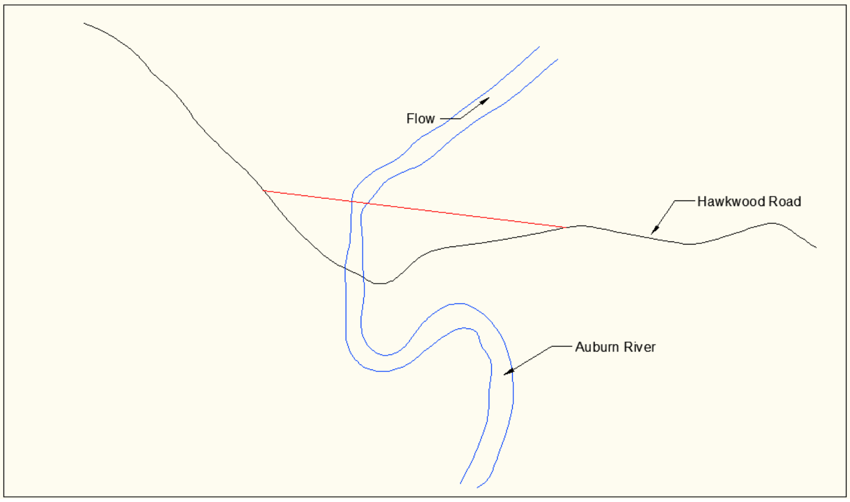


Figure 23: Plan view of proposal four for Flagstone Bridge

4.3.3 Derrabungy Bridge

4.3.3.1 Option One – Base Case

In this situation the base case alignment will be taken as the alignment of the previous bridge which was destroyed in a recent flood event.

4.3.3.2 Option Two – Reduce level

Description

This option involves reducing the deck height to the height of the original bridge which was replaced by the previous destroyed bridge. This represents a reduction in height of approximately 1.5m.

4.4 Local Analysis Results

4.4.1 Jack Parr Bridge

Table 6

	Option					
Criteria	**1**	**2a**	**2b**	**3**	**4**	**5**
Capital Cost	1	-3	-3	-2	-5	-5
Flood Immunity	1	2	2	-1	1	1
Scour Potential	1	3	-3	2	1	1
Potential for Meanders	1	1	1	1	1	1
Bank Stability	1	1	1	1	1	1
Disturbance to Waterway	1	3	-3	2	-4	-4
Destruction of Habitat	1	1	1	1	-4	-4
Isolation	1	2	2	-1	1	1
Safety	1	-2	-2	1	3	-3
Effect on Nearby Residents	1	1	1	1	-3	-2

Table 7

	Economical	Environmental	Social
Option			
1	9	20	10
2a	-7	34	-2
2b	-7	-8	-2
3	-14	27	4
4	-21	-30	12
5	-21	-30	-16

4.4.1.1 Base Case

Capital Cost – As this option involves no position shifts in the bridge, it will require limited road and bridge approach works. The only approach work will be specific to the option chosen and therefore will be covered in a further analysis. This option does not require any acquisition of land nor will it require any other survey to be undertaken or permits to be gained.

Flood Immunity – This option does not significantly alter the flood immunity of the serviced area. Currently it is suggested that the area serviced is isolated on average for approximately six days every year due to closure of this bridge. Anecdotal evidence suggests that this closure is over at least two to three flood events. Every other bridge which could be used for access to population centres are generally closed when this bridge is closed. The size of this community is relatively large for the region. The predominant industry in this area is cattle grazing. It is suggested that due to the proximity of the bridge to the head of the Burnett Catchment, in rain events of sufficient size and duration to cause a flood large enough to close the bridge, significant rainfall would also be had in the serviced area. This rainfall would significantly restrict the activities which are undertaken in the industry. It is suggested that activities such as importing and exporting cattle and feed from the property would be heavily restricted due to the resulting ground conditions. It is expected that this would also apply to the effected citrus and irrigated cropping properties which use the bridge.

Scour Potential – Depending upon which replacement or repair system is selected, it is not expected that this option will significantly increase the scour potential of this site. There is currently a large potential for scour at the site due to the large embankment on the Coonambula which significantly restricts flow. Due to the geometry of the site it is expected that the embankment would begin to cause restrictions in relatively low flows. The scour is not currently apparent due to stone pitching work which has been undertaken along the embankment. There does not appear to be any natural scour in the vicinity of the site. The construction of a temporary side track immediately adjacent to the bridge does further increase the potential to cause significant scour if the area of waterway is constricted. This occurrence is highly likely as the temporary nature of sidetracks generally results in the main selection criteria being capital cost and not environmental protection.

Meanders – Figure 24 shows a top view of the river system in the vicinity of the bridge.

Figure 24

Figure 24: Top view of the Burnett River system in the vicinity of Jack Parr Bridge. The location of the bridge is shown in the black box. The river flows from the top of the diagram to the bottom.

This aerial photograph suggests that there are no meanders in the river system upstream of the bridge location. It is suggested in the literature that meanders travel downstream. Therefore it is not expected that this will be an issue in this area.

Bank Stability – No significant erosion was found during the inspection of the site. This suggests that erosion should not be a significant issue in the current location.

Disturbance to Waterway – At low flow conditions it is suggested that fish passage is adequately provided. However as the flow rises and is constricted by the embankment, the velocity through the bridge increases. This creates difficulties in fish migration. It is suggested that the current system does not provide significant constraints for terrestrial species movement. This constriction is currently provided by barbed wire cattle fencing on both the upstream and downstream sides of the bridge. There is currently a large disturbance to the natural waterway due to the embankment. When considering the waterway and channel both upstream and downstream of the bridge it appears that there is little change to the waterway directly adjacent and underneath the actual bridge.

Destruction of Habitat – Depending on the final replacement or repair system chosen, it is expected that this option has the potential to result in minimal destruction of habitat. If a side track is required around the structure it is likely that some vegetation clearing will be necessary. However as a side track has previously been constructed around this bridge it is expected that only a minimal amount of regrowth will be required to be cleared.

Isolation – As mentioned previously this option results in no change to the flood immunity of the area. Anecdotal evidence suggests that the six days of isolation due to closure of the bridge does not occur consecutively and that generally the bridge is not closed for more than 48 hours at a time.

Safety – The only safety aspects considered in this investigation was road alignment and approach road, the safety of the bridge will be considered further in the further analysis. The current approach from Mundubbera can be seen below in figure 25. As can be seen the driver traverses a horizontal and vertical curve before coming onto a small straight section before approaching the bridge. This road has two lanes and is well signed. Therefore the driver is prepared for entering the bridge well before approaching it.

Figure 25

Figure 25: The approach to Jack Parr Bridge from Mundubbera

The current approach from Coonambula is shown below in figure 26. As can be seen this approach also involves a horizontal and vertical curve, however the vertical curve is shorter in length and has a larger radius. Although it cannot be clearly seen, there is a large straight between the approach curve and the bridge of approximately 70m which is relatively flat. This once again allows the driver sufficient time to prepare for entering the bridge.

Figure 26

Figure 26: The approach to Jack Parr Bridge from Coonambula

Effect on Nearby Residents – The current alignment allows for a sufficient buffer between the road and the nearby houses.

4.4.1.2 Capital Cost

Option 2

Bridge

For the option of extending the bridge deck out towards the Coonambula end, the increase in capital costs depends entirely upon the replacement system chosen. However when considering a cost estimate on a cost per square metre basis, it can be seen that this option would be approximately double the capital investment of constructing the same system in the existing location. There would also be considerable earthworks required to form a new level approach and to reconstruct the road to the appropriate alignment.

Embankment

This option would also require significant earthworks to increase the embankment, which is currently approximately 70m long, by one metre. Similar earthworks would be required to alter the road alignment to suit.

Option Three

On the Coonambula approach there would be significant cost involved in removing a significant proportion of the embankment and reconstructing the road to meet the bridge. On the Mundubbera approach there would be cost involved in reconstructing the approach road to the new bridge. Unless more embankment work was undertaken, there would not be a considerable reduction in deck area required due to the geometry of the channel bed.

Option Four

This option would incur several large costs. Firstly, depending on the actual location of the road reserve, a considerable portion of land would need to be bought back from the local land owners for the road to be constructed. Secondly, a large cutting would need to be built into the waterway bank on both sides of the river to ensure that an appropriate slope is acquired for the construction of the new approach road. Finally, a relatively large stretch of new road would need to be constructed to join the bridge to the existing road at an appropriate alignment. This road would require significantly more work in comparison to the reconstruction of roads mentioned in the previous options as for this road, the proposed stretch has not been cleared and there is no existing base material to form the new road on.

Option Five

It is expected that the capital costs involved in this option would be similar to those incurred with the previous option.

4.4.1.3 Flood Immunity

Option Two

Both of these options would significantly increase the flood immunity of the serviced region.

Option Three

This option would significantly decrease the flood immunity of the serviced region.

Option Four

It is not expected that this option will cause a significant change in the flood immunity of the serviced region compared to the current situation.

Option Five

It is not expected that this option will cause a significant change in the flood immunity of the serviced region compared to the current situation.

4.4.1.4 Scour Potential

Option Two (a) (Bridge)

It is suggested that this option would decrease the scour potential of the site as the waterway area would be significantly increased. This would reduce the constriction of the waterway which is currently present and would therefore reduce the potential for constriction scour. The increased potential for local scour due to the probability of a greater amount of substructure components in the waterway has not been considered here as this depends largely on the final replacement or repair option selected. It is not expected that this option will significantly alter the potential for natural scour.

Option Two (b) (Embankment)

It is suggested that this option would significantly increase the potential for constriction scour due to the one metre increase in height of the embankment. Whilst the area of flow under the bridge is greater, the amount of flow constricted is also significantly larger and it is suggested that this would increase the potential for constriction scour. It is not expected that this option will significantly alter the potential for local or natural scour.

Option Three

It is suggested that this option will decrease the potential for constriction scour due to the reduction in height of the embankment. Even though the flow area under the bridge is less, the flow will move over the embankment much earlier due to the reduction of height and therefore there will be significantly less constriction. It is not expected that this option will significantly alter the potential for local or natural scour.

Option Four

It is not suggested that this option will significantly alter the potential for constriction scour however this is based on the assumption that another embankment will be constructed. There did not appear to be any evidence of natural scour along any other part of waterway in the vicinity of the bridge during the inspection and therefore it is suggested that there will be no change in the potential for natural scour. It is not expected that this option will significantly alter the potential for local scour.

Option Five

It is suggested that the potential for scour for this option is similar to the Option Four discussed above.

4.4.1.5 Meanders

Option Two

The effect of meanders is not expected to change between the existing alignment and the proposed alignment for both options.

Option Three

The effect of meanders is not expected to change between the existing alignment and the proposed alignment.

Option Four

As this option is further upstream from the existing bridge and hence further upstream from the most significant meanders of the waterway section, it is suggested that this location has less potential for the effects of meandering.

Option Five

This option is closer to the most significant meanders of the waterway section and therefore it is suggested that this location has a greater potential for effects of meandering.

4.4.1.6 Bank Stability

Option Two

The bank stability is not expected to change between the existing alignment and the proposed alignment.

Option Three

The bank stability is not expected to change between the existing alignment and the proposed alignment.

Option Four

No sign of bank erosion was found during the site inspection. Therefore it is not suggested that this site will represent an increase in erosion potential.

Option Five

No sign of bank erosion was found during the site inspection. Therefore it is not suggested that this site will represent an increase in erosion potential.

4.4.1.7 Disturbance to Waterway

Option Two (a)

The first option will decrease the current disturbance to the waterway. Initially there will be some disturbance to the waterway as the embankment is removed and the construction work is undertaken. However, it is expected that eventually the waterway will be able to return to an increasingly natural form. At low flow conditions it is not expected that there will be a change in the fish passage of the crossing. However at higher flows it is expected that this option will increase the fish passage through the crossing as the removal of the embankment, and hence the constriction, will reduce the velocity of the flow in larger flows. This will better enable fish migration. It is expected that this option will increase terrestrial passage as it is expected that there will be a greater area under the bridge for passage instead of over the road which requires crossing a barbed wire cattle fence.

Option Two (b)

The second option will significantly increase the disturbance to the waterway due to the increase in the height of the embankment. The second option is expected to reduce the fish passage through the crossing as the embankment will increase the velocity of the flow in higher flows, making migration more difficult. It is not expected that that this option will significantly affect terrestrial passage as it only has the potential to increase the height of the deck and will not create more longitudinal distance for animals to move.

Option Three

In low flow conditions it is not expected that this option will significantly alter the ability for fish to migrate. At higher flows it is expected that the ability for fish to pass will be increased for two different reasons. Firstly the velocity under the bridge will be decreased as due to there being no constriction which will aid in fish passage. Secondly as the flow height increases, the roughness of any scour protection as well as the roughness of the bitumen road, will aid the passage of fish moving over it. It is not expected that the ability for terrestrial species to pass the crossing will be significantly affected by this option for the same reasons as mentioned in the previous option. It is suggested that after the embankment is removed the waterway would better be able to return to its natural state and therefore the disturbance to the waterway will be decreased.

Option Four

It is not expected that this option will have a significant effect on fish and terrestrial passage. The construction of an additional cutting into the waterway will create a large disturbance to the waterway.

Option Five

It is expected that this option will have a similar effect on fish and terrestrial passage as the previous option.

4.4.1.8 Destruction of Habitat

Option Two

It is not expected that any of these options will create any additional destruction of habitat.

Option Three

It is not expected that this option will create any additional destruction of habitat.

Option Four

This option results in a significant amount of clearing for both the construction of the approach road and for the bridge construction across the waterway. During the inspection there was no evidence of endangered or of concern species on site. There was no of concern or endangered ecosystems found. This site does not appear to be under any native title claims and there does not appear to be any culturally significant items at the site.

Option Five

This option is expected to result in a similar form of clearing as the above option.

4.4.1.9 Isolation

Option Two

This option reduces the isolation for several residences.

Option Three

This option increases isolation to the area

Option Four

This option is not expected to have a significant effect on the isolation of the area.

Option Five

This option is not expected to have a significant effect on the isolation of the area.

4.4.1.10 Safety

Option Two

An increase in height would mean a reduction in the length of the straight from the Mundubbera approach which allows drivers greater time to prepare for the bridge. Drivers would travel directly from the horizontal and vertical curve and straight onto the bridge. The approach from the Coonambula direction would be similar if the embankment was not increased, however if it was it would remain similar to the existing situation.

Option Three

It is not expected that this option would cause a significant change in the safety of the crossing.

Option Four

It is expected that this option will increase the safety of the crossing. Figure 17 shows the proposed alignment of the new crossing. It can be seen that this significantly increases the radius of the horizontal curves making them easier for the driver to traverse. One potential associated problem is that due to the improved alignment the driver may attempt to approach the cutting and bridge with a speed higher than the recommended speed.

Option Five

It is expected that this option will decrease the safety of the crossing. It can be seen from figure 18 that the radius of the horizontal curves will need to be reduced to economically reconstruct the road to the bridge. This will create an extra hazard for the driver.

4.4.1.11 Effects on Nearby Residents

Option Two

Neither of these options is expected to change the effect on nearby residents.

Option Three

This option is not expected to change the effect on nearby residents.

Option Four

This option will have a significant effect on nearby residents. As can be seen in Figure 17 a large portion of land will need to be purchased from a local landowner. It can also be seen that the new road will run closer to a household on the Coonambula bank and therefore the noise and dust etc from the road will increase.

Option Five

This option is expected to have a similar effect on nearby residents as the previous option.

4.4.2 Flagstone Bridge Results

Table 8

	Options			
Criteria	**1**	**2**	**3**	**4**
Capital Cost	1	-2	-1	-4
Flood Immunity	1	2	-1	1
Scour Potential	1	2	-2	1
Potential for Meanders	1	1	1	1
Bank Stability	1	1	1	1
Disturbance to Waterway	1	3	-2	-3
Destruction of Habitat	1	1	1	-3
Isolation	1	2	-1	1
Safety	1	-2	2	2
Effect on Nearby Residents	1	1	1	-1

Table 9

	Economical	Environmental	Social
Option			
1	9	20	10
2	-2	32	-2
3	-9	-1	9
4	-16	-20	11

4.4.2.1 Base Case

Capital Cost - The capital cost of this option is suggested to be minimal as not significant excavation would be required. A functioning heavy vehicle side track is already in place and it is suggested that it would be capable of sustaining an increase in vehicles.

Flood Immunity – There is currently on average approximately 10 -12 days of isolation every year due to submergence of this bridge. There is another route which people in the area can take which has increased immunity. The isolated area is predominantly involved in cattle grazing.

Scour Potential – It is difficult to accurately assess the long term scour potential of this site due to the change sustained to the natural waterway from the construction of the side track immediately upstream of the bridge. However by assessing the position of the bridge within the natural waterway, it appears that there would be limited constrictions to flow apart from within the immediate vicinity of the abutments. This would suggest that the potential for constriction scour at this position is limited. No evidence was found during the site inspection of natural scour.

Meanders – An aerial view of the Auburn River in the vicinity of the bridge is shown below in figure 27.

Figure 27

Figure 27: The Auburn River in the vicinity of the Flagstone Bridge. The bridge can be seen in the top of the diagram where Hawkwood Road crosses the river.

The above aerial view of the Auburn River shows that there is significant potential for the waterway to continue to meander. No evidence was found however, during the site inspection that the waterway was in the process of changing.

Bank Stability – No evidence was found during the inspection that the bank was showing signs of instability.

Disturbance to Waterway – It is suggested that the current bridge does not produces any issues with fish passage. It is suggested that the current bridge does hinder the passage of terrestrial species due to the low deck height. The current alignment does not create a significant disturbance to the natural waterway apart from the cutting on both approaches.

Destruction of Habitat – This option will not cause significant destruction of habitat as limited clearing will be necessary for construction of repair of any bridge and a side track is already in place.

Isolation - There is currently on average approximately 10 -12 days of isolation every year due to submergence of this bridge. There is another route which people in the area can take which has increased immunity.

Safety – The current alignment of the approach road is shown in the aerial view below in figure 28.

Figure 28

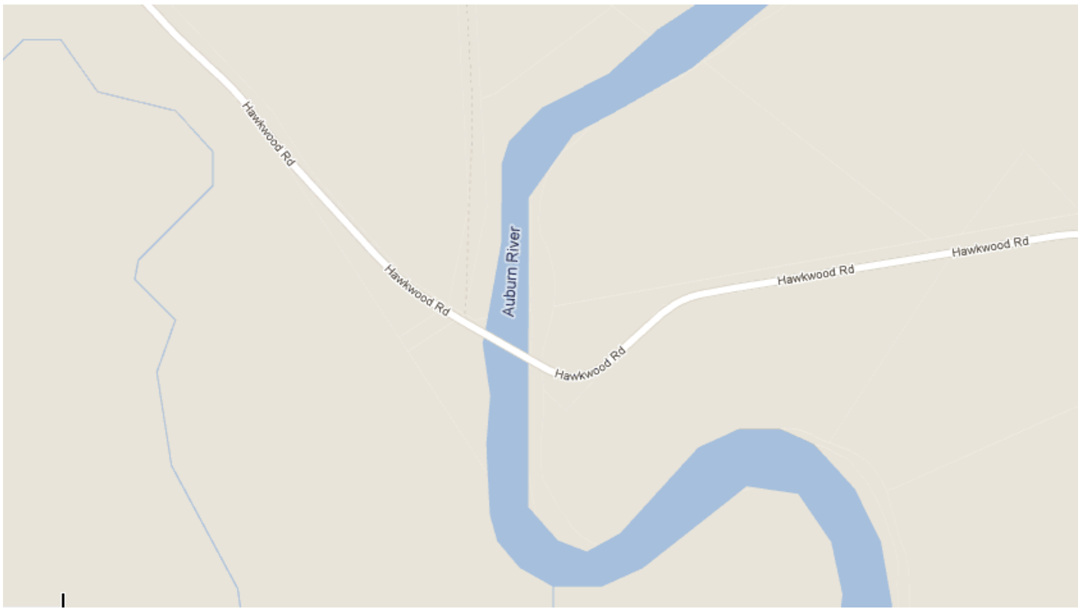


Figure 28: Current alignment of approach road to Flagstone Bridge

Figure 29 below shows the approach to Flagstone Bridge from Mundubbera.

Figure 29

Figure 29: The approach to Flagstone Bridge from Mundubbera

Figure 30 below shows the approach road to Flagstone Bridge from Hawkwood.

Figure 30

Figure 30: The approach to Flagstone Bridge from Hawkwood

It can be seen that the approach from the Mundubbera involves the driver traversing a combined vertical and horizontal curve before encountering a small straight section and then entering the bridge. There is a significant amount of signage on the approach to warn drivers of the bridge. The road is sufficient width to allow two vehicles to safely pass in different directions. The approach from Hawkwood involves the driver traversing a straight vertical curve. Providing they are driving at a reasonable speed for the road conditions, the driver has sufficient time to see any obstacles on the bridge before approaching it. There is also sufficient width for two cars to pass each other.

4.4.2.2 Capital Cost

Option Two

It is suggested that the most significant capital costs involved in increasing the deck height by one metre would be in the large increase of deck area required. The approach slopes on both sides are not very steep and therefore a large extra length would be required. There would be some earthworks required to reconstruct the approach road however it is not considered that this would be significant.

Option Three

Due to the current height of the deck above the waterway it is not expected that there will be a large reduction in deck area associated with lowering the bridge. There will be some earthworks involved in reconstructing the road to meet the new bridge.

Option Four

There will be significant earthworks involved in reconstructing a large stretch of road to join the new bridge to the network. There will also be earthworks required to construct a new cutting into the waterway bank. Another capital cost involved with this option is in the purchase of land for the new approach road.

4.4.2.3 Flood Immunity

Option Two

This option will increase the flood immunity to the area.

Option Three

This option will decrease the flood immunity to the area.

Option Four

This option is not expected to change the flood immunity of the area.

4.4.2.4 Scour Potential

Option Two

It is suggested that this option will reduce the potential for constriction scour. Even though there is limited potential for the existing situation, this option will place the embankment around the abutments further up the bank. This will allow a greater flow before any constriction occurs.

Option Three

It is suggested that this option will increase the potential for constriction scour due to the new abutments being constructed closer to the main waterway channel. This means constriction will occur at a lower flow than the existing situation.

Option Four

It is not expected that this option will alter the potential for constriction scour. There was no evidence of natural scour further downstream and therefore it is not expected that this option will significantly change the potential for natural scour.

4.4.2.5 Meanders

Option Two

It is not expected that this option will significantly alter the potential for scour.

Option Three

It is not expected that this option will significantly alter the potential for scour.

Option Four

Considering the scale of the meanders in the system it is not expected that this option will significantly alter the potential for damage due to meanders. As figure 27 above shows, the meanders in the system occur over a large distance. It is therefore suggested that if a meander affects the existing location, it will also affect the proposed location to some extent.

4.4.2.6 Bank Stability

Option Two

It is not expected that this option will significantly alter the bank stability in the area.

Option Three

It is not expected that this option will significantly alter the bank stability in the area.

Option Four

No evidence was found during the site inspection that there are any changes in the bank stability between the proposed site and the existing location.

4.4.2.7 Disturbance to the Waterway

Option Two

By reducing the flow constriction, it is suggested that there will be a benefit to fish passage. As the existing structure provides limited restriction it is not expected that this benefit will be substantial. It is expected that this option will aid the passage of terrestrial species due to the increase in deck height. It is suggested that lifting the structure further out of the waterway enables a greater potential for the waterway to return to a more natural condition.

Option Three

It is expected that this option will have the reverse effect on fish passage as the Option Two above. However it is also suggested that it will only have a minimal effect on fish passage. It is also suggested that this option will have a negative effect on terrestrial animal passage due to the decrease in height. This will force more terrestrial animals to cross on the road which causes safety issues for both the animal as well as drivers. It is also suggested that placing the structure further into the waterway will increase the disturbance on the natural waterway.

Option Four

It is not expected that this option will provide a significant change in the passage of fish and terrestrial species. It will however cause significant disruption to the natural waterway due to the required construction of an additional cutting into the bank.

4.4.2.8 Destruction of Habitat

Option Two

It is not expected that this option will cause a significant amount of habitation clearing.

Option Three

It is not expected that this option will cause a significant amount of habitation clearing.

Option Four

This option will create extensive destruction to the natural habitat through the clearing of trees to provide access for the new approach road as well as the clearing necessary in the waterway bed required for the new structure. There was no of concern or endangered ecosystems found. This site does not appear to be under any native title claims and there does not appear to be any culturally significant items at the site.

4.4.2.9 Isolation

Option Two

This will result in less isolation than the existing situation.

Option Three

This will result in more isolation than the existing situation.

Option Four

This is not expected to affect the isolation of the area.

4.4.2.10 Safety

Option Two

It is expected that this option will decrease the safety of the bridge approach. Raising the height of the bridge decreases the sight distance for drivers approaching from Mundubbera after exiting the horizontal curve. This decreases the time they have to detect obstacles on the bridge.

Option Three

This option will increase the site distance after exiting the horizontal curve discussed above. This will enable more time for the driver to react to the bridge.

Option Four

It is not expected that this option will provide a significant change in the safety of the approach road. This option will remove a portion of the horizontal curve approaching from Mundubbera which will increase the safety of approach however it is not suggested that this will be a large improvement.

4.4.2.11 Effect on Nearby Residents

Option Two

It is not expected that this option will alter the effect the bridge has on any nearby residents.

Option Three

It is not expected that this option will alter the effect the bridge has on any nearby residents.

Option Four

This option will require the resumption of a portion of land from nearby landholders which will have an effect on them.

4.4.3 Derrabungy Bridge

Table 10

	Options	
Criteria	**1**	**2**
Capital Cost	1	-2
Flood Immunity	1	1
Scour Potential	1	2
Potential for Meanders	1	1
Bank Stability	1	1
Disturbance to Waterway	1	1
Destruction of Habitat	1	1
Isolation	1	1
Safety	1	-1
Effect on Nearby Residents	1	1

Table 11

	Economical	Environmental	Social
Option			
1	9	20	10
2	-6	22	0

4.4.3.1 Base Case Scenario

In this situation the base case alignment will be taken as the alignment of the previous bridge which was destroyed in a recent flood event.

Capital Cost - There is minimal capital costs involved with this option. The only costs involved repairing the approach road as well as some minor earthworks required in restabilising the abutments and providing erosion protection.

Scour Potential - There is potential for constriction scour with the current alignment due to the small embankment which is currently protruding into the waterway area on both approaches. There does not appear to be any evidence of natural scour.

Meanders - An aerial view of Derrabungy Creek in the vicinity of Derrabungy Bridge is shown below in figure 31.

Figure 31

Figure 31: Derrabungy Creek in the vicinity of Derrabungy Bridge

This aerial photograph shows that there is significant meandering in the vicinity of Derrabungy Bridge. It is therefore suggested that there is significant potential for further meandering to occur at near the current bridge position.

Bank Stability - During the bridge inspection there was no sign of bank instability found.

Disturbance to Waterway - There is currently only slight impedance to both fish and aquatic passage through the crossing. The small constriction of the embankment is expected to create a small increase in velocity of the flow which would not be beneficial to fish passage. However as there is limited flow through this creek during long passages of the year, it is not expected that this creek has significant aquatic life. There is significant area between the waterway base and existing bridge suggesting that terrestrial animal passage would not be restricted. The embankment out into the waterway does provide a disturbance to the natural waterway however this does not appear to be a significant disturbance.

Destruction of Habitat - It is not expected that this option will cause a significant destruction of habitat as no major clearing is necessary.

Safety - The driver traverses a minor vertical curve and a large radius horizontal curve approaching from Mundubbera. Approaching from Beeron the driver also traverses a minor vertical curve and a large radius horizontal curve. The approach road is gravel with sufficient width to allow two vehicles to pass. It is suggested that there are no significant safety issues involved with this alignment.

Effect on Nearby Residents - There does not appear to be any houses in the near vicinity of the bridge and therefore it is suggested that there are no significant effect on any nearby residents.

4.4.3.2 Capital Cost

There will be significant capital costs involved with this option. This cost will be a result of the earthworks required to bring the approach road down to the level of the bridge in both directions. There will also be a cost involved with removing a component of the concrete abutment to reduce its height on both ends.

4.4.3.3 Flood Immunity

Even though this option will reduce the flood immunity of the bridge it is not expected to have a significant effect. There is another low level crossing approximately two kilometres past the bridge which will restrict further traffic flow. There are few property entrances between the two crossing points. In addition to this the waterway is known to rise and fall rapidly. Therefore it is not expected that proposed bridge will be submerged for significantly longer than the existing bridge. In addition to this the area is predominantly involved in cattle grazing. Therefore it is expected that production will be limited during this time.

4.4.3.4 Scour Potential

It is expected that this option will reduce the potential for constriction scour as it will reduce the height of the embankment in the waterway. Therefore as the flow height increases it will overtop the bridge with less obstruction to the flow. It is not suggested that this option will affect the potential for natural scour at the site.

4.4.3.5 Meanders

It is not suggested that this option will affect the potential for the problems associated with meanders in the waterway.

4.4.3.6 Bank Stability

It is not suggested that this option will change the stability of the bank in the area. There was no evidence of bank instability found during the site inspection.

4.4.3.7 Disturbance to Waterway

This option will not provide significant changes to fish passage through the crossing. The reduction in constriction will reduce the velocity through the crossing however it is not suggested that this will provide a significant benefit. The reduction in deck height will provide an increased constriction for terrestrial passage through the site. It is not suggested that this option will provide a significant change to the disturbance to the natural waterway, however the reduction in embankment and associated reduction in constriction has the potential to reduce the disturbance.

4.4.3.8 Destruction of Habitat

It is not expected that this option will result in any destruction of habitat.

4.4.3.9 Isolation

Similar to the flood immunity.

4.4.3.10 Safety

This option will increase the length of the vertical curve of both approaches. This has the potential to slightly reduce the safety of the alignment as the sight distance to the bridge will be reduced. However with appropriate signage it is not expected that this will provide a significant reduction in safety of the alignment.

4.4.3.11 Effect on Nearby Residents

It is not expected that this option will change the effect of the bridge on any nearby residents.

4.5 Network Analysis

4.5.1 Networks

This analysis was undertaken using two different networks. Due to the close proximity of Derrabungy, Jack Parr and Flagstones Bridges, one network was used to analyse each of these bridges. This network is bounded by the Eidsvold Theodore Road in the north, the Mundubbera Durong Road in the south, the North Burnett Regional Council boundary in the west and the Burnett Highway in the east. This area is depicted in figure 32. It should be noted that the Eidsvold Theodore Road, Mundubbera Durong Road and the Burnett Highway are all state controlled roads. A second network analysis was then undertaken on an area North of Monto known as Mungungo. The network analysed involves the loop formed by the two intersections of Monal Road and Cahalane Road. This network is shown in figure 33.

Figure 32

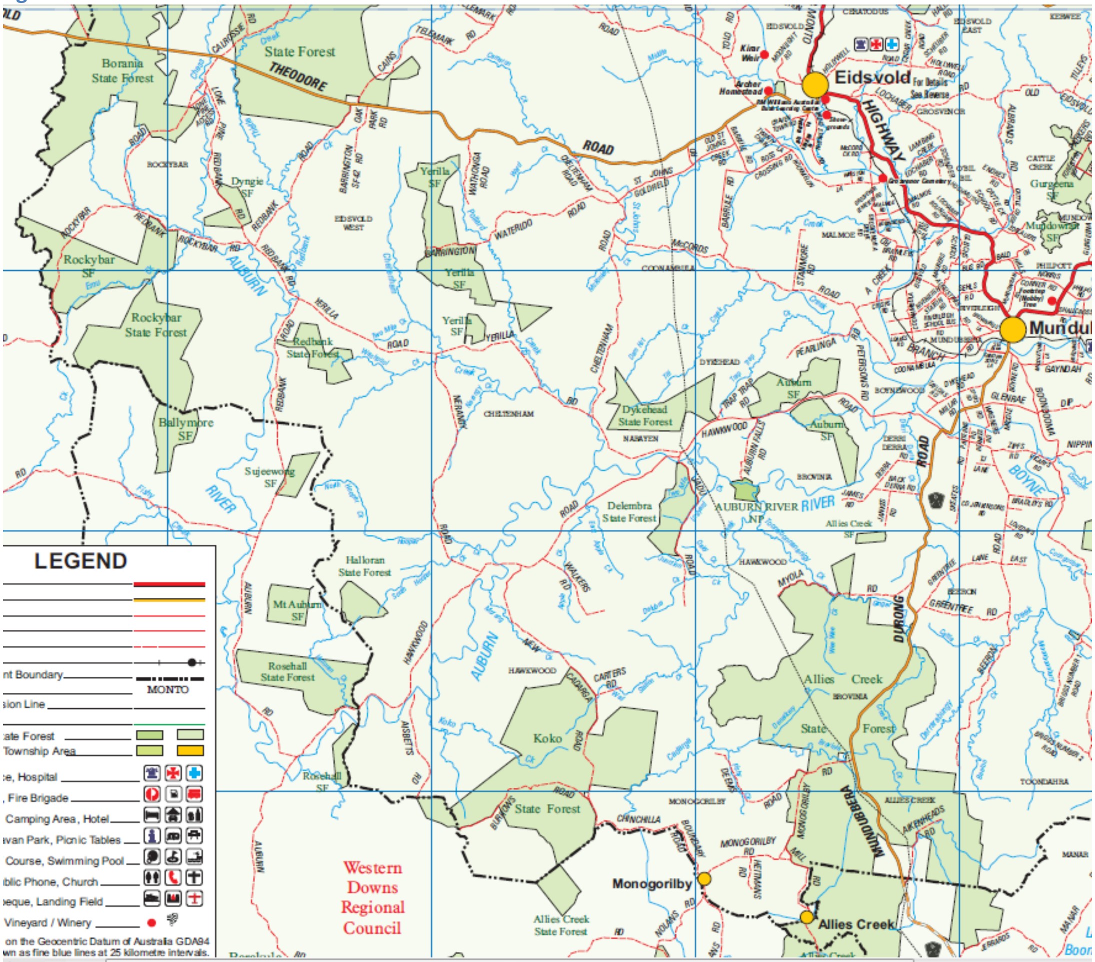


Figure 32: An overview of network one area

Figure 33

Figure 33: Network Two as shown by drawn area

4.5.2 Scenario Selection

4.5.2.1 Network One

To assess the first network a scenario was created whereby each of the major river systems in the area (Boyne River, Burnett River and Auburn River) was in flood and that each bridge crossing these systems in the area was submerged. The following scenarios were then further simulated:

- Jack Parr Bridge only is open
- Flagstone Bridge only is open
- Derrabungy Bridge only is open
- Jack Parr Bridge and Boyne River Bridge is open
- Flagstone Bridge and Boyne River Bridge is open
- Derrabungy Bridge and Boyne River Bridge is open

To allow an accurate and consistent assessment of each scenario a number of trips where analysed for each proposal. These trips are detailed below.

- Trip from west of network travelling along Eidsvold Theodore Road and attempting to travel South along Mundubbera Durong Road (Trip one)
- Trip from west of network travelling along Eidsvold Theodore Road and attempting to travel east along Burnett Highway past Mundubbera (Trip two)
- Trip from west of network travelling along Eidsvold Theodore Road and attempting to travel north along Burnett Highway past Eidsvold (Trip three)
- Trip from south of network travelling along Mundubbera Durong Road and attempting to travel north along Burnett Highway past Eidsvold (Trip four)
- Trip from South to network travelling along Mundubbera Durong Road and attempting to travel East along Burnett Highway (Trip five)

To allow an accurate assessment of travel distances consistent points have been used throughout the analysis. For trip one these the travel time will be measured between the intersection of Eidsvold Theodore Road and Cheltenham Road and the Mundubbera Durong Road crossing of the Boyne River. For trip two the set points are the intersection of Eidsvold Theodore Road and Cheltenham Road and the intersection of Mundubbera Durong Road and Leichardt Street. For trip three the set points are the intersection of Eidsvold Theodore Road and Cheltenham Road and the intersection of Eidsvold Theodore Road and Burnett Highway. For trip four the set points are the Mundubbera Durong Road crossing of the Boyne River and the intersection of Eidsvold Theodore Road and Burnett Highway. For trip five the set points are the Mundubbera Durong Road crossing of the Boyne River and the intersection of Mundubbera Durong Road and Leichardt Street.

4.5.2.2 Network Two

The second network will be assessed by considering the effect on the network if Waratah Bridge was closed to traffic. There was one trip taken into consideration through this analysis. This trip is from the intersection of Monal Road and Cahalane Road near the township of Mungungo to the same intersection point further along Cahalane Road.

4.5.3 Data Collection

4.5.3.1 Network One

Travel Distance

To determine the travel distance between points a series of extensive inspections were undertaken. Details of each inspection are provided below:

Inspection One

This inspection was centred around Jack Parr Bridge on Coonambula Road. The inspection started at the corner of the Mundubbera Durong Road and Leichardt Street (Coonambula Road). The inspection continued along Coonambula road until chainage point one Jack Parr Bridge. From here the inspection continued until the intersection of Coonambula Road and A – Creek Road (CP2). The inspection continued along A – Creek Road until its intersection with Malmoe Road and Grosvenor Road (CP3). Malmoe Road was taken to Malmoe Bridge (CP4). The inspection then continued along Grosvenor Road from the intersection of A – Creek Road, Malmoe Road and Grosvenor Road. Grosvenor Bridge was taken as another

Chainage Point before the inspection continued to the intersection of Grosvenor Bridge and the Burnett Highway (CP6). The inspection then continued along the Burnett Highway until its intersection with the Eidsvold Theodore Road (CP7). The Eidsvold Theodore Road was then taken until its intersection with Barrule Road (CP9), with another Chainage Point (CP8), being taken at Eidsvold Station Bridge. The inspection continued along Barrule Road until its intersection with McCords Road (Coonambula Road) (CP10). The inspection continued along McCords/Coonambula Road until Jack Parr Bridge where the inspection finished.

Inspection Two

This inspection was centred around Flagstone Bridge on Hawkwood Road. The inspection started at the Burnett River Bridge on the Mundubbera Durong Road in Mundubbera. The inspection continued along the Mundubbera Durong Road until its intersection with Hawkwood Road (CP1). The inspection then followed along Hawkwood Road to its intersection with Cheltenham Road (CP3), with Flagstone Bridge taken as CP2. From here the inspection continued along Cheltenham Road to its intersection with Eidsvold Theodore Road (CP5), with the intersection of Cheltenham Road and St John's Creek Road taken as CP4. The inspection continued along the Eidsvold Theodore Road with chainage points taken at St John's Creek Road intersection (CP6), Barrule Road intersection (CP7), Eidsvold Station Bridge (CP8) and the intersection of Eidsvold Theodore Road and the Burnett Highway (CP9). The inspection then continued along the Burnett Highway until its intersection with Malmoe Road (CP11), with the intersection of the Burnett Highway and Grosvenor Road taken as CP10. Malmoe Road was then taken and Malmoe Bridge was recorded as CP12. The inspection then continued along the Burnett Highway before moving onto the Mundubbera Durong Road where the inspection finished at the intersection of the Mundubbera Durong Road and Leichardt Street (Coonambula Road, CP13).

Inspection Three

This inspection centred around Derrabungy Bridge on Beeron Road. The inspection started at the Burnett River Bridge on the Mundubbera Durong Road in Mundubbera. The inspection continued along the Mundubbera Durong Road until its intersection with Beeron Road (CP1). The inspection continued along Beeron Road until Derrabungy Bridge where the inspection finished.

Isolation

As part of the analysis for the effects of each bridge on the isolation of the area, the average length in time the area is isolated for was determined. The fundamental assumption of this analysis is that when the Boyne River Bridge and the Eidsvold Station Bridge are submerged the area is isolated. Figure 34 plots the flood heights of the Derra flood gauge in the immediate proximity of Boyne River Bridge on the Boyne River. The Bureau of Meteorology suggests that the bridge is at a height of 3.8m with respect to the flood gauge.

Figure 34

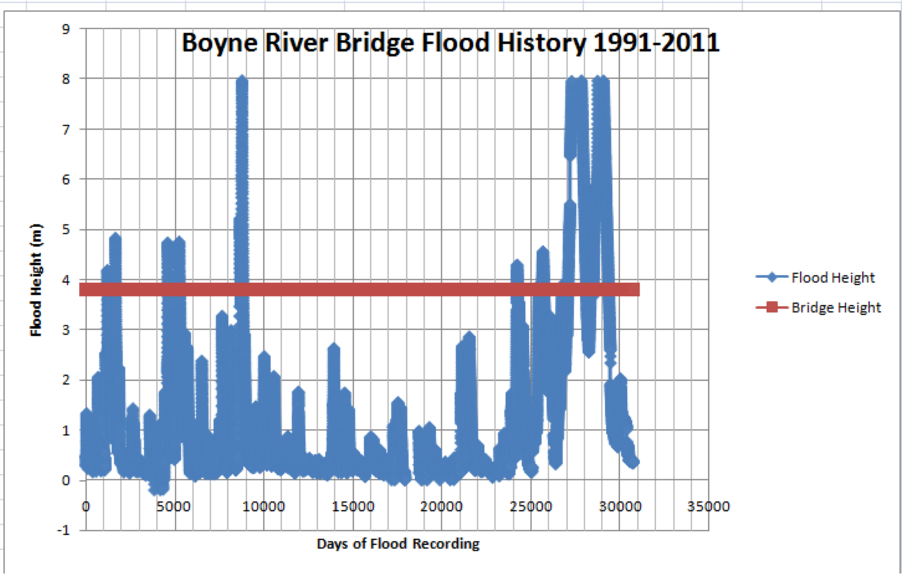


Figure 34: Boyne River Bridge Flood History 1991 – 2011

A closer analysis of this data resulted in table 12. It is important to note that the flood gauge has been in operation since 1992.

Table 12

Date Submerged	**Period of Submersion (days)**
12/02/1992	1
26/02/1992	1
22/11/1995	1
10/01/1996	2
3/05/1998	2
4/05/1998	2
3/03/2010	1
9/10/2010	1
10/10/2010	2
12/12/2010	1
19/12/2010	14
6/01/2011	1
8/01/2011	8
Total	37
Years	19
Average flooded days/year	1.94736842

Figure 35 below shows the flood heights at Eidsvold Station Bridge. The bridge is at 6m relative to the flood gauge.

Figure 35

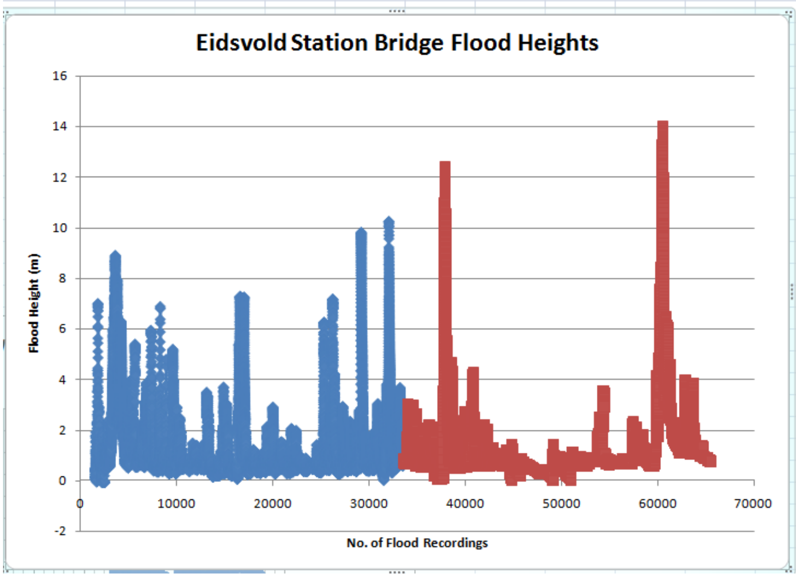


Figure 35: Eidsvold Station Bridge flood heights

A further analysis of this data resulted in table 13. It is important to note that the flood gauge began recording in 1960. The data used in figure 35 above began in 1967.

Table 13

Date Submerged	Period of Submersion (days)
14/01/1968	1
27/03/1968	2
3/02/1971	2
4/02/1971	8
23/02/1971	2
21/01/1976	1
3/05/1983	2
28/05/1983	2
19/12/1988	1
26/04/1989	2
17/03/1992	2

10/01/1996	2
7/02/2003	3
23/12/2010	2
26/12/2010	6
7/01/2011	2
Total	40
Years	51
Average	0.78431373

4.5.3.2 Network Two

Travel Distance

This inspection centred around Waratah Bridge on Cahalane Road. The inspection started at Waratah Bridge and followed along Cahalane Road until its intersection with Collingwood Road (CP1). The inspection then continued along Collingwood Road until its intersection with Monal Road (CP2). The inspection then resumed along Cahalane Road from its intersection with Collingwood Road, with the Cahalane Road intersection with Monal Road being taken as the next chainage point (CP3). The inspection continued along Monal Road with chainage points taken at Dahtlers Bridge (CP4) and the Monal Road - Collingwood Road intersection (CP5). The inspection then finished at the next intersection of Monal Road and Cahalane Road.

4.5.4 Network Analysis Results

Table 14

	Travel Distance	**Capital Cost**	**Economic Benefit**	**Safety**	**Isolation**
D	1	1	1	1	1
D + BRB	1	1	1	1	1
JP	2	-4	3	-3	3
JP + BRB	4	-4	5	-3	5
FS	1	-3	2	-2	2
FS + BRB	3	-3	5	-2	5
W	1	-1	1	-1	1

D: Derrabungy

BRB: Boyne River Bridge

JP: Jack Parr Bridge

W: Waratah Bridge

Table 15

	Economic	Social
Base Case	12	8
D	12	8
D+BRB	12	8
JP	-2	-6
JP + BRB	12	0
FS	-4	-4
FS + BRB	14	5
W	-1	-2

4.5.4.2 Network One

Base Case Scenario

Description

The base case scenario is all bridge being submerged and closed to all traffic.

Travel Time

None of the specified trips are possible when under the conditions of the base case scenario. For the purpose of the comparison the trip distances under normal conditions were calculated. The assumption was made that under normal conditions the state roads would be utilised where possible. The routes and distances are shown in table 16.

Table 16

Trip		**Distance (km)**
1	Eidsvold Theodore - Burnett Highway - Mundubbera Durong	76.2
2	Eidsvold Theodore - Burnett Highway	64.9
3	Eidsvold Theodore	28.3
4	Mundubbera Durong - Eidsvold Theodore	47.9
5	Mundubbera Durong	11.3
	Total	228.6

Isolation

The base case scenario results in no trips out of the network. Therefore the entire network area is isolated from the greater region.

Safety

There are no trips possible to assess the safety. However for the purpose of the analysis the safety of the normal routes are taken into consideration. All of these are state roads and have been assessed to be in good condition and have appropriate alignment. They are all two lane bitumen sealed.

Economic Benefit

As there are no trips possible outside of the network there are no opportunities for transportation of produce outside of the region.

Travel Distance

Jack Parr Bridge

Table 17 details the route and travel distance of all possible trips. The column on the right shows the distance travelled on state roads.

Table 17

Trip	Route	Distance (km)	State Road (km)
1	NP		
2	Barrule Rd-Coonambula Rd	63.8	16
3	Barrule Rd - Coonambula Rd - Mundubbera - Burnett Highway	100.4	52.6
4	NP		
5	NP		
	Total	164.2	68.6

Jack Parr Bridge and Boyne River Bridge

Table 18 shows the route, travel distance and distance travelled on state roads for all possible trips.

Table 18

Trip	Route	Distance (km)	State Road (km)
1	Barrule Rd - Coonambula Rd - Mundubbera Durong Rd	75.1	27.3
2	Barrule Rd - Coonambula Rd	63.8	16
3	Barrule Rd - Coonambula Rd - Mundubbera - Burnett Highway	100.4	52.6
4	Mundubbera Durong - Burnett Highway	47.9	47.9
5	Mundubbera Durong	11.3	11.3
	Total	298.5	155.1

Flagstone Bridge

Table 19

Trip	Route	Distance (km)	State Road (km)
1	Cheltenham Rd - Hawkwood Rd	70.3	0
2	NP		
3	NP		
4	NP		
5	NP		
	Total	70.3	0

Table 19 shows the route, travel distance and distance travelled on state road for all possible trips.

Flagstone Bridge and Boyne River Bridge

Table 20 shows the route, travel distance and distance travelled on state roads for all possible trips.

Table 20

Trip	Route	Distance (km)	State Road (km)
1	Cheltenham Rd - Hawkwood Road	70.3	0
2	Cheltenham Rd - Hawkwood Rd- Mundubbera Durong	81.6	11.3
3	Cheltenham Rd - Hawkwood Rd- Mundubbera Durong - Burnett Highway	118.2	36.6
4	Mundubbera Durong - Burnett Highway	47.9	47.9
5	Mundubbera Durong	11.3	11.3
	Total	329.3	107.1

Derrabungy Bridge

Table 21 shows the route, travel distance and distance travelled on state roads for all possible trips.

Table 21

Trip	Route	Distance (km)	State Road (km)
1	NP		
2	NP		
3	NP		
4	NP		
5	NP		
	Total	0	0

Derrabungy Bridge and Boyne River Bridge

Table 22 shows the route, travel distance and distance travelled on state roads for all possible trips.

Table 22

Trip	Route	Distance (km)	State Road (km)
1	NP		
2	NP		
3	NP		
4	Mundubbera Durong - Burnett Highway	47.9	47.9
5	Mundubbera Durong	11.3	11.3
	Total	59.2	59.2

Isolation

Derrabungy Bridge

Raising Derrabungy Bridge will only increase the immunity for residences on Beeron Road past Derrabungy Bridge.

Derrabungy and Boyne River Bridge

This will allow trip one to commence however Derrabungy Bridge will not be used in this trip.

Jack Parr Bridge

Raising Jack Parr Bridge alone will allow both trips two and three to commence. If the Boyne River Bridge is opened in conjunction with Jack Parr Bridge this will allow all trips to commence. However only trip one, trip two and trip three will involve crossing Jack Parr Bridge.

Flagstone Bridge

Raising Flagstone Bridge alone will allow trip one to occur. Raising Flagstone Bridge in conjunction with the Boyne River Bridge will allow all trips to occur. However, as before only two trips will involve the use of Flagstone Bridge.

Capital Costs

Derrabungy Bridge

As there are no trips possible with this option there are no capital investments required for road infrastructure repair.

Derrabungy Bridge and Boyne River Bridge

The only trips possible utilise State Roads and therefore there is no capital investment on council's behalf required.

Jack Parr Bridge

Both of the options considered will involve travel along Barrule Road and Coonambula Road. An analysis of these roads was conducted during the inspection phase. The alignment and condition of Coonambula Road reduces past Jack Parr Bridge. The majority of this work will be required to ensure the road can sustain the traffic loading during wet weather. In addition to this some realignment and widening works will be required to increase the safety to at least a minimum standard. The alignment of Barrule Road has been assessed as mainly sufficient except for some small areas. However it is suggested that work will be required on the road surface to ensure it can withstand the increase in traffic. The increase in traffic numbers is not known however due to the current limited use of these roads it is estimated that it could result in more than a 10 times increase in AADT. It is also expected that the ESA loading of the road will increase due to a greater portion of heavy vehicles expected to use the road.

Flagstone Bridge

Both of these options will involve extensive travel on Hawkwood Road and Cheltenham Road. It is expected that only minimal work will be required on the section of Hawkwood Road utilised as it is predominantly two lane bitumen seal in good condition with appropriate alignment. However there will be extensive work required on Cheltenham Road to improve both the alignment and road surface. As before the exact increases in traffic numbers are not known.

Safety

Derrabungy Bridge

There are no changes in any trip properties therefore there will be no change in safety.

Jack Parr Bridge

As previously mentioned both of these options involve travelling along Barrule Road and Coonambula Road. Even if realignment and widening work is undertaken to achieve a minimum safety standard it is expected that this section of the route will be as safe as the base case scenario. It is suggested that there will be no significant alignment issues on Barrule Road. The safety of the proposed options will also be decreased due to the road surface. A major portion of all trips resulting from both options will involve traversing gravel roads. Considering the wet conditions it is expected that this will decrease the safety.

Flagstone Bridge

As previously mentioned both of these options will result in travel along Hawkwood Road and Cheltenham Road. It is not expected that there are any major safety issues with Hawkwood Road as the alignment is generally acceptable and a majority of the trips the road is double lane bitumen sealed. There is however some alignment issues with Cheltenham Road which will decrease the safety as will the fact that it is a gravel road.

Economic Benefit

Derrabungy Bridge

This option is not expected to alter the economic status of the area or surrounding areas.

Jack Parr Bridge

Opening Jack Parr Bridge alone will allow the transportation of produce from west of Mundubbera to the north and east and vice versa. It will also allow the products of Mundubbera industry to be transported out in these directions. Opening both Jack Parr Bridge and the Boyne River Bridge will allow transportation from all directions as in the base case scenario.

Flagstone Bridge

Opening Flagstone Bridge alone will allow the transportation of products from the west of Mundubbera to the south and vice versa. Opening Flagstone Bridge in conjunction with the Boyne River Bridge will result in no restriction to transportation.

4.5.4.3 Network Two

Travel Distance

An analysis of the travel distance inspection results produced table 23.

Table 23

Route	Distance(km)
Cahalane Road (Across Waratah Bridge)	11
Monal Road (Waratah Bridge Closed)	10

Isolation

Due to the lower deck level it is expected that a large area will experience isolation during a sustained flood event. It is not expected that the flood event required to cause significant isolation will occur frequently and nor is it expected that the duration of such an event will be extensive.

Capital Costs

The closure of Waratah Bridge would result in traffic using Monal Road. It is expected that only minor works will be required on Monal Road to withstand the increase in traffic. It is estimated that there are already a significant portion of heavy vehicles using Monal Road as a result of the timber industry in the area. The estimated relative increase in traffic is therefore not expected to significantly increase the ESA loading of the road.

Economic Benefit

It is expected that this option will result in a slight disturbance to economic status in the event of a flood and Dahtlers Bridge is isolated. Even though there will be slight disruption to the production during flood events it is not expected these events will be relatively frequent nor are they expected to result in a significant period of isolation.

Safety

It is expected that the Monal section of the detour road will not significantly alter the safety of the route in respect to the alignment. As the Monal section of the road is bitumen sealed it is expected to increase the safety of the route.

4.6 Options Analysis

Table 24

	Options				
Criteria	**Modular Concrete**	**Concrete Culvert**	**Steel Culvert**	**Steel Truss**	**Fibre Composite**
Capital Cost	2	-2	-3	-2	-1
Maintenance Cost	4	4	-2	3	1
Day Labour	2	3	4	2	2
Construction Ease	-1	-3	-4	-2	1
Economic Status of Area	1	1	1	1	1
Scour Potential	1	-3	-3	-2	1
Disturbance to Waterway	1	-3	-3	-2	1

Table 25

	Economic	Environmental
Base Case	17	9
Modular Concrete	28	9
Concrete Culvert	2	-12
Steel Culvert	-29	-15
Steel Truss	0	-2
Fibre Composite	9	1

4.6.1 Jack Parr Bridge

4.6.1.1 Base Case

Capital Cost

An analysis of the level two bridge inspection has revealed that the following major components are in need of immediate replacement:

- 10 piles
- 7 corbels
- 29 girders
- 8 headstocks

In addition to this there are several minor components which will require replacement.

The following price scheme was adopted:

Girder: $3000 each

Corbel: $1750 each

Headstock: $1750 each

Piles: $3000 each

An estimate of materials costs is provided in table 26.

Table 26

Component	Amount	Price/item	Cost
Girders	29	3000	87000
Corbels	7	1750	12250
Headstocks	8	1750	14000
Piles	10	3000	30000
Deck/minor components			15000
Total Material Cost			$158250

It is expected that the following process will be undertaken to complete the required works:

- Installation of a side track around the bridge
- Lifting of two adjacent spans of deck
- Replacement of required components of exposed headstock or abutment
- Continue until all spans are completed
- Construct appropriate surfacing
- Demolish side track

It is expected that it will take the dedicated bridge crew of five people two weeks to complete each span. It is expected that a further two weeks will be required for construction of side track, bridge inspection and demolition of side track. Therefore it is assumed the job will take 20 weeks to complete.

Considering the condition of the other components of the bridge a life span of 30 years has been assumed for this bridge.

Maintenance

The existing bridge is a timber beam bridge. It will require a general inspection on a yearly basis and a more thorough inspection every five years. The yearly maintenance will include tightening of bolts and clearing of debris in conjunction with an inspection of components to locate any visible defects which require closer attention. A level two inspection will be required every five years and has the potential to result in further repair works being required. The level two inspection report shows several other components with minor defects which must be closely monitored for further deterioration. In addition to the two inspections, termite preventative treatments will also need to be applied as necessary under the North Burnett Regional Council's guidelines.

Day Labour

It is within the capabilities of the day labour staff to undertake all required works.

Construction Ease

The repair process is not considered difficult. The same process is undertaken for each span. There are no major difficulties expected. The repair process will result in road users being forced to use the side track for approximately six months.

Economic Status of the Area

Once the appropriate repairs have been undertaken there will be no weight restrictions and hence the bridge will operate as a two lane bridge and will not represent any restriction to production.

Scour Potential

There are currently eight piers in the waterway and no large constrictions as a result of the structure.

4.6.1.1 Capital Cost

The capital costs considered do not include the cost of the engineering investigations or fees required. This is expected to be similar for each option unless otherwise discussed.

Modular Concrete Bridge

It is assumed that 12m spans will be used in the installation. Considering the length of the current crossing is 84m this will result in 7 spans being required. In addition there will be 6 headstocks and two abutments required.

The cost of the deck units is not known.

It is expected that the following construction process will be undertaken:

1. Construction of side track
2. Complete demolition of existing structure and salvage of recyclable components

3. Construction of pile foundations (Geotechnical analysis required however it is assumed piles will be appropriate) – Assume 7 spans therefore 8 pile groups
4. Installation of superstructure – will require crane
5. Construction of approaches

It is expected that one span could be installed on a weekly basis. It is expected that it will take four weeks to complete the preliminary works and to construct the foundations. Therefore it is expected that the bridge will be completed in 11 weeks.

It is expected that the structure will have a life span of at least 70 years.

Concrete Box Culverts

Taking into consideration the approximate cross section of the waterway recorded in the inspection the following list of culvert requirements was generated:

- 4 – 1800*3600 culverts + 4 link slabs
- 3 – 2100*3600 culverts + 2 link slabs
- 2 – 3600*3600 culverts + 3 link slabs
- 3 – 2100*3600 culverts + 2 link slabs

An approximate average price of $3500/culvert unit and $1500/link slab has been assumed for the purpose of the calculations. The width of each culvert unit is 1.2m therefore it has been assumed that there will be six culvert units in each row. Therefore there will be a total of 72 culvert units and 66 link slabs. This results in a culvert material cost of approximately $350 000.

It is expected that these units will have a similar life span as the modular concrete units.

It is expected that steps one and two from the previous option will be repeated in this process. Upon the complete of those activities the following processes are expected to occur:

3. Construction of concrete base slab
4. Installation of box components and link slabs
5. Installation of wing walls and aprons
6. Construction of road over bridge
7. Construction of approaches

Steel Truss Bridge

Considering the span sizes of similar structures in the region it is expected that the crossing could be completed in three spans. This would involve two abutments and two headstocks. It is assumed that concrete headstocks and abutments will be used.

An approximate value of $4200/m^2 has been obtained for the complete design, prefabrication and installation of the bridge. Considering a length of 83m and an approximate width of 7m this equates to a total cost of $2.44 million dollars. It is expected that this infrastructure will have a life span of at least 70.

It is expected that steps one and two from option two will be repeated in this process. From this point it is expected that the following process will be undertaken:

3. Construction of pile foundations – Assume three spans and therefore four pile groups
4. Installation of superstructure – It is expected that the superstructure will be built up in location using prefabricated components.
5. Construction of approaches

Steel Culverts

Due to the similar size ranges of concrete and steel culverts the amount of steel culverts required can be determined from the calculations for concrete culverts. It can be seen that most of the culverts required have a span of 2.1m. Therefore for the purpose of approximating the required culverts it has been assumed culverts with a diameter of 2.1m will be used. As fill materials is required to be placed between adjacent culverts it is being assumed that they will be placed at centres of 3m. Using these parameters it has been calculated that approximately 28 culverts will be required.

The cost of these units is not known.

It is expected that providing the appropriate protective material is used these culverts will have a life span of approximately 75 years.

It is expected that steps one through to three of the concrete box culvert option will be repeated in this process. From this point it is expected that the following process will be undertaken:

4. Installation of the steel pipes – appropriate engineering fill brought in and evenly compacted on both sides of each culvert
5. Construction of wing walls and aprons

6. Construction of road over the culverts

7. Construction of approaches

Fibre Composites

It is expected that this will involve the same process as repairing the bridge in the base case scenario except fibre composite components will be used. It is being estimated that the material cost of fibre composites will be approximately double the cost as the traditional timber components. The cost of installation is expected to be similar to the traditional components. Due to the relatively new presence of these materials in the construction industry the life span is not known. It has been assumed that they will have a life span of at least 70 years.

4.6.1.2 Maintenance

Modular Concrete Bridge

As this is a prefabricated structure it is expected that there will be minimal repair requirements due to design and construction problems. Therefore it is expected that only regular visual inspections will be required. It is expected that these will be on a five yearly basis. Regular removal of debris will also be required.

Concrete Box Culverts

It is expected that similar inspections and maintenance regime will be applied to this structure as the previous structure. Regular removal of debris will also be required.

Steel Truss Bridge

It is expected that this bridge will require frequent visual inspections similar to precast concrete structures. It is expected that a corrosion protection treatment will be applied ever 20 – 30 years. It will also require removal of debris. It will also require regular bolt tensioning to prevent excessive movement. Due to the distance from the ocean it is not expected that excessive corrosion will be an issue.

Steel Culverts

Due to recent failures of similar structures it is expected that this structure will be subjected to a more frequent and intensive inspection regime. Depending on the final treatment used in prefabrication it is expected that corrosion protection treatment will need to be applied within 40 – 50 years. It will also require regular removal of debris.

Fibre Composite

As this is a relatively new civil construction material the long term maintenance requirements are not known. It is expected that a similar inspection and maintenance regime used for timber components will be adopted for this structure. It is not expected that it will require any termite prevention treatments.

4.6.1.3 Day Labour

Modular Concrete Bridge

It is expected that council's day labour team will have sufficient capabilities to undertake the work required under appropriate guidance. It is expected the bridge crew supervisor has sufficient experience to manage the construction appropriately. This form of construction is relatively new to the North Burnett Regional Council and will therefore result in the wider day labour staff obtaining new skills. It is expected that not only the designated bridge crew but the wider day labour force will be utilised allowing good utilisation of capital investment on projects undertaken by the day labour force. There will be contractors required for the piling operations and the crane work.

Concrete Box Culverts

Box culvert installation is common process undertaken by the general day labour force in the North Burnett Regional Council. Despite the significant increase in scale it is expected that the day labour force would be capable of this construction. This would also lead to gaining experience in larger construction operations. There will be contractors required for the crane work.

Steel Truss Bridge

This form of construction has been undertaken twice before in the North Burnett Region. On both occasions the day labour crew has been extensively involved. Therefore it is expected that a majority of this project could be undertaken by the day labour crew in conjunction with a specialised supervisor. Further involvement with this construction would add to the skill base in this area. As with the modular concrete option external contractors would be required for the piling work and crane operation.

Steel Culverts

It is expected that council's day labour crew will be capable of this construction considering the similarities to concrete box construction. It is expected that the new components of the construction can be achieved through adherence to construction plans.

Fibre Composites

Although this form of repair has never been utilised in the region it is expected that with external guidance the day labour crew will be capable of the construction. This will once again add to the skill base.

4.6.1.4 Construction Ease

Modular Concrete Bridge

There are no major difficulties expected in this construction. Once the external contractors have installed the piles it is expected that a similar process will be used for each span. Upon complete of the foundations it is expected that most of the construction will launched off the previous span. Therefore there are no difficulties expected due to the low flow channel.

Concrete Box Culvert

There are several construction difficulties expected in this operation. Firstly the low flow channel must be either blocked or diverted to allow the base slab to be constructed. This has a high potential to cause unforseen problems and associated delays. Secondly due to the size of the culverts only two are expected to fit on a low loader transporter. This will result in the provision of either a large area for storage or careful consideration of arrival and installation times. This has significant potential for delays. Thirdly due to the large scale of construction there is a significant potential for further problems to arise.

Steel Truss Bridge

Despite the experience the day labour crew has in this field it is still expected that this construction process will be difficult primarily due to the high amounts of joints required and the precision required in aligning the structure. However the experience of the crew and external supervisor are expected to be beneficial in overcoming the problems encountered.

Steel Culverts

It is expected that this form of construction will result in a significant amount of construction difficulties primarily associated with ensuring the constant form of the structure through the even compaction of engineering fill on either side. The difficulties encountered in the concrete box culvert will also be encountered in this construction.

Fibre Composites

It is expected that this construction process will be similar to that encountered in the base case scenario. Fewer difficulties are expected due to the lighter component weight however some difficulties are expected due to the usage of different tools.

4.6.1.5 Economic Status of the Area

There are no weight restrictions expected from any of the options considered.

4.6.1.6 Scour Potential

Modular Concrete

It is expected that this option will result in slightly fewer piles in the waterway. Assuming the pile diameter is the same this is expected to result in a reduced potential for local scour. There is no substantial change in waterway area and constrictions therefore the potential for constriction scour is not expected to change.

Concrete Box Culvert

The potential for local scour is expected to be less due to the base being concrete. However there are a considerable amount of constrictions across the waterway due to the culvert legs and any fill material between the culvert lid and the road. Therefore the potential for constriction scour is considered to be high.

Steel Truss

Due to the longer span of this structure there will be fewer piles in the waterway. Therefore the potential for local scour is reduce. There is however a large truss structure in the waterway which has the capabilities to collect debris. When this truss has a significant debris loading it will act as constriction to flow and will result in a large potential for constriction scour.

Steel Culverts

It is expected that this will have a similar scour potential as the concrete box culvert option.

Fibre Composite

It is expected that this option will result in a similar scour potential as the base case.

4.6.1.7 Disturbance to Waterway

Modular Concrete

It is not expected that this option will significantly change the current disturbance to the waterway. There will be minor disruptions associated with demolition of the existing bridge and creation of an access path for the piling equipment.

Concrete Culvert

Due to the excessive constriction of the waterway resulting from this option it is expected that the ability for fish passage to occur will be reduced. This is expected to occur despite adherence to the appropriate guidelines. As waterway area will decrease it is also expected to reduce the ability for terrestrial species to pass. Due to the extensive work required to reshape the waterway in the vicinity of the crossing it is expected that this option will also cause further disruption to the natural waterway.

Steel Truss Bridge

In low flow situations it is not expected that this option will significantly affect the fish passage. However as the flow height approaches the level of the truss it is expected to create significant difficulties and dangers to fish passage.

Fibre Composites

There is not expected to be any changes in disturbance to the waterway in comparison to the base case scenario.

4.6.2 Flagstone Bridge

4.6.2.1 Base Case Scenario

Capital Cost

An analysis of the level two bridge inspections has found that the following major components require immediate replacement:

- 18 Girders
- 12 Corbels

There are no other significant differences between this bridge and Jack Parr Bridge when considering this analysis.

Options Analysis

The same options are being considered in this analysis. The only significant difference between the proposals for Jack Parr Bridge and Flagstone Bridge is the length of the crossing and therefore the amount of units required. Due to the limited depth of this analysis it is not expected that this will create significant differences scores of each proposal. Therefore the same scores have been awarded for these options.

4.6.3 Derrabungy Bridge

4.6.3.1 Base Case Scenario

The previous Derrabungy Bridge was destroyed in the December 2010/January 2011 flood event. There is however an existing bridge across the waterway which is not currently connected to the roadway. This bridge is a timber beam bridge similar in design to the other structures considered in this investigation. Therefore the same scores have been awarded for these proposals.

4.6.4 Waratah Bridge

4.6.4.1 Base Case Scenario

The existing structure is a timber beam bridge. There are no significant differences between the proposals for this option and the other proposals analysed for Jack Parr Bridge. Therefore these options have been given the same scores as the options for Jack Parr Bridge.

5 Discussion

5.1 Selection of Case Studies

5.1.1 Jack Parr Bridge

Jack Parr Bridge is situated 12km west of Mundubbera on Coonambula Road. The existing structure is a nine span two lane timber beam bridge which crosses the Burnett River. The existing bridge can be seen in figure 36. Coonambula Road has been classified as a Local Road of Regional Significance. It is a two lane bitumen sealed road from Mundubbera to Jack Parr Bridge and turns to a well maintained gravel formation past the bridge. The bridge services a citrus orchard, a significant amount of cattle properties and a low density rural sub division. Local anecdotal evidence suggests that the bridge is submerged on average three times a year for between 24 – 48 hours. During the December 2010 – January 2011 flood event the bridge was submerged for a considerably longer period. The bridge is the first major waterway crossing on Coonambula Road from Mundubbera.

Figure 36

Figure 36: Jack Parr Bridge

5.1.2 Derrabungy Creek Bridge

Derrabungy Creek Bridge is situated 35km south of Mundubbera on Beeron Road. The previous structure was a single span steel truss bridge which was destroyed in a January 2011 flood event as can be seen in figure 37. The creek is a tributary of the Boyne River which in turn is a tributary of the Burnett River. In the vicinity of the bridge Beeron Road consists of a gravel formation. The previous structure serviced approximately three permanent residences with the predominant industry in the area being beef cattle. Between the township of Mundubbera and Derrabungy Creek there is a relatively low level crossing of the Boyne River. Approximately 10km past this crossing Beeron Road crosses Beeron Creek at a low level crossing. Derrabungy Creek has been described through local anecdotal advice as being a fast rising and fast falling creek. It has been suggested that the low level structure in place prior to the steel truss bridge was only submerged on average for a total of one day every year. There is currently a single lane side track in place around the existing structure.

Figure 37

Figure 37: The existing steel truss bridge after being destroyed.

5.1.3 Flagstone Bridge

Flagstone Bridge is located on Hawkwood Road approximately 19km south west of Mundubbera. The existing six span bridge crosses the Auburn River just upstream of its confluence with the Burnett River. The existing one lane structure comprises a timber girder superstructure with concrete piers as a substructure. This structure can be seen in figure 38. Hawkwood Road is a Local Road of Regional Significance which was once a part of the state road system. It varies between single lane and double lane bitumen in the vicinity of Flagstone Bridge. The bridge services a relatively large cattle industry, a feedlot, a citrus orchard and an irrigated broad acre cropping property. The relatively low level Boyne River Crossing mentioned previously also forms part of the route between Mundubbera town ship and Flagstone Bridge. There is also another low level crossing of the Auburn River further along Hawkwood Road. Local anecdotal evidence suggests that Flagstone Bridge is submerged for approximately 12 days every year. It has been suggested that this flooding is through both natural flow and through back up flow from the Burnett River.

Figure 38

Figure 38: Flagstone Bridge

5.1.4 Waratah Bridge

Waratah Bridge is located on Cahalane Road approximately 10km North of Monto, near the small township of Mungungo. The existing single lane four span timber beam bridge crosses Monal Creek. The area around Waratah comprises irrigation farming, dairy farming and beef cattle grazing. Cahalane Road between Mungungo and Waratah Bridge is single lane bitumen seal and is a gravel formation past Waratah Bridge. Anecdotal evidence suggests that the bridge is rarely submerged during flood events.

5.1.5 Case Study Selection

The selection of the case studies provides a good cross section of the features discussed in the methodology. Firstly, the roads the bridges are on cover different categories. Coonambula Road and Hawkwood Road are both Local Roads of Regional Significance meaning that they have strategic importance as a connection in the wider road network outside of the North Burnett Region. Beeron Road is collector road which services only the properties which are located on it and as a collection for several minor roads. Cahalane Road is similar to Beeron Road except the location of Waratah Bridge means that it services a substantial more amount of people. This leads to another difference between the bridges. Both Flagstone Bridge and Jack Parr Bridge service a significant amount of properties in comparison to Derrabungy Bridge, which only services approximately three properties. Each of the bridges crosses a different waterway. Jack Parr Bridge crosses the Burnett River which is the predominant river system in the area. Flagstone Bridge traverses the Auburn River which is one of the major tributaries of the Burnett River. Monal Creek, which Waratah Bridge crosses, is another significant tributary of the Burnett River. Derrabungy Creek however is a smaller creek which based on anecdotal evidence, generally only has reasonable flows after periods of rainfall. This is related to another key difference between the bridges. Flagstone Bridge is generally expected to be submerged for approximately 12 days every year, Jack Parr six days a year, Derrabungy a total of one day a year and Waratah never. Another difference between the bridges is the types of industry which they service. The area which

Derrabungy Bridge is located is predominately cattle grazing whereas the other bridges service more diverse and intensive industries. Both Flagstone Bridge and Jack Parr Bridge service citrus orchards and irrigated cropping, both of which are considered more intensive industries than cattle grazing. Waratah Bridge services the dairy industry which could also be considered a more intensive industry than cattle grazing. The differences mentioned above will allow for a wide variety of issues to be discussed throughout the investigation.

5.2 Local Analysis Discussion

5.2.1 Criteria Selection

The criteria used for assessing each of the options in the first analysis have been formed from the literature, through the advice of North Burnett Regional Council employees and through experience in local government engineering. The criteria selected have been deemed to be relevant to positional changes of the bridge.

Economic Criteria

Capital Cost

In this analysis the capital costs refer to the cost incurred with constructing the bridge in each different location. Due to the scope of this assessment the capital cost involved in constructing the actual infrastructure has not been considered. Incorporated into this analysis includes the cost of earthworks required to reconstruct the approach road, the clearing and grubbing required in the bridge alignment, the cost of purchasing any required land, any extra engineering or surveying costs required and the extra cost or saving from any changes in deck area. The cost of earthworks and clearing is considered as this has the potential to incur significant costs. Detailed plans would be required to determine an accurate estimation of the earthworks required. The development of these plans for each option is a time consuming and expensive activity which is unlikely to be replicated in a practical situation. Therefore a rough approximation of the earthworks required has been developed by considering both the type required and the quantity. For some of the options considered the proposed alignment of road is outside the existing road reserve. The purchase of neighbouring land would therefore be required. Due to the difficulty in accessing previous sales data in the area, the costs of purchasing the land was rated by considering the size of the parcel required, its location and its previous land use. If the alignment of the bridge is to be moved there will be surveys required to map the natural waterway and engineering plans required for the earthworks required and for the survey required. Further costs may be incurred to obtain the required permits for works within a waterway. As accurate cost of these plans, surveys and permits is unknown, this cost will be rated by considering what is required. When increasing or decreasing the height of the deck height it can be seen that there is a corresponding potential for an increase or decrease in the length of the structure. As the actual revised cost due to the change in deck area can only be accurately determined by considering which replacement or repair option is used, this relative cost will be rated by considering the extent to which the deck area will be changed.

As with any project undertaken by any entity the capital costs of the bridge repair or replacement is an important consideration for local government authorities. Therefore the capital costs of the project have been given a rating of 5. As the base case option maintains the current bridge alignment it can be seen that there is minimal costs associated with this option. Therefore there is limited scope for any other proposal to be scored a positive value. One possible scenario which could arise which would result in reduced cost from the base case scenario would be if upon investigation it was found that the current alignment encroached on neighbouring properties and the local government authority was required to purchase the land. Whilst it is relatively uncommon for this scenario to eventuate, it has been known to occur and must therefore be considered. In most other situations it is therefore considered that the all other proposals will achieve a negative score. For an option to achieve a score of negative five it must result in significant costs being incurred for each of the components previously discussed. A score of negative one has been given to an option where there are only limited costs associated with the work required.

Flood Immunity

This is an economic criterion used primarily to assess the economic response to a change in the flood immunity offered to a region. This has been assessed by considering the change in time in which the area is isolated and the productivity of the isolated area. When considering the time the area is isolated for the flood behaviour of the waterway is assessed. In this assessment both the frequency of large flood events and the average length of flooding is considered. If flood data suggests that a particular option will result in the bridge being submerged frequently for large periods of time the option will be given lower rating than if it would result in the bridge being infrequently submerged and when submerged only for brief periods. Another important consideration is the productivity of the isolated area. This rating will be based upon the industries which are known to operate within the isolated area. This rating will range from high where the area is predominately residential and the production lost is due to workers being unable to travel to work and for low intensity industries such as beef cattle grazing to a low rating where intensive industries such as dairy farming and pork production take place. Another component of the rating will be based upon the effect of the weather conditions on the productivity. The productivity of many rural enterprises is largely dependent upon the weather. Therefore depending upon the catchment area of the waterway and the location of the crossing, assumptions can be made regarding the affect of the rainfall on the productivity of the area. If the catchment area is relatively small it can be assumed that the rainfall required to create flood conditions in the waterway would also have fallen in the isolated area. This assumption becomes less accurate as the catchment area increases and hence the possibility of high rainfall in another area increases.

The crossing infrastructure is an asset of the local government authority. From the literature it was found that any cost benefit analysis should be undertaken from the perspective of the asset owner. It is known that the productivity of an area is proportional to the rates which are charged by council to the land owner. Therefore it is acknowledged that if as the replacement or repair option has the potential to affect the productivity of the area it can also affect the income of the local government authority. However this relationship is minor when comparing the potential increase in income compared to the capital investment required. From this perspective the effect of flood immunity on the production of the area should be rated significantly lower than the capital cost of the investment. However it is also acknowledged that there is a political dimension which also needs to be considered. An aim of the local government is to represent the constituents. Therefore the decisions made by the local government authority must consider the welfare, and subsequently the economic performance, of the constituents. When considering both of the points previously raised this criterion has been rated a four.

Environmental Criteria

Scour Potential

This assesses the potential for scour at each location. Whilst the final design of the infrastructure will have a significant effect on the scour at the site, it is possible to assess the potential for scour by considering the most likely cross sectional area of flow and any constrictions which have the potential to initiate constriction scour. If an option removes any obstacle in the waterway which would cause constriction of the flow, it will be rated higher than an option which increases the constriction in the flow. The potential for natural scour has also been assessed by considering the existing condition of the waterway. If there is evidence of natural scour at the proposed site this proposal will receive a lower score than a proposal where no evidence of natural scour found.

Scour can have a potentially damaging effect on the bridge infrastructure as well as on the habitat in the local vicinity of the bridge. There are however design considerations which can be implemented to reduce the scour on sight. As the problems associated with scour can mostly be overcome through design considerations this option has been rated a two.

Meanders

This is to determine the likelihood and effect of changes to channel location through the waterway meandering. This has been assessed by analysing aerial images of the site to determine the presence of any meanders further upstream. It has been found through the literature that meanders migrate downstream and increase in amplitude therefore only the upstream waterway has been considered. The extent to which the waterway has meandered in the past and the rate at which it appears to be meandering have both been considered.

A change in stream bed location can have a significant impact on the performance of the bridge. This natural shift in location cannot easily be altered through intervention. Therefore this option has been given a rating of five.

Bank Stability

This assesses the stability of the waterway immediately adjacent to the proposal. This has been assessed from the site inspection by determining if the bank has eroded in the vicinity of the possible sites. If there is evidence of significant instability at the site of a proposal, this proposal will be scored considerably less than a proposal with no evidence of instability.

An unstable bank has the potential to cause extensive destruction to a bridge. However with appropriate design considerations the extent of this damage can be substantially reduced. It is suggested that the design considerations required to overcome bank instability are more complex than those required for overcoming scouring and therefore this option has been rated a three.

Disturbance to the Waterway

This is to assess the relative disturbance which each option creates in the waterway. Although the total disturbance to the waterway will be dependent upon the final replacement or repair option selected, the potential for disturbance can be assessed for each option. The relative disturbance to the waterway will be determined by considering the effect on fish passage, terrestrial animal passage and the disturbance of the natural waterway. The ability for fish passage is determined by considering the appropriate government guidelines for allowing adequate fish passage. The ability for terrestrial animals to pass is determined by considering the height of the proposal above the waterway, the adjacent waterway conditions and the animal species known to be in the area. The disturbance to the natural waterway is determined by considering the effect of the proposal on the waterway returning to its natural state.

Allowing maximum connectivity between sections of a waterway is an essential component in maintaining the environmental health of that waterway. Ensuring adequate fish passage and terrestrial animal passage through crossings removes the potential for a break in waterway connectivity. Ensuring that the crossing meets the government legislation and guidelines also prevents the local authority being prosecuted. Allowing the waterway to return to a more natural state is beneficial to the species in the area and also provides a more attractive landscape for the area. Considering fish passage is a requirement by legislation and for the other reasons discussed above this criterion has been rated five.

Destruction of Habitat

This is to assess the amount of flora to be removed as well as the relative ecological importance of the species removed. The ecological importance of the species is considered through two different means. Firstly the site has been inspected to determine if any known endangered or of concern species are present in the area. Secondly a search is undertaken through the Department of Environment and Resource Management to determine if any of the habitats present on site match the descriptions provided for endangered or of concern habitats. This criterion also considers the need for clearing permits under the appropriate legislation.

The clearing of habitat is closely scrutinised under both the Vegetation Management Act and the Nature Conservation Act. Any work which is undertaken outside of these acts can potentially result in significant fines. It can also result in the destruction of endangered stands of habitat. In addition to this clearing of habitat is one of the most evident forms of environmental destruction witnessed by the public and can therefore affect public opinion of council. For these reasons this criterion has been rated a five.

Social Criteria

Flood Isolation

The concept of flood isolation is closely related to the immunity aspect covered under the economic criteria. However this criterion assesses the social aspect of isolation. It assesses the time in which a portion of the community is isolated from the larger community and the detrimental effects on the mental and social well being which could potentially result. It also assesses the practical effects on the community. As there is no access to the population centres, affected residents are unable to purchase living necessities and must sustain on pre purchased supplies or have supplies brought in by boat or by air. It also takes into consideration the fact that students are not able to attend their learning institution. As with the economic aspect of isolation this criterion also takes into account the frequency of the isolation as well as the average duration of isolation. In addition to this it also takes into account the size of the isolated area and the access to essential services.

The social health of the community is an important consideration. However periodic isolation is common feature of life outside of population areas in many regions of Australia. Households are capable of preparing for such events by increasing non perishable food supplies and by installing generators. In addition to this the rapid development of communications technology enables people remain connected with the larger community. With regard to emergency services, rescue helicopters are within close proximity and can be dispatched to access the isolated area when necessary. For these reasons this option has been given a rating of 3.

Safety

This assesses the safety of the proposed alignment. Whilst the safety of travel on the bridge will be influenced by the final replacement or repair option selected, the position of the bridge will have an effect on travel safety. This will be assessed by considering the resulting alignment of the road as well as the sight distance each option provides for the driver to the bridge.

The safety of road users is of the utmost importance to any authority in control of any road network. For this reason alone this option has been given a rating of 5.

Effect on nearby residents

This assesses the impact on the surrounding properties. This criterion considers the distance between the road and any nearby houses and any land which will need to be purchased for construction to take place. The distance between the approach road and a household will affect the noise and dust levels from the household. The expected traffic counts as well as the road surfacing have been taken into consideration in this assessment. Whilst the landholder will be adequately reimbursed for the purchase of land, it is possible that there will be some emotional cost associated with losing the land.

The noise and dust nuisance will only impact a small amount of landholders. There are also certain buffer distances which will be adhered to between the road and the nearest property. When considering the purchase of land, it is expected that this will only be a small portion of land in each circumstance. As it is unlikely to involve the purchase of entire allotments it is not expected that this will have a significant effect on the land owner. For these reasons this option has been rated a two.

5.2.2 Results Discussion

5.2.2.1 Jack Parr Bridge

Capital Cost

Option three has been given a score of -2. This option involves minimal earthworks in altering the vertical alignment of the road to suit the vertical shift in the bridge. It does not provide any cost savings as the deck area is expected to remain constant. Option two (a) has been scored -3 as, in addition to altering the vertical alignment of the road, it also involves the increased cost of the increase in deck area of the bridge. Options four and five have both been given a score of -5. These options both involve a relatively high cost activity of constructing approximately one kilometre of Coonambula Road. In addition to this they both require extensive cuts to be made into the waterway. An additional cost involves the purchase of land outside of the existing road reserve and the associated legal and surveying costs to complete the transaction. Extensive geotechnical investigations would be required to determine the geological characteristics of the new site.

Flood Immunity

Option two has been given a score of two. As was previously discussed, due to the industry in the area being predominantly weather dependant it is not expected that there will be great losses in productivity due exclusively to isolation. One benefit of the increase in immunity is that residents in the affected area are not isolated from jobs in industries not as heavily weather dependant as cattle grazing which in turn reduces the economical impact for the region. For primarily the same reasons as discussed above option three has been given a score of -1. There is expected to be a slight increase in the average amount of days the area is isolated resulting in a poorer economic outcome for non weather dependant industries. Options four and five have been given a rating of 1 as they are not expected to affect the flood immunity of the area.

Scour Potential

Option two (a) has been given a score of 3 as the reduction in the embankment is expected to significantly reduce the potential for constriction scour. Option three has been given a rating of 2 as it represents a similar constriction in the waterway at a lower flood height than the option two (a). Option two (b) has been given a score of -3 as it represents a significant constriction to the flow. Both options four and five have been scored a 1 as it is not expected that they result in changes to the scour potential. For an option to be given a score greater than three they would need to represent a further increase in flood height before the flow was constricted. Any greater flow constriction, as well as an increase in potential for natural scour, would result in an option been given a lower score than option two (b).

Meanders

Both options two and three have been given a score of 1 as they do not represent any change in the potential for meanders. As the distance between the proposed options four and five are relatively small, the change in potential for meanders is considered insignificant and both of these have been given a score of 1.

Bank Stability

All options have been given a score of 1 due to there being no evidence of instability found during the inspections.

Disturbance to Waterway

Option two (a) has been scored 3. This option represents an increase in the potential for fish passage due to the decrease in the embankment. It also aids the terrestrial passage and allows the waterway to return to a natural state. Option three has been scored a two as while it does increase the potential for fish passage and aid in the waterway returning to a natural state, it decreases the ability for terrestrial species to pass. Options four and five have been given ratings of -4 as while they are not expected to have impacts on fish or terrestrial passage they do represent substantial environmental disturbance through the construction of a new cutting and the substantial disruption to a previously untouched crossing location. Option two (b) has been given a rating of -3 as it decreases the fish passage and negatively impacts the ability of the waterway to return to its natural state. It would be scored lower except for the increase in potential for terrestrial passage.

Destruction of Habitat

Options two and three have been given scored 1 as they do not result in any clearing of habitat. Options four and five have both been scored -4 as they require substantial clearing for both the approach road and the crossing of the waterway. These options would be scored lower if the habitat to be cleared was endangered or of concern.

Isolation

Option two has been scored two. This option decreases the isolation of the affected area. However the effect of the isolation has been considered to be minimal. Firstly there is another route which has increased immunity which could be utilised by residents to access services. The isolation of this secondary route has been estimated at average of one day every year. Therefore the social disadvantage of isolation can be primarily attributed to the nuisance of not being able to use the normal travel route. Secondly in times when the secondary route is isolated there is a relatively large community which is isolated. It is therefore expected that due to the size of the community the social effects of isolation will be reduced. Thirdly, the existing crossing provides a good launching point for flood boats to transport the required food and material supplies to the affected area. Finally, considering the flood heights and flood durations it is not expected that an increase in deck height of 1 – 2m will result in a substantial decrease in the amount of days the bridge is currently submerged. For an option to be rated higher it would be required to provide further increases in immunity and would need to result in a more profound effect on the community. For primarily the same reasons s discussed above option three has been rated -1. Options four and five have been rate one as they are not expected to alter the isolation of the area.

Safety

Option four has been scored 3 as it represents an increase in safety due to changes in the horizontal alignment. This option would be scored higher if it represented further changes in the horizontal alignment in conjunction with beneficial changes in vertical alignment. Option three has been scored 1 as it is not expected to provide a significant change in the safety. It may result in a localised increase in gradient but considering the relative mild gradient of both approaches this is not expected to represent a significant safety issue. Option two has been given scored -2 as it represents a reduction in sight distance for drivers entering onto the bridge from the horizontal curve. As it is assumed this is a two lane bridge the effect is not expected to be as significant as if it was a single lane bridge requiring the entering driver to give way. Option five has been scored -3 as it represents a significantly worse horizontal alignment. This option would be scored lower if it resulted in a worse vertical alignment and if the road surface was in worse condition.

Effects on Nearby Residents

Options two and three have been rated one as they are not expected to have any impact on nearby residents as the horizontal alignment will not change. Option five has been scored -2 as it represents a significant purchase of land and results in the approach road being closer to a house. Option four has been rated -3 as it also results in a significant purchase of land in conjunction with the horizontal alignment being close to a house. This has been rated lower then option five as the approach road will be closer to the house and a portion of the land lost is a citrus block which is considered more productive than the land lost in option five. A lower score would be given if the road was dirt, which results in greater dust, if further productive land was required or if a house was to be resumed.

5.2.2.2 Flagstone Bridge

Capital Cost

Option three has been scored -1. It has the potential to slightly reduce the deck area required. However there are earthworks required to reconstruct the approach road. It is suggested that these approach works will more than offset the small reduction in deck area. For an option to be scored higher it would require a significant reduction in the deck area required. Option two has been scored -2 as it represents a significant increase in deck area required. It also results in works to reconstruct the approaches. Option four has been scored -4. This option results in significant clearing and earthworks in the waterway to create the approaches to the bridge. It also requires extensive work to realign Hawkwood Road. This option would be scored lower if it also resulted in an increase in deck area.

Flood Immunity

Option two has been scored two. This option represents an increase in immunity for several residents on Hawkwood and Cheltenham Roads. However approximately 20km past the Flagstone Bridge there is another crossing of the Auburn River on Hawkwood Road with a similar immunity to the existing bridge. Therefore it does not affect the immunity of residences past this point. It is expected that the majority of people on Cheltenham Road will not normally travel along Hawkwood Road to access essential supplies. In addition to this the area is predominantly used by the beef cattle industry and as discussed for Jack Parr Bridge, the wet weather is expected to severely limit production. This option would be scored greater if it serviced more residences or was more greatly relied upon by industry. Option three has been scored -1. This option will decrease the flood immunity of the area, however for the reasons discussed above this is not expected to have a substantial effect on the area. Option four has been scored 1 as it does not affect the flood immunity of the area.

Scour Potential

Option two has been scored two. The reduction in scour potential which is achieved through this option is considered minimal. For an option to be scored higher it would require a further reduction in scour potential. Option three has been scored -2 as it results in scour at lower flows which results in a longer opportunity for scour during large flood events and more opportunity for scour as scour occurs during lesser flood events. Option four has been scored 1 as it is not expected to affect the potential for scour.

Meanders

Option four has been scored one. Considering the scale of the meanders and the distance between the existing bridge and the proposal it is suggested that there is limited change in potential. If the waterway bed was known to be meandering at a rapid rate and a proposal was downstream of the existing bridge, this option would be scored lower. Both options two and three have been scored 1 as they represent no change in the potential for the effects of meanders.

Bank Stability

All options have been scored one as there is no evidence of bank instability in any locations.

Disturbance to the Waterway

Option two has been scored 3. This option results in benefits to fish passage, terrestrial passage and further encourages a return to the natural waterway. To be scored higher it would need to result in further benefits to the natural waterway and further reduce obstacles to fish passage. Option three has been scored -2. This proposal results in a negative impact on the three key components of this criteria discussed previously. It would be scored lower if it further reduced fish passage and created a greater disturbance on the natural waterway. Option four has been scored -3. Although this option is not expected to affect the potential for fish or terrestrial passage, it will have a significant effect on the natural waterway through the construction of a new cutting into the bank. This option would be scored lower if it resulted in further disturbances to the waterway in conjunction with a decrease in the ability for fish and terrestrial passage.

Destruction of Habitat

Option four has been scored -3. This option results in significant clearing of trees and shrubs both in the waterway and on the bank. It would be scored lower if it resulted in the clearing of protected, endangered or of concern regional ecosystems or species. Options two and three have both been scored one as they do not result in any habitat clearing.

Isolation

Option two has been given a score of 2. Although it does result in reduced isolation for several residences the impact of this is reduced by the fact that there is another bridge on Hawkwood Road with similar immunity. In addition to this there is an alternative route which offers people slightly greater immunity than Flagstone Bridge. Further to this, considering the flood behaviour of the Auburn River, it is not expected that there will be frequent occasions when Flagstone Bridge is submerged for a high amount of consecutive days. The effect of isolation was also taken into account as discussed for Jack Parr Bridge. Option three has been scored -1 for primarily the same reasons as discussed above. If Flagstone Bridge is isolated at this lower level then traffic can be diverted through the alternative route. Option four has been scored 1 as it will not affect the isolation.

Safety

Option two has been scored -2. This option results in a decreased sight distance from the horizontal curve to the start of the bridge in both directions. This option has been rated lower due to the fact that it is a one lane bridge and requires one direction of traffic to give way. However taking into consideration the design speed of the road and the surface material it is expected that the sight distance provided is sufficient to meet the appropriate guidelines. An option would be rated lower if it resulted in worse horizontal or vertical alignment or if the stopping sight distance did not meet the required guidelines. Option three has been rated 2. It offers an advantage to the driver by increasing the stopping sight distance. It is suggested that a portion of this benefit is offset by the small increase in slope required to allow the approach road to meet the bridge. Option four has also been scored 2. It does represent a slight improvement in the horizontal alignment of the road. This option would be rated higher if it resulted in further improvements to the horizontal alignment, improvements to the vertical alignment or an increase in bridge width to allow two lanes of traffic.

Impact on Nearby Residents

Option four has been scored -1. This option does result in a portion of land being resumed however this is only a small portion and does not appear to be land used for intensive production. In addition to this it is not expected to significantly increase the affect on any nearby households. Options two and three have been rated 1 as they do not result in any change to the impact on the nearby residents.

5.3 Network Analysis

5.3.1 Selection of Criteria

Economic Criteria

Travel Distance

When analysing the differences between trips using different routes travel time is a usual criterion. However as most of the roads used in the analysis have a gravel pavement, their condition changes considerably depending upon use, weather and time elapsed since maintenance work. This change in condition has the potential to result in a significant change in travel time. Therefore the travel time of each of the trips will vary considerably. In addition to this, due to the current condition of some of the roads it is expected that significant upgrade works will be required on the road which will have a greater affect on travel time then on travel distance. Therefore it is expected that the travel distance is a more reliable comparative indicator than travel time in this situation. The portion of each trip which is undertaken on sealed roads of appropriate standard will also be considered in this analysis as the average speed through these sections is expected to be greater than through a section of gravel road.

The travel distance associated with a trip affects both the financial and nuisance costs of the trip. However this has no direct affect on the local government authority and is not expected to be a significant cost to road users. Therefore this has been rated a three.

Economic Benefit

This assesses the effect of the proposal on the economic status of the region. To differentiate this criterion from the similar criterion in the local positional shift analysis this will consider the effects of being connected to the outside region. Although the primary focus is on the economic status of the affected area, this criterion has also considered the effect on the larger region by maintaining a link to the affect area. A proposal will be rated high if it can be demonstrated that it will result in greater economic value than the current situation.

This criterion has a similar effect as in the previous analysis and will therefore also be rated a four.

Capital Cost

This assesses the capital investment required by the local government authority to undertake the appropriate upgrades to the transport infrastructure to allow for changes in traffic flow as a result of each proposal. The proposals may result in traffic being diverted to other roads. If these roads have not been designed for this increased traffic flow then damage can occur. This criterion will primarily consider the current condition of the road, the increase in traffic flow, the expected weather conditions when the route will be used and the intended upgrade. In addition to this the usage of the upgrade will also be considered. For this particular aspect of the criterion if a proposal results in an upgraded section of road being used for high traffic flows on average only every five years, it will be rated lower than a proposal which results in the upgraded section of road being used on a daily basis.

As this represents a direct capital investment by the local government authority it has been rated a five.

Social Criteria

Isolation

This assesses the social aspect of isolation from population centres. This criterion is essentially the same as considered in the previous analysis with one key difference. This criterion also assesses the effects of the isolation from larger population centres outside of the region.

Due to the similarities between this criterion and one used in the first analysis, it has also been rated a three.

Safety

This assesses the safety of the routes used under the scenarios. This criterion will primarily consider the alignment of the roads. It is assumed that the pavement condition will be to an appropriate standard to ensure adequate safety considering the upgrades discussed in the previous criterion. In conjunction to the alignment of the roads this criterion will also consider the expected weather conditions when alternative routes are required.

As in the previous analysis the safety of the road user is of the utmost importance. This option has therefore been given a rating of five.

5.3.2 Results

Travel Distance

The opening of Jack Parr Bridge in conjunction with the Boyne River Bridge has been scored 4. The opening of Flagstone Bridge in conjunction with the Boyne River Bridge has been scored 3. Both options allow the opening of all routes however the first option provides a lower amount of travel distance and a greater amount of travel along state roads. For an option to be rated higher it would be approaching a similar travel distance as achieved under normal conditions and would have a greater amount of travel on the state roads. The option of opening Jack Parr Bridge alone has been scored 2. This option allows for two trips to be made with a considerable portion of these trips on state roads. However, one trip option results in considerably longer travel than under normal conditions. The option of opening Flagstone Bridge alone has been scored 1. It only allows one trip to be made and this trip, despite being of similar length as under normal conditions, is entirely on council roads. The two options involving Derrabungy Bridge have been scored one as they do not provide a change from the base case conditions.

Isolation

As the raising of Derrabungy Bridge will have no effect on the isolation of the area it has been rated a one. Although raising the Boyne River Bridge in conjunction with Derrabungy Bridge will result in an increase in immunity for area, Derrabungy Bridge has no network function and therefore this option has also been scored one. Raising of Jack Parr Bridge will result in two trips being possible. To accurately analyse the benefits this reduction in isolation has on the area, the effect of isolation must be determined. The flood analysis results suggest that both the Boyne River Bridge and the Eidsvold Station Bridge are submerged for, on average, 1-2 days every year and that they are generally not submerged for more than two days in succession. Whilst isolation of two successive days could be considered a nuisance to residence it is not suggested that this will cause a significant problem across the area. Being isolated for greater than three days could result in more practical problems such as limiting food re – supply and not being able to attend work or/school. However, as was witnessed in the most recent flood events in the region, flood boats are capable of making food drops to affected areas. Another important consideration is access for emergency services. Although road access would be greatly restricted, aerial access could still be attained. In addition to this the fact that the area is only ever isolated for short periods of time suggests that there will not be a substantial social cost from being isolated from larger population centres. As it does result in an increase in services and reduction in nuisance cost this option has been given a score of three. Raising of Flagstone Bridge results in one trip being able to occur. Taking into consideration the reasoning discussed above and that only one trip can be made this option has been given a score of two. The two options which involve raising the Boyne River Bridge have been scored 5. Despite the fact that the effects of isolation have been considered as limited these options do result in the best possible outcome and must therefore been given the highest possible score.

Capital Costs

The two options regarding Jack Parr Bridge have been scored -4. They represent a significant investment in repairing the road. The nature of the widening and gravel sheeting works also adds to the capital investment. In conjunction with this there is only limited effective use of this upgrade as the isolation of the area occurs infrequently. For an option to be rated lower it would represent the need for further works to be undertaken and the upgrade to be more extensive such as the installation of drainage structures or bitumen sealing work. The two options involving Flagstone Bridge have been scored -3. They represent similar works to be undertaken as for the Jack Parr Bridge options however it is expected that there will be less as only Cheltenham Road will require extensive work. As before there will be limited effective use of the upgrade. The options associated with Derrabungy Bridge have been scored 1 as they do not represent any upgrade works.

Safety

The options associated with Jack Parr Bridge have been scored -3. The detour through Coonambula Road will still represent a decrease in safety even if the alignment is upgraded to the minimum standard. In conjunction with this the new route represents a significant increase in length of gravel road travelled in wet conditions. The options associated with Flagstone Bridge have been scored -2. The alignment of Cheltenham Road will also represent a decrease in safety as well as an increase in the length of the gravel road travelled. However the length of the travel through the most dangerous sections is expected to be greater with the Jack Parr Bridge options. The options associated with Derrabungy Bridge have been rated one as they represent no change to safety. For an option to be rated less than -3 it would represent an alignment below the standard and on worse surface conditions. For an option to be scored greater than one it would represent an alignment better than the base case scenario.

Economic Benefits

The options associated with Derrabungy Bridge have been scored 1 as they represent no change in economic situation of the area. The option of opening Flagstone Bridge alone has been scored two as it represents a small increase in the allowable production. The option of opening Jack Parr Bridge alone has been scored 3 as it represents a further increase in allowable production. The options of opening Jack Parr Bridge and Flagstone Bridge in conjunction with the Boyne River Bridge have been scored five as they represent no production restrictions. The scores assigned could be altered if consideration was taken for the importance of each route to the production of the area. This further analysis has not being undertaken in this investigation and hence the option was assessed against the number of routes opened.

5.3.3 Local Shift Analysis Results Discussion

5.3.3.1 Jack Parr Bridge

The results of the local positional shift and network analyses are repeated below in table 27 and table 28.

Table 27

	Economical	**Environmental**	**Social**
Option			
1	9	20	10
2a	-7	34	-2
2b	-7	-8	-2
3	-14	27	4
4	-21	-30	12
5	-21	-30	-16

Table 28

	Economic	**Social**
Base Case	12	8
D	12	8
D+BRB	12	8
JP	-2	-6
JP + BRB	12	0
FS	-4	-4
FS + BRB	14	5

The first process in deciding the most appropriate position for the new bridge is to eliminate all options which result in a worse performance than the base case scenario. From table 27 it can be seen that option five and two (b) meet this criteria. On closer inspection it can be seen that option four results in a significantly worse economical and environmental outcome and only a slighter better social outcome. Due to the significantly worse environmental and economical outcomes this option has been disregarded. Therefore the only options left in consideration are raising the bridge without increasing the embankment (option two (a)) and lowering the deck height. It can be seen that option 2a represents a significantly increased environmental performance. This increase in performance is offset by the subsequent substantial decrease in social and economical performance. As this option represents an increase in deck height it must be considered in conjunction with the network analysis. It can be seen from table 28 that neither of the options which involve Jack Parr Bridge represents a better performance than the base case scenario. Therefore the option of raising the deck height has also been disregarded. A similar outcome from the local analysis is achieved for option three. The fundamental reason behind not using addition of scores between criteria category boundaries was to ensure that a sever deficiency in one category will not be offset by substantially better performance in another category. Therefore for any option to be further considered it would require at least a similar performance as the base case scenario in all categories and a better performance in at least one. Therefore it is recommended that the base case scenario be adopted for Jack Parr Bridge.

5.3.3.2 Flagstone Bridge

Table 29

	Economical	**Environmental**	**Social**
Option			
1	9	20	10
2	-2	32	-2
3	-9	-1	9
4	-16	-20	11

Option three, lowering the deck height, has been disregarded due to the resulting worse performance in all categories. It can be seen that option four, moving downstream, results in a slightly increased social performance. This is however offset by a significantly worse economical and environmental performance. Therefore this option has been disregarded. As option two involves increasing the deck height it must be considered in conjunction with the network analysis. Table 28 shows that neither option involves an increase in performance in the network analysis. Table 29 shows that from a local perspective only the environmental performance will be improved from raising the bridge. Therefore this option has also been disregarded. Therefore it is recommended that the most appropriate position for the bridge is in the current location.

5.3.3.3 Derrabungy Bridge

Table 30

	Economical	**Environmental**	**Social**
Option			
1	9	20	10
2	-6	22	0

It can be seen from Table 30 above that there is no significant advantages in lowering the height of the bridge (option two). The slight environmental improvement is offset by a reduction in social and economical performance. Therefore this option has been disregarded. Even though an analysis of the option of increasing the deck height was not undertaken in the local analysis it must still be taken into consideration in the network analysis. Table 28 suggests that there is no additional network benefits achieved in any of the option involving Derrabungy Bridge. It is therefore recommended that the most appropriate position for the bridge is the current alignment.

5.4 Options Analysis

5.4.1 Criteria Selection

The list of criteria was chosen through the literature, previous experience in local government engineering and through advice from experienced members of North Burnett Regional Council.

Economic Criteria

The predominant form of economic assessment utilised in this investigation is a life cost analysis. As can be seen in the literature it is common practice in project evaluation to complete a cost benefit analysis of each option and determine the cost benefit ratio of each option. However in this form of analysis the accuracy of the result depends entirely upon the accuracy to which the costs and benefits associated with the project can be determined. In most projects undertaken by local government authorities the only economical benefits obtained through a project is increased economic potential for the community which does not offer direct financial benefit to council. The actual value of this benefit to council is difficult to assess accurately and hence a life cost analysis was determined as providing a better representation than a cost benefit analysis. The costs which must be included in life cost analysis include the capital cost and the maintenance costs. In addition to the life cost analysis the other assessment criteria include the use of day labour to complete the task and the effects on the economical bearing of community.

Capital Cost

This assesses the initial capital costs involved in the construction of the crossing. The costs considered in this criterion include the costs of demolishing the existing bridge, site establishment costs, material costs, installation costs, road furniture costs, disestablishment costs and any other costs directly associated with the proposed option. Another component taken into consideration in this criterion is the expected life span of the proposal. Typically in a cost benefit analysis a set time period of analysis is used when assessing the range of options. If a particular proposal is still expected to be in operation at the end of the analysis period, its value at that time, taking into consideration the depreciation, is considered as a benefit. There is no defined time period for this analysis and therefore to incorporate this benefit the expected life span of each proposal will be taken into consideration with a proposal resulting in only a short term solution being rated lower than an option with a longer term solution.

As previously discussed, the capital cost associated with a project is an important consideration for any entity. For this reason this criterion has been rated a five.

Maintenance Cost

This assesses the estimated costs involved with maintaining the structure to an appropriate standard for safe and continued use by the public. This involves the labour costs of inspections and approximate labour and material costs of both scheduled and emergent maintenance works. It is difficult to accurately assess the maintenance costs involved with a proposal over the entirety of its expected life span. However, an estimation of the type and frequency of scheduled maintenance activities can be developed by considering the predominant construction material used. For the options used in this analysis it is considered that timber construction would result in the most frequent and intensive maintenance schedule, especially considering the age of existing structures. Therefore any proposal involving a considerable amount of timber construction has been rated low in this criterion. Any proposal using predominantly steel construction has been rated above timber as it is expected that this will result in a less intensive maintenance schedule. Any concrete construction will also generally be rated higher than timber. Despite the generalisations discussed above an exact rating has not been given to each construction material as the final form of the construction will ultimately determine the maintenance schedule of the expected maintenance works. No accurate assessment of emergent maintenance works can be developed due to the erratic nature of events which create damage. It is suggested however that a considerable amount of emergent maintenance works is caused from erosion of approach roads due to flooding and the collection of debris within the structure. Therefore the likelihood of these occurrences has been considered in this criterion.

The maintenance cost represents the long term investment in the crossing from the local government authority. It has been a constant assumption through all of the previous analyses to give any criterion which assessed any capital investment by council with the highest rating. However it is common practice in any cost benefit analysis to discount future costs to incorporate the time value of money. As no numerical values are assessed in this criterion it is not possible to use a conventional numerical discount factor to incorporate the time value of money into the assessment. To incorporate this discount factor into the analysis this criterion has been rated four.

Day Labour

This assesses the portion of the construction which can be undertaken by the local government authority's day labour staff. In a small region such as the North Burnett, the council is not only responsible for maintaining public assets but they also serve the function as one of the largest single employer of local people in the region. To maintain this role as an economic driver of the community it is essential that the workforce is not significantly reduced through forced redundancies. The cost of replacing a bridge can take up a significant portion of the operating budget of the council. If council's day labour force cannot be utilised on this project, the cost of the project represents a significant decrease in the budget allowable for the works to be undertaken by the day labour force. It is therefore seen as a benefit if the scope of the project complies with the day labour forces' capabilities. Another component of the proposal which will be assessed through this criterion is the potential for increasing the skill base of the day labour force. The works undertaken on bridge construction is often considerably different to the scope of work undertaken in other forms of road construction. This broadening of skills developed across the work force can lead to increase in efficiency in future bridge replacements. In addition to this, the skills developed can also be used in other road projects. The development of new skills can also lead to increased enthusiasm within the workforce which has the potential to increase the efficiency. Another component taken into consideration is the actual capital cost of the proposal. This will determine, if the day labour force cannot be used for the construction of the project, the ability for other projects to be maintained in the budget.

Through the above discussion it can be seen that the use of day labour on large construction projects can have an effect on the economic prosperity of the region. However it is expected that with sufficient forward planning of the works program, projects can be created to ensure that there is sufficient work to maintain the day labour staff even when there is a high capital expense project being undertaken which does not utilise their capabilities. A prime example would be programming the crossing construction project in the same time period as the day labour force is contracted to undertake a project for a state road authority. In addition to this point it is expected that with the generally larger size of local government authorities after the 2008 Queensland Government amalgamations the local government authority would have sufficient financial capabilities to absorb the capital costs involved in creating sufficient projects to maintain the day labour force. For the reasons discussed above this option has been given a rating of two.

Ease of Construction

This is to assess the ease at which the construction process can be undertaken. This criterion takes into consideration the difficulty of the task, the plant and equipment required, the skill set of the construction gang and the location of the crossing. The difficulty of the task is assessed by considering the processes undertaken to complete the job. It is considered that the greater the complexity of the task the greater the potential for problems and delays to arise. If the plant and equipment required is difficult to source there is greater potential for delays and a greater risk of problems arising. The skill set of the construction gang is generally only relevant when considering a project undertaken by the day labour force. If the gang has limited experience in undertaking the required tasks it could result in problems arising and in insufficient quality. The location of the job is considered from two perspectives. Firstly the distance from the nearest population centres is an important consideration. If the job is located a long distance from the nearest centre, unless a camp is developed, there will be less hours spent actually working on the job due to increased travel times. In addition to this it could represent problems in bringing construction materials, such as concrete, to the site. In the absence of a batch plant on site, the nearest concrete batch plant will generally be in the nearest centre. If concrete is not poured within a relatively short time of mixing, it will begin to set in transit. This will affect the slump characteristics when the concrete reaches the site and could potentially result in significant structural deficiencies in the crossing. The second location perspective considered refers to the terrain of the site. The site terrain can have significant effects on the construction processes used and the safety measure enforced.

As has been discussed above the ease of construction is closely linked to the potential for problems to arise in the construction process. This has the potential to create delays and extra costs for the project. Whilst many of the problems discussed above can be mitigated through careful planning and by incorporating the increased risk into the budget, it still represents the potential for increased capital investment in the project. Therefore this criterion has been given a rating of four.

Effect on Economic Status of Nearby Community

This assesses the effect that the proposal will have on the economic status of the area. The primary component of this assessment is the weight limits applied to the infrastructure. Load limits on bridges restrict the class of vehicle which is capable of traversing it. If a transport operator is required to bring 42 tonnes of produce out of a property and across a 10 tonne load limited bridge, five trips would have to be made which significantly increases the vehicle cost as well as time related costs. This would significantly decrease the economic viability of the operation which may force the operator to downsize or change operations. It may also lead to potential investors forfeiting the region in favour of other regions. This issue also arises if the alignment or structure of the bridge and its approaches results in a B-Double permit being withheld on a particular route. This criterion is primarily assessed by considering the potential for a weight limit to be enforced on the structure. It is also assessed by considering any potential issues it poses for a B – Double permit approval.

As can be seen from the discussion above the particular form of the bridge has the potential to affect the economic status of the area. However it is suggested that most replacement or repair options would not result in any significant weight restrictions. If a crossing was weight restricted it would be the result of damage or deterioration. If this was to occur it would require either immediate repair or the construction of a suitable side track. Therefore the weight restriction would only be temporary and would not affect long term productivity of the area. It is also suggested that the actual form of the crossing would not affect the assessment of a B – Double route. For the reasons discussed above this option has been given a rating of two.

Environmental Criteria

Council has a responsibility to the community to uphold the environmental integrity of the region. The environmental components of a bridge which must be assessed include the materials used, the disruption to the natural waterway, the effect of flora and fauna and the contamination of waterway.

Scour Potential

This is to assess the potential for damage due to scouring. The forms of scour most dependent upon the system used are constriction scour and local scour. The potential for constriction scour has been determined by the relative constriction of the waterway. The potential for local scour has been determined by the size, amount and orientation of any bridge components located within the waterway. The effect of the local scour has been determined by considering the extent of local scour currently present at the site.

As discussed previously there are considerations which can be incorporated into the design to minimise the effects of constriction scour. However it is suggested that the effects of local scour are more difficult to mitigate. Local scour can have a significant detrimental effect on the structural integrity of the crossing as well as result in environmental damage to the waterway. For these reasons it is suggested that this criterion must be rated higher than the scour criterion in the local positional shift analysis. Therefore it has been given a rating of four.

Disturbance to Waterway

This is to assess the disturbance to the waterway created by each proposal. As in the local positional shift analysis the disturbance to the waterway is assessed by considering the constriction of fish and terrestrial passage through the crossing as well as the disturbance to the natural condition of the waterway. In this situation the disturbance of the natural condition is assessed by considering the amount of works required within the waterway.

As discussed previously the disturbance to the waterway is an important environmental consideration. It is suggested that the final replacement or repair option will have an equivalent affect on the disturbance to waterway criterion as the position of the crossing. For this reason the criterion has been given a rating of five.

5.4.2 Results

Capital Cost

Due to the limitations in sourcing accurate pricing information it is difficult to make an objective cost comparison between different options. The following scores have been justified based on the available information. The steel culvert option has been scored -3. Whilst the cost per unit of these culverts is unknown it is expected that it will be similar to that of concrete culverts. In addition to this it requires the diversion of the river and the completion of the concrete slab across the river. It also requires precise compaction of the engineering fill around the culvert units. There is also expected to be significant costs involved in freighting the large amount of units into place. This option would be scored lower except for the extensive life span that it represents. The concrete culvert option has been scored -2 for primarily the same reasons as suggested above. These units however do not require the same amount of compactive effort as required by the steel units. The steel truss bridge has also been scored -2. Whilst it does not require the construction of the concrete slabs it is expected that the capital cost of the units will be greater. In addition to this it is expected that this option will require more significant engineering design investigation. The fibre composite bridge option has been scored -1. Whilst the installation and transportation costs are expected to be similar to the base case scenario this option has been scored lower because of the material costs. It would be scored lower if the expected life cycle of the structure was less. The modular concrete bridge option has been scored 2. It is expected that the foundation construction of this option will be similar to the steel truss option. However the capital cost of the components is expected to be less as are the construction time and the engineering design required.

Maintenance

The fibre composite option has been scored one for two reasons. Firstly, in the short term it is expected that it will require a similar inspection and routine maintenance schedule as used for the timber bridge. Secondly it is not known what maintenance will be required in the future and therefore to be conservative it should not be rated highly. The steel culvert option has been rated -2 as it requires extensive inspections to be undertaken on a relatively regular basis to ensure both the safety and peace of mind of the public. The steel truss bridge has been rated 3 as it requires minimal inspections and low probability of major repair works except for periodic bolt tensioning. The modular concrete bridge option has been rated four as it represents very limited inspections and a low probability of major repair works required. The modular concrete bridge option has been rated greater than the steel truss bridge for two reasons. Firstly the modular concrete option does not require periodic bolt tensioning and secondly it is expected that due to the truss structure, the steel truss bridge will be more difficult to thoroughly inspect. For an option to be scored five it must not result in any future maintenance expenditure by the organisation. This would represent a structure not owned by the council.

Day Labour

The steel culverts option has been scored four. It represents a job which can involve a large percentage of the workforce in the area if required as well as providing new skills in large area concreting, working in a riverbed and the precise earthworks required for construction of the culverts. The concrete box culverts have been scored three as they also involve a large percentage of the workforce and considerable new skills. They do not however represent the same skill base as acquired with steel culverts as the work force is already skilled in basic box culvert installation. The steel truss option and the modular concrete option have both been scored two as the day labour force used will primarily be the existing bridge crew team. With regards to the steel truss option most of the bridge crew are already experienced in this form of construction so few new skills will be acquired. The construction of the modular concrete bridge is not expected to result in substantial new skills due to the simplicity of the construction. The fibre composite option has also been scored two as it is also only to be undertaken by the bridge crew. Due to the similarities between installation of these components and timber components it is not expected that there will be significant new skills acquired.

Construction Ease

The steel culverts option has been scored -4. This option represents significant construction difficulties and a high probability for construction issues and delays. The concrete box culvert option has been scored -3 as although it represents similar issues as the steel culverts it does not require precise earthworks. The actual installation of the culverts is also a process which has been undertaken several times before and is not expected to create significant difficulties. The steel truss option has been rated -2. It does not result in the same construction difficulties as the previous options however there will be some construction difficulties associated with working over the running river channel. There are also difficulties associated with achieving the required precision in construction. The modular concrete bridge option has been rated -1 as there are less difficulties expected with this option. There is less precision work required as there are larger components which must be handled. Also as the construction is launched from one side there are fewer difficulties associated with working over the river channel. The fibre composite option has been scored one. It is expected to represent a slightly different construction process however the difficulty in this is expected to be offset by the lighter weight of the components.

Economic Benefits to Nearby Community

All options have been rated one as there are no changes expected.

Scour Potential

Both the steel and concrete culvert options have been scored -3. They represent significant potential for constriction scour due to the large flow restriction they initiate. They would be rated lower if they also resulted in an increase in local scour potential. The steel truss option has been rated -2. At low flow situations it offers less collective scour potential due to a reduction in obstructions however the large constriction resulting in the truss structure filling with debris has been considered. This option would be scored higher if the truss structure was further out of the waterway and if it did not have a high potential of becoming clogged with debris. The fibre composite and modular concrete options have been scored one as they do not represent significant changes to the scour potential.

Disturbance to Waterway

The steel and concrete culvert options have been rated -3 as they represent significant impedance to the passage of both aquatic and terrestrial species. They also result in extensive disruption to the natural waterway. For an option to be rated lower it would not adhere to the recommended guidelines for ensuring fish passage through culverts. It could also represent further disruption to the natural waterway. The steel truss option has been rated -2 as although it represents a good opportunity for the waterway to return to its natural state it does result in significant obstacles to fish passage in high flow situations. If the truss was further out of the waterway this option would be rated higher. It would also be rated higher if the truss chords and members did not represent such an obstacle to the fish passage. The modular concrete and fibre composite options have been scored one as they do not represent a significant change to the disturbance to the waterway.

5.5 Forms of Analysis

5.5.1 Local Shift Analysis

The possible options being considered for this analysis include moving the bridge upstream, downstream, lowering the deck height, increasing the deck height and maintaining the current alignment. The options of increasing or decreasing the deck height have been used previously in the North Burnett Region. This option allows the designer to consider the importance of the deck height in the functionality of the bridge. The option of moving the alignment allows the designer to explore a wider range of possibilities for the location of the bridge. This option has previously not being considered to the same extent as altering the deck height. Other options which have not been considered in this investigation but which could be incorporated into further analyses include the option of aligning the bridge at an inclined angle to perpendicular to the waterway and locating the bridge further upstream or downstream than currently considered. The option of inclining the crossing at a different angle than perpendicular to the waterway is not recommended in certain components of the literature due to the possible environmental effects. However there are other potential alignment, environmental and economic benefits which could result from this option and therefore it could be further analysed. The current option considered of moving the bridge upstream or downstream involves a shift of approximately 200 – 700m. However a further analysis could be undertaken to determine the effects of moving the bridge to a crossing point on a different road. This option relates closely to a network option however the effect on the localised area could be analysed.

The full range of options was considered for the Jack Parr Bridge analysis. This was so that each option could be explored in detail and the possible generic benefits and disadvantages found. However for the analysis on Flagstone Bridge the option of moving the bridge upstream was not considered. Taking into consideration the outcomes of the analysis on Jack Parr Bridge it could be seen that the option of moving the bridge upstream would not be feasible. The predominant possible advantages of this option are based on alignment and environmental factors. From the initial considerations and the site inspection it could be seen that there are no advantages in this option in this situation. Not undertaking a full analysis on this option replicates industry practice. The local government engineer is not expected to use the limited resources at the departments disposal to undertake an in – depth analysis on an option which can be seen from the onset as being non – feasible. The list of options analysed was further reduced for Derrabungy Bridge. The only option considered in conjunction with the base case scenario was the decreasing the deck height. The options of moving the bridge upstream or downstream were not considered for reasons discussed above. From the site inspection there was found to be no environmental or alignment benefits in moving the bridge. In addition to this the existing bridge was at a substantially greater level than the previous structure and was almost level with the top of the bank. Any further increases in height would require a substantial increase in deck length and therefore the option was rejected. A localised positional shift analysis was not undertaken on Waratah Bridge. In addition to significant time constraints an analysis of this option had previously been undertaken by North Burnett Regional Council staff using an alternative methodology and the option considered as a result of this analysis was to maintain the current alignment.

Raising the Deck Height

An analysis of the results suggests that no option involving raising the deck height improves the economic outcomes for the local area. It is acknowledged that there is limited potential for an option involving raising the deck height to reduce the capital investment required. Therefore for this option to improve the economic outcomes for an area it must result in significant benefits from an increase in flood immunity. This would suggest an area which is has intensive industry which is not weather dependant and an existing crossing which frequently floods for extended durations. It is evident from the analysis that there are potential environmental benefits which could be achieved from raising the deck height. These benefits would be further accentuated if the existing alignment was environmentally unsustainable or if the area contained environmentally significant species. Providing the safety of travel is not impaired there is potential for this option to provide social benefits to the area. It is not expected that that this option has significant potential to change the affect on nearby residents. Therefore if there is significant impact on the area due to isolation this option has the potential to provide an improvement to the social outcomes of the bridge.

Lowering the Deck Height

The results of the analysis suggest that there is no economic benefit resulting from any option which involves lowering the deck height. It can be seen however that there is potential in other situations where this option could result in a reduced capital investment due to a reduction in the deck area required. This would be most evident in a gradual slope water way. In addition to this the importance of flood immunity would need to be minimal. This is similar to many situations in the North Burnett Region. The results suggest that there is substantial potential for negative environmental impacts to result from this option. Most of these are directly associated with the potential for scour and disruption to the waterway. It is suggested that the negative environmental impacts of this option could be minimised at location where there is no requirement for fish passage. Such a location would be a small waterway which is regularly dry where the state government requirements for fish passage do not apply. The results suggest that there is potential for this option to provide social benefits to the area. This would involve both an increase in safety and an area with a limited effect of isolation. It is acknowledged that there is limited scope for benefits to be obtained regarding isolation of the area. However providing the waterway floods infrequently and for a limited duration there is potential for these negative impacts to be minimised.

Horizontal Location Shift

The results of the analysis suggest that there is no economic benefit resulting from a horizontal location shift. It is acknowledged that this option will generally result in an increased capital investment due to the new approach road construction. In addition to this it is unlikely that this option will result in any increased benefits in regards to flood immunity. Therefore for this option to be considered the capital investment required must be minimised. The capital investment would be minimised if there was an existing road approach to the proposed location. This would also minimise the environmental impact of the proposal. The results suggest that there are no net environmental benefits associated with any option involving a horizontal location shift. This can be primarily attributed to the environmental impacts associated with constructing a new approach road through the waterway and clearing habitat in the waterway. These impacts would therefore be minimised if there was an existing road or cutting constructed. The environmental impacts could also be offset if the existing location was prone to bank instability or natural scour. The results suggest that there are some horizontal shift options which result in similar social outcomes as the base case scenario. Therefore providing the safety is improved it is suggested that this option could prove to be beneficial.

5.5.2 Network Analysis

The purpose of a network analysis is to determine and asses the reaction in the greater region, and in particular the larger transport network, resulting from a change to the bridge. In effect is assesses the relationship between the area and the bridge. In this analysis the reaction of the region is assessed by considering the changes in travel distance, flood immunity/isolation, economic status, safety and capital investment. In the context of this discussion the first four criteria are collectively referred to as the satisfaction of the area whilst capital investment is referred to as council’s contribution. The relationship between the satisfaction of the region and the characteristics of an individual bridge is not linear. For example an increase in the height of a bridge does not result in a proportional alteration in the satisfaction of the area. For this reason it is not possible to mathematically determine the ideal bridge characteristics which maximise satisfaction and minimise council’s contribution. For this reason a number of realistically possible scenarios must be developed and simulated. The effect of changing certain bridge characteristics can then be determined and assessed. If the overall combination of the satisfaction of the area and councils contribution is found to be better than the existing situation then a change in bridge characteristics is further considered.

Choice of Scenarios

Network One

Due primarily to the characteristics of the waterways and relatively low traffic volumes, there are several low level crossings in the area. Therefore in a large flood event it is a common event that all crossings are isolated. This restricts the movements not only within the region but also to outside of the region to the west and south. The aim of this network analysis was to determine the effect on this situation by raising each of the bridges. To ensure the realistic validity of the simulations it is essential to take into consideration further factors which have the potential to affect the outcomes. In this situation one factor taken into account was raising the Boyne River Bridge. The Boyne River Bridge forms a vital link in the Mundubbera Durong Road, a road which forms part of a connection between the Burnett Highway at Mundubbera and larger regional centres to the south including Dalby and Toowoomba. During the most recent prolonged flood event in December 2010 and January 2011 this link was severed for several days. This, and previous flooding events, have created considerable political pressure at the state government level to increase the immunity of this bridge. There are no definite proposals for this bridge to be upgraded. However considering the life cycle of a new bridge could be in the order of 70-80 years it is essential to take into consideration the known possible future factors which affect the network. The likelihood of such an occurrence is then taken into consideration in determining the height of the bridge in conjunction with the local shift analysis.

Network Two

To save money on maintenance budgets the option of completely closing down a maintenance intensive bridge is often considered. Due to its age, level of deterioration and form, Waratah Bridge meets this criterion.

5.5.3 Options Analysis

Only one in – depth analysis of the replacement and repair options has been undertaken. To incorporate the fact that some options result in different characteristics in different locations a more generalised analysis has been undertaken for the other sites to consider the differences.

The repair options being considered in this analysis include traditional repair using timber components and a relatively new method of replacing deteriorated components with fibre composite components. This analysis effectively compares existing traditional methods against new and emerging technology. The replacement options being considered in this analysis include a modular concrete bridge, concrete box culverts, steel culverts and a steel truss bridge. These options represent the most common materials and systems currently used. An analysis of these options allows the engineer to explore the benefits of each of the common systems and make objective comparisons between them. There is however a lack of new technologies being represented. In further analyses it would be possible to include emerging technologies such as entire fibre composite bridge. In addition to this other systems not commonly used in regional centres such Super Tee Girders and DMR deck units could be analysed. This would allow the engineer to explore the characteristics of options outside of the normal scope considered for bridge replacement. This forms the basis for a more informed decision to be made.

5.6 Survey Results

An analysis of the survey results suggests that a majority of respondents would place more importance on different categories of criteria. The results of question one reveal that economic criteria are of primary importance in the analysis of bridge options with all respondents rating it the highest score. The social criteria are ranked at the second highest level of importance followed by environmental and lastly political criteria.

The results suggest that within the economic criteria the direct capital investment to council is of the greatest importance. The longer term maintenance is ranked closely behind. The effect on the economic status of the area is also ranked of significant importance. This suggests that the economic state of parties outside of the organisation is valued at high importance. The use of council day labour is not of primary importance among the respondents.

Within the social criteria flood immunity is considered of the most importance. It has not however been given the highest score. The size of the affected community is ranked as the next most importance followed by the travel distance and the aesthetic characteristics. An analysis of the average scores of these criteria suggests that they are not given the same level of importance as the economic criteria.

Within the environmental criteria complying with the relevant legislation is of primary importance. This is followed by minimising the disturbance to the waterway and maintaining fish passage.

5.6.1 Comparison between Survey and Selected Criteria Scores

Due to the differences in scale used there can be no direct comparison between the assigned criteria scores and the average scores achieved in the surveys. It is still possible to undertake a comparison of the level of importance assigned. As part of the assessment process each criteria category is valued at the same level of importance. However the results of the survey suggest that each category has a different level of importance when considering bridge replacement. Another category considered in the survey was political criteria. Due to the nature of this category it was not taken into consideration in the analysis, however it should be noted that this criteria was not considered to be of a high level of importance by the recipients of the survey.

When considering the economic criteria it can be seen that the results of the survey generally align with the scores given. A good example of this is the direct investment required by council. All survey respondents suggest that this criterion should be regarded with the highest level of importance. Throughout the three analyses the direct capital investment required by council is given a rating of five. Another example is the economic status of the area. The results of the survey suggest that the economic benefits of the surrounding area should be regarded with less importance than the capital investment required by council and the future maintenance costs. This is reflected in assignment of scores. In the local shift and network analyses the economic affect to surrounding parties is given a score of four. This represents a slightly lower level of importance than the direct capital investment and a similar level of importance as the long term maintenance costs. A further example is the use of day labour. The results of the survey suggest that it should be given limited regard which is reflected by assigning it a score of two.

It is difficult to assess the similarities between the level of importance given to the social category in the investigation and the survey due to the different criteria used. In the survey the change of travel time was assessed. This is related to the travel distance criterion which was assessed in the investigation. The primary difference is that in the survey this was considered as part of the social category whilst in the investigation it was considered as an economic cost. The level of importance assigned to this criterion is similar between the survey and the investigation. One discrepancy between the survey and the investigation is the social affect of flood immunity. This is given a high level of importance in the survey but has only been scored 3 in the investigation.

Within the environmental category there are several discrepancies between the level of importance given in the survey and the scores assigned. The survey results suggest that a limited amount of importance should be given to both the disturbance to the waterway and to maintaining fish passage. This differs to the scores assigned which suggest that both of these criteria should be regarded with the highest level of importance.

5.7 Assessment Methodology

A cost benefit analysis was initially considered for the assessment. However considering the organisation responsible this was not considered appropriate. To ensure an accurate comparison of benefits and cost in a CBA a monetary value must be assigned to all cost and benefits. To an engineer untrained in economics it would be difficult to accurately devise appropriate monetary values for most of the potential benefits. This would lead to significant inaccuracies in the assessment. This form of multi criteria analysis however, users a more generalised non-monetary scale to make the comparison. Making the comparison in a non monetary scale allows for increased consistency across the analysis resulting increased accuracy. This form of analysis also allows the user to place more importance on individual criterion within the three categories. This is considered a natural component of any professional decision making process. Another benefit of this form of analysis is that engineering judgement is used in the decision making process. Input from the engineer is required in every stage of the analysis process. They are responsible for any additions or changes to the criteria selection and ranking and ultimately for scoring each proposal. They are then responsible for interpreting the results of the analysis and deciding on which option to utilise. Another benefit of analysis process is in the separation of categories. Interpreting the categories separately provides a thorough indication of the characteristics of the proposal. This prevents an obvious shortfall in one category from being offset by considerable benefit in another category. This is important in local government as it reflects the ideal of society that the social wellbeing of the community and the environmental health of the region should be held in similar regard as the economic characteristics of a project. Another benefit of the analysis process is that it provides an indication of the performance of the proposal relative to the performance of the existing crossing. This relative comparison simplifies the analysis process as it involves the engineer determining if the new proposal will provide an improved or a worse performance, and to what extent this change will be, and not assessing the characteristics of the proposal against a predetermined standard.

6 Conclusion

The aim of this investigation was to develop a framework for rural local government authorities to determine the most appropriate replacement and repair options for deteriorating bridge infrastructure. The assessment system developed consists of three related analyses used in combination to determine the most appropriate option in any unique situation. The outputs of the assessment system are the physical location of the crossing in conjunction with the replacement or repair form. Each of the three analyses which make up the assessment process involves the assessment of realistic options against a set of criteria developed to represent the interests of the organisation and the constituents that it represents. Four case studies within the North Burnett Regional Council area were used to demonstrate how the assessment process could be used within the significant resource and time constraints faced by a typical rural local government authority.

6.1 Criteria

It is the role of local government authorities to maintain the local road network to a level which ensures safe, economic and consistent travel throughout the entire region and into neighbouring regions. To ensure that the organisation can maintain the network to this level it is essential that several factors be taken into consideration before undertaking any major replacement or repair works. Firstly the economic characteristics of the project must be determined. This includes the cost incurred by the council from the construction or installation of the infrastructure and any associated works. This also includes the lifecycle cost incurred to maintain the bridge to a safe and functional standard for the entirety of its physical life. The other economic characteristic of the bridge which must be taken into consideration is the potential economic benefit offered to people in the area as a result of each proposal. Secondly the environmental characteristics of the bridge must be taken into consideration. The local government has a responsibility to the community that it serves to maintain, and where possible upgrade, the environmental integrity of the area. Considering the primarily aquatic nature of the work considered it can be seen that there is potential for significant environmental destruction. The primary forms of potential environmental degradation considered in these analyses involve the destruction of habitat, disruption to the waterway and associated disruption to fish passage and the effects of scour. Finally the social characteristics of the proposal must be taken into consideration. The social characteristics being taken into consideration include the safety of each proposal as well as the potential effects of isolation due to flooding.

6.2 Methodology

The assessment process developed uses a combination of three analyses to determine the physical location of the crossing and the form of the crossing. The process used is visually depicted in figure 39 below. The location of the bridge is determined through the first two analyses. The first analysis considers the effect of the bridge location on the localised area. The second analysis then takes into consideration the effect of the bridge location on the greater transport network. The outcomes of these analyses are then taken into consideration and using a process primarily involving engineering judgement the location of the crossing is determined. The next step of the process involves using the combined result of the first two analyses to undertake the final similar analysis to determine the form of crossing to be used. Within each analysis there are several criteria selected which represent the relevant environmental, economical and social considerations discussed in the previous section. Each of the selected criteria is given a rating to represent its relative importance. Each proposal is then assessed and is given a score for each criterion based on the performance of the proposal relative to the existing situation. The product of each criterion rating and the score given is then found. This product is then summed for each category of criteria in each analysis.

Figure 39

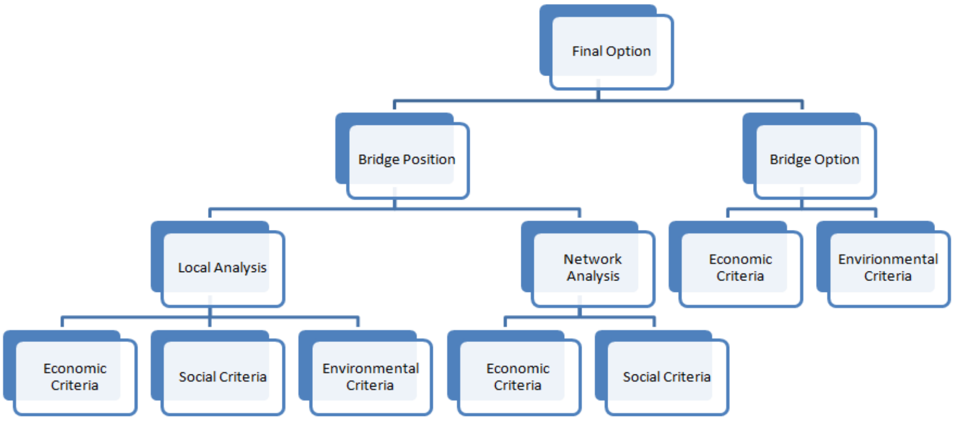


Figure 39: An overview of the assessment process adopted

6.3 Case Study Results

The investigation found that for each case study the most appropriate solution was the complete replacement of the crossing using a precast modular concrete system while maintaining the existing horizontal and vertical alignment. Despite the aim to demonstrate the process using a wide variety of case studies there are significant underlying similarities between each case study. It is suggested that this is the reason that the assessment process resulted in the same option for each case study.

6.4 Future Work

As discussed above the same options have been suggested for each case study. To further demonstrate the applicability of the assessment process in any rural local government situation it would be appropriate for the process to trialled using other case studies. To ensure a thorough test it would be appropriate for the other case studies to include a crossing located in an area with high intensity industry, a crossing of a waterway with more frequent and sustained flood events, a crossing which provides immunity to a larger area and a crossing in an area of endangered or of concern ecosystems. A further investigation could be undertaken to determine an adoption of this methodology and criteria which could be used in the selection of a greater range of local government projects. The current methodology and criteria used are aimed predominantly at bridges and other crossing infrastructure. Another potential field of investigation would involve developing a more generic method of bridge inspection for the purpose of the assessment. This would enable an inspection to be undertaken which records sufficient information to undertake an accurate assessment.

Through the demonstration of the four case studies it can be seen that the framework developed is capable of determining replacement and repair options for rural local governments. The limited investment of both time and resources necessary for an accurate and thorough analysis suggests that this tool will be a beneficial addition to the bridge infrastructure management process in any rural local government authority and could be easily adopted for the goals of larger road authorities.

7 References

Sharp A,2010, ‘More aging bridges to close as councils too poor to fix them’, *The Sydney Morning Herald*, 1st July, viewed 22/04/2011, www.smh.com.au

2007, ‘Aging infrastructure under scrutiny after bridge collapse’, *ABC News*, 3rd August,viewed 22/04/2011, www.abc.net.au

Giummarra, G(ed) 2000, *Local Roads Bridge Management Manual*, ARRB Transport Research, Australia

Coe, D, *Risk Based Bridge Asset Management*, Pitt & Sherry, viewed 23/04/2011, http://www.pittsh.com.au/documents/RiskBasedAsse%20Management.pdf

Hearn, G, Purvis, RL, Thompson, P, Bushman, WH, McGhee, KK, McKeel, WT jr, *Bridge Maintenance and Management A Look to the Future*, Committee on Structures Maintenance and Management, www.pdth.com/images/future.pdf

Tasmanian Government 2003, *Environmental Best Practice Guidelines: Siting and Designing Stream Crossings*, viewed 10/05/2011, www.environment.tas.gov.au

Road Transport Authority of New South Wales, *RTA Timber Bridge Management*, n.d, manual, Road Transport Authority New South Wales, viewed 22/03/2011 www.rta.nsw.gov.au/constructionmaintenance/downloads/timberbridges

South Australian Government, *History of South Australia – Bridges*, n.d, South Australian Government, viewed 23/03/2011, <www.history.sa.gov.au/chu/programs/sa_history/road/road_history/bridges.htm>

Road Transport Authority of New South Wales 2008,*Timber Bridge Manual*, manual, Road Transport Authority New South Wales, viewed 22/03/2011, www.rta.nsw.gov.au

Crossman, M & Simm ,J 2004, *Manual on the use of Timber in Coastal and River Engineering*, Thomas Telford Publishing

Murray, G, *Rural Bridges - Getting the Most for your Budget Dollar*, IPWEA, viewed 25/02/2011, www.ipwea.org.au/papers/download/Murray_g.pdf

Types of Concrete Bridges, Concrete Bridge Development Group, UK, viewed 22/03/2011, http://www.cbdg.org.uk/

Bridgeman, 2000, *Bridge Building Materials*, Bridgeman, viewed 22/03/2011, http://www.nireland.com/bridgeman/Bridging%20Materials.htm

Cement and Concrete Association of Australia 2002, *Guide to Concrete Construction*, Cement and Concrete Association of Australia, Australia

Austroads 1996, *Benefits Cost Analysis Manual*, Austroads, Australia

Graham N 2007, *Stingray Creek Bridge Route Options*, Version 3, Maunsell Australia, viewed 04/04/2011, www.hastings.nsw.gov.au

Tsolakis, D, Preski, K, Patrick, S 2005, *Guide to Project Evaluation*, Austroads Australia, viewed 10/05/2011, www.austroads.com.au

Nicolas, J & Journard, R 2010, 'Transport project assessment methodology within the framework of sustainable development', *Ecological Indicators*, Volume 10, Issue 2

Hendrickson, C 1998, *Economic Evaluation of Facility Investments*, Carnegie Melon University Pittsburgh, viewed 01/05/2011, http://pmbook.ce.cmu.edu/

CIV2605 Construction Engineering: study book 2011, University of Southern Queensland, Toowoomba

Boardman, A, Greenberg, D, Vining, A, Weimer, D 2006, *Cost - Benefit Analysis Concepts and Practice*, Pearson Prentice Hall, New Jersey

American Association of State Highway and Transportation Officials 2003, *User Benefit Analysis for Highways Manual*, American Association of State Highway and Transportation Officials, United States of America

Department of Transport and Regional Services 2007, *Ex – post economic evaluation of National Highway projects Case study 1: Wallaville Bridge*, Bureau of Transport and Regional Economics, Australia

Arup 2009, *Multi Criteria Analysis*, Queensland Water Commission, viewed 05/05/2011, http://www.qwc.qld.gov.au/planning/pdf/desalination/appendix-f-multi-criteria-analysis-final-a2.pdf

Argyrous G, *Cost – benefit analysis and multi - criteria analysis: competing or complementary approaches?*, Australian and New Zealand School of Government, viewed 15/05/2011, http://www.anzsog.edu.au

Department of Employment, Economic Development and Innovation, *Code for Self – Assessable Development Minor Waterway Barrier Works*, 2010, Guide,Department of Employment, Economic Development and Innovation, viewed 15/05/2011, www.deedi.qld.gov.au

An Aquatic Conservation Assessment for riverine wetlands of the Burnett River catchment: Riverine Ecology Expert Panel report, 2005, Queensland Environmental Protection Agency, viewed 15/05/2011, www.derm.qld.gov.au

Department of Infrastructure and Planning 2009, *Population and Housing Fact Sheet North Burnett Regional Council*, Department of Infrastructure and Planning, viewed 25th June 2011, http://dlgp.qld.gov.au/

Department of Environment and Resource Management 2010, *Burnett Basin Plan Area*, Department of Environment and Resource Management Queensland Government, viewed 25th June 2011, http://www.derm.qld.gov.au/wrp/burnett.html

Department of Environment and Resource Management 2011, Department of Environment and Resource Management Queensland Government, viewed 1st September 2011, <http://www.derm.qld.gov.au/>

Australian Academy of Technological Sciences and Engineering 1988, *Technology in Australia 1788 – 1988*, Australian Academy of Technological Sciences and Engineering, viewed 4th May 2011, www.austehc.unimelb.edu.au

Taplin G & Fenwick J 2009, *Guide to Bridge Technology Part 1: Introduction and Bridge Performance*, Austroads, viewed 5th May 2011, http://www.austroads.com.au/

Carter D 2009, *Guide to Bridge Technology Part 3: Typical Superstructure, Substructures and Components*, Austroads, viewed 20th May 2011, http://www.austroads.com.au/

Humes 2010, Holcim Australia, viewed 21st May 2011, http://www.humes.com.au/

Rocla 2011, viewed 21st May 2011, http://www.rocla.com.au/

Bell D 2006, *Monto Shire Bridge Infrastructure*

Atlantic Civil 2011, viewed 22nd May 2011, http://atlanticcivil.com.au/

Structural Concrete Industries, *Design Information Standard Sections Super-T Girders*, Structural Concrete Industries, viewed 22nd May 2011, http://www.sciaust.com.au/wdesroadsupert.html

Ibrahim A 2002, *Introduction to Structural Steel Design*, University of Maryland, http://www.assakkag.com/courses/ENCE355/lectures

World Steel Association n.d, World Steel Association, viewed 2nd August 2011, http://www.worldsteel.org/

McGuire F 2009, *Guide to Bridge Technology Part 7: Maintenance and Management of Existing Bridges*, Austroads, viewed 25th August 2011, http://www.austroads.com.au/

Strategic Environmental Management 2001, *Environmental Risk Management Guidelines and Tools for Road Projects*, Austroads, viewed 25th August 2011, http://www.austroads.com.au/

Queensland Environmental Protection Agency, *Aquatic Biodiversity Assessment and Mapping Method*, Queensland Environmental Protection Agency, viewed 25th August 2011 http://www.epa.qld.gov.au/wetlandinfo/site/SupportTools/AssessmentMethods/AquaBAMM/Method.html

Marek, M, *Hydraulic Design Manual*, Texas Department of Transportation, viewed 12th August 2011, http://onlinemanuals.txdot.gov/txdotmanuals/hyd/manual_notice.htm

Kattell J and Eriksson M 1998, *Bridge Scour Evaluation: Screening, Analysis and Countermeasures*, US Forestry Service, viewed 1st August 2011, www.fs.fed.us

Applied University Research, *Causes of Bridge Scour*, Applied University Research, viewed 10th August 2011, http://www.noscour.com/Causes_of_bridge_scour.php

Appendix A

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

PROJECT SPECIFICATION

FOR: Tyronne MEREDITH

TOPIC: OPTIONS FOR REPLACEMENT OF AGING BRIDGES UNDER LOCAL AUTHORITY CONTROL IN RURAL AREAS OF QUEENSLAND

SUPERVISOR: Professor Ron Ayers – University of Southern Queensland

Ron Smith - North Burnett Regional Council

PROJECT AIM: To investigate the options available to local government authorities to replace aging bridges in rural areas. This will involve determining and exploring the issues currently faced by in-depth investigation of four case studies in the North Burnett Regional Council area.

PROGRAMME:

1. Research the background of bridges used in rural areas (within Queensland, and around the world). This will include:

- Types of bridges used and the differing forms of construction
- History of bridge building in Queensland rural areas
- Current bridge maintenance, rehabilitation and replacement practices.

2. Investigate the average condition of the bridge network in various rural areas and particularly within North Burnett Regional Council area.

3. Identify the possible replacement alternatives currently available.

4. Investigate the financial, hydrologic, accessibility, environmental, construction maintenance and aesthetic issues for each alternative.

5. Investigate as case studies four aging bridges in the North Burnett Regional Council area and provide recommendations for possible rehabilitation/replacement actions for each case.

6. Present information and results in required written and oral formats

As time permits

1. Looking at current funding schemes available

2. Investigate further case studies.

AGREED:

Student: Tyronne Meredith Supervisor: Professor Ron Ayers

Appendix B

Replacing Aging Timber Bridges in Rural Area - Survey

For the purpose of completing a Bachelor of Engineering (Civil) degree I am undertaking an investigation into the options for replacing aging timber bridges in rural areas. Four distinct case studies from the North Burnett Regional Council area have been selected and a number of options have been identified to replace, repair or close each bridge. Each of these options will be assessed against select criteria to determine the most appropriate solution. In the knowledge that one option will not be appropriate in each unique situation, the aim of this investigation is to determine a framework in which regional councils can assess the array of options available and determine an appropriate solution without undertaking a time consuming and costly investigative report.

The following survey has been constructed to determine the current importance placed on certain considerations which go into deciding on an appropriate replacement option. The results from this survey will be used in developing a weighted assessment criteria for which each option will be assessed against.

Any time that you have to complete this survey is greatly appreciated.

Please number priority from 1 – 4 with 1 being of the greatest level of importance and 4 being of least importance.

It is possible to rank two or more considerations with the same importance

1. In evaluating each alternative how would you rank the relative importance of each of the following considerations?

a. Economic Considerations – For council and surrounding community

Priority:

b. Social Considerations – Flood immunity/access for public, changes in travel times etc

Priority:

c. Environmental Considerations – Fish passage, waterway disruption etc

Priority:

d. Political Consideration

Priority:

Comments (Optional):

2. In evaluating the economical considerations how would you rank the relative importance of the following factors?

a. Capital costs

Priority:

b. Maintenance costs

Priority:

c. Industry benefits (increased industry production due to increase of load limit, B-double access, less isolated days etc)

Priority:

d. Being able to use council day labour

Priority:

Comments (optional):

3. In evaluating the social considerations how would you rank the relative importance of the following factors?

a. Delay for user (if exiting crossing site was changed)

Priority:

b. The amount of people affected by changes (size of community who use the bridge)

Priority:

c. Flood immunity (significant increase or decrease)

Priority:

d. Aesthetics

Priority:

Comments (optional):

4. In evaluating the environmental considerations how would you rank the relative importance of the following factors?

a. Complying with relevant legislation (Nature Conservation Act, Fisheries Act)

Priority:

b. Minimising waterway disruption

Priority:

c. Maintaining fish passage

Priority:

Comments (optional):

Please send survey to tjmeredith90@hotmail.com or to the address from which it was sent

Thank you for your time and consideration

Tyronne Meredith

Appendix C

Jack Parr Bridge Level Two Inspection Report

A1 Backing boards – Perishing & worn

Headstock 1 – Rotted out & perishing on both ends & 50mm pipe

Headstock 2 – Perishing on both ends but OK

Pile 1 – Shell only above headstock & 150mm pipe below headstock less than 25% inspected

Pile 2 – Top rotted out & 125mm pipe dia 350mm under headstock

Pile 3 – OK

Pile 4 – Shell only in top below headstock 180mm pipe dia 360mm

Span 1 Girder 1 – E1 250mm pipe 400 dia pipe is in front of headstock – spiking plank falling in – E2 Top of girder coned & 125mm pipe dia 400mm

Girder 2 – E1 OK – E2 OK

Girder 3 – E1 OK – E2 OK

Girder Length

Girder 4 – E1 OK – E2 150mm pipe dia 450mm top crushing in

Girder 5 – E1 230mm pipe dia 400mm badly cracked & crushing – E2 OK

Pier 1 Corbel 1 – 100mm over headstock dia 400mm crack & rotted both ends

Corbel 2 – Oil but split on both ends

Corbel 3 – OK but badly split full length

Corbel Length 3.6

Corbel 4 – Cracked on E2 OK

Corbel 5 – Split both ends badly 130mm pipe dia 400mm & perishing

Headstock 1 – Rotted out on pile head & pile head rotted out P1 & P4

Headstock 2 – Rotted out on pile head & pile head rotted out P1 & P4

Pile 1 – 150mm pipe dia 400mm under headstock top of pile rotted

Pile 2 – OK

Pile 3 – OK

Pile 4 – OK under headstock & shell only at top

Span 2 Girder 1 – E1 230mm pipe dia 400mm at end of corbel & crushing – E2 230mm pipe badly split

Girder 2 – E1 200 pipe & splitting – E2 shell only rotted out completely rolling off corbel

Girder 3 – E1 OK – E2 OK
Girder Length 9.2

Girder 4 – E1 crushing 200mm pipe 450mm dia – E2 250mm pipe 50% consumed crushing

Girder 5 – E1 Badly split 150mm pipe –MS- 150mm pipe & rotted out at top full length E2 – Badly cracked & perishing 150mm pipe dia 400mm

Pier 2 Corbel 1 – OK

Corbel 2 – Badly cracked & crushing 150mm pipe dia 450mm

Corbel 3 – OK **Corbel Length 3.6**

Corbel 4 – Cracked on end 75mm pipe dia 450mm

Corbel 5 – OK & badly cracked & perishing

Headstock 1 – E1 OK & perishing started – E2 Same as E1

Headstock 2 – E1 OK & perishing started – E2 Same as E1

Pile 1 – OK under headstock badly crack & head rotted out

Pile 2 – Top of pile rotted out under headstock 250mm pipe dia 400mm badly split top to GL

Pile 3 – OK

Pile 4 – OK top of pile rotted out

Span 3 Girder 1 – E1 220 pipe badly cracked perishing & crushing dia 400mm – E2 75mm pipe to falling in

Girder 2 – E1 200mm pipe badly split under side – E2 150mm pipe top crushing

Girder 3 – E1 OK – E2 OK
Girder Length 9.2

Girder 4 – E1 OK – E2 150mm pipe dia 450mm top of girder coned

Girder 5 – E1 200mm pipe badly split & crushing & perishing – E2 250mm pipe dia 400mm

Pier 3 Corbel 1 – Badly cracked & splitting 100mm pipe dia 400mm & crushing E2

Corbel 2 – OK

Corbel 3 – Badly cracked & splitting OK **Corbel Length 3.6**

Corbel 4 – Badly cracked & splitting & crushing 75mm pipe dia 450mm

Corbel 5 –

Headstock 1 – E2 OK but starting to perish on end 1 &2

Headstock 2 – E2 OK but starting to perish on end 1 & 2

Pile 1 – Top of pile shell rotted & under headstock seat OK but split

Pile 2 – Top of pile split & under headstock OK

Pile 3 – 130mm pipe under headstock dia 420mm

Pile 4 – Top of pile rotted out 130mm pipe dia 430mm

Braces – worn & perishing on ends

Span 4 Girder 1 – E1 perishing on outside & splitting 250mm pipe – E2 200mm & same as E1

Girder 2 – E1 OK – E2 OK

Girder 3 – E1 180mm pipe dia 450mm – E2 150mm pipe **Girder Length 9.2**

Girder 4 – E1 150mm pipe cracked in top – E2 badly splitting full length at top end OK

Girder 5 – E1 whole girder rotted out & broken out over pier 4 sitting partly on headstock NEEDS URGENT REPAIRS ASAP

Pier 4 Corbel 1 – Badly cracked 75mm pipe dia 400mm

Corbel 2 – Badly cracked end 1 & 2 150mm pipe over headstock dia 450mm

Corbel 3 – Large crack in corbel mid span for about 900mm x 30mm test solid Corbel 4 – Split both ends & OK

Corbel Length 3.6

Corbel 5 –Split both ends & perishing & rotted out end 2

Headstock 1 – Rotted out between pile 3 & corbel 3 hart wood missing & pile face rotted

Headstock 2 – E1 OK – E2 perishing on ends

Pile 1 – Top shell only & below headstock OK but split

Pile 2 – OK

Pile 3 – OK but cracked from top to just above water level

Pile 4 – OK

Braces – worn on ends

Span 5 Girder 1 – E1 170mm pipe dia 400mm perishing – E2 125mm pipe crushing –MS-

Girder 2 – E1 75mm pipe dia 450mm – E2 OK

Girder 3 – E1 200mm pipe dia 450mm – E2 OK **Girder Length 9.0**

Girder 4 – E1 OK – E2 OK

Girder 5 – E1 perishing badly cracked & worn out – E2 perishing & badly rotted out topside of girder has bad splits & cracks & crushing

Pier 5 Corbel 1 – OK

Corbel 2 – Badly split & OK

Corbel 3 – OK **Corbel Length 3.6**

Corbel 4 – OK

Corbel 5 – OK a bit cracky & split on ends

Headstock 1 – E1 perishing on end & at pile 2 – E2 perishing on end & pile seat

Headstock 2 – E1 perishing & rotted at pile seat – E2 perishing on end & seat

Pile 1 – 125mm pipe dia 500mm badly split top rotted out

Pile 2 – OK

Pile 3 – OK

Pile 4 – Pile head shell, perishing, cracky & split

Braces – worn & perishing on ends

Span 6 Girder 1 – E1 150mm pipe badly split & perishing –MS 200mm pipe – E2 OK

Girder 2 – E1 160mm pipe dia 450mm – E2 OK

Girder 3 – E1 OK – E2 OK
Girder Length 9.3

Girder 4 – E1 100mm pipe dia 450mm & has large split at top of girder – E2 OK

Girder 5 – E1 drilled solid but is badly cracked & splitting & top is cracking & rotted out under spiking plank at MS is worn out & 75mm pipe & perishing badly – E2 75mm pipe 480dia

Pier 6 Corbel 1 – Perishing on both ends 200mm pipe on end 1

Corbel 2 – OK

Corbel 3 – OK **Corbel Length 3.6**

Corbel 4 – OK

Corbel 5 – Cracked on ends & badly rotted & worn out but test OK

Headstock 1 – E1 perishing – E2 Badly split through to pile bolts

Headstock 2 – OK

Pile 1 – Top pile head rotted & below headstock OK

Pile 2 – OK

Pile 3 – OK

Pile 4 – Splitting but OK

Span 7 Girder 1 – E1 OK – E2 OK

Girder 2 – E1 125mm pipe dia 450mm – E2 280mm dia 450mm 50%+ consumed

Girder 3 – E1 OK – E2 OK
Girder Length 9.1

Girder 4 – E1 OK – E2 OK

Girder 5 – E1 75mm pipe dia 400mm – E2 weather worn OK

Pier 7 Corbel 1 – OK

Corbel 2 – OK

Corbel 3 – 75mm pipe dia 450mm split E1 **Corbel Length 3.6**

Corbel 4 – OK

Corbel 5 – OK

Headstock 1 – Perishing E1 & E2

Headstock 2 – E1 heart wood splitting out between P1 & P2 – E2 perishing

Pile 1 – OK

Pile 2 – OK

Pile 3 – OK

Pile 4 – Rotted out at top & under headstock is OK

Span 8 Girder 1 – E1 75mm pipe dia 400mm & weather worn – E2 OK at mid span has long rot pocket 1m long 75mm deep 50mm wide

Girder 2 – E1 OK – E2 OK

Girder 3 – E1 OK – E2 OK **Girder Length 9.1**

Girder 4 – E1 OK – E2 150mm pipe dia 450mm

Girder 5 – E1 125mm pipe & is badly weather worn & perishing – E2 weather worn & top badly perished & 200mm pipe 50% consumed & crushing

Pier 8 Corbel 1 – OK

Corbel 2 –OK

Corbel 3 – OK **Corbel Length 3.6**

Corbel 4 – OK

Corbel 5 – Weather worn but OK

Headstock 1 – E1 OK – E2 has knot or heart wood pocket

Headstock 2 – E1 OK – E2 OK

Pile 1 – OK

Pile 2 – OK

Pile 3 – Split but OK

Pile 4 – OK

Span 9 Girder 1 – E1 OK but weather worn on outside – E2 100mm pipe

Girder 2 – E1 150mm pipe dia 450mm – E2 OK **Girder Length 9.6**

Girder 3 – E1 OK – E2 100mm pipe dia 450mm girder has cracks opening up along girder side

Girder 4 – E1 OK – E2 100mm pipe dia 450mm same as girder 3

Girder 5 – E1 OK but is weather worn – E2 OK but split & perishing

A2 Headstock 1 – Perishing in both ends to pile seat

Headstock 2 – Perishing in both ends to pile seat

Backing Boards Concrete – OK

Pile 1 – Badly cracked 100mm pipe

Pile 2 – 100mm pipe dia 380mm

Pile 3 – OK but cracky

Pile 4 – OK

(water way) Span 4, 5 & 6 debris in water way from flood water fire hazard

Deck in all spans has rotted ends and some more than others

Spiking plank all spans has rot between deck & girders and has help with the deterioration of all outside girders more so with girders that are crushing from being rotted out at the top side.

RECOMMEND REDUCING TO SINGLE LANE & REDUCE SPEED. RUN TRAFFIC UP CENTRE OF BRIDGE AND PUT GUIDE POST TO INDICATE BETWEEN KERBS 6.1M.

Flagstone Bridge Level Two Bridge Inspection Report

A1 Concrete headwall – partly buried but looks OK

Span 1 Girder 1 – E2 200mm pipe dia 400mm – MS – 175mm pipe – E1 125mm pipe

Girder 2 – E2 75mm pipe dia 450mm – E1 150mm pipe

Girder 3 – E2 180mm pipe dia 450mm – E1 175mm pipe **Girder Length 9.6**

Girder 4 – E2 150mm pipe dia 400mm – E1 75mm pipe

Pier 1 Corbel 1 – 150mm pipe & badly split dia 400mm

Corbel 2 – OK

Corbel 3 – Solid over pier wall & 100mm pipe E2 **Corbel Length 3.7**

Corbel 4 – 200mm pipe & badly split

Concrete Pier - OK

Span 2 Girder 1 – E2 100mm pipe dia 400mm – E1 150mm pipe

Girder 2 – E2 75mm pipe dia 450mm – E1 OK

Girder 3 – E2 125mm pipe dia 450mm – E1 175mm pipe **Girder Length 9.2**

Girder 4 – E2 75mm pipe dia 400mm – E1 125mm pipe

Pier 2 Corbel 1 – Split badly perishing in from E1

Corbel 2 – 100mm pipe & cracky dia 450mm

Corbel 3 – Split OK **Corbel Length 3.7**

Corbel 4 – Split 75mm pipe dia 400mm

Concrete Pier – OK

Span 3 Girder 1 – E2 125mm pipe dia 400mm – E1 100mm pipe

Girder 2 – E2 200mm pipe dia 450mm – E1 100mm pipe

Girder 3 – E2 OK – E1 OK **Girder Length 9.1**

Girder 4 – E2 150mm dia 400mm – E1 OK

Pier 3 Corbel 1 – 100mm pipe dia 400mm

Corbel 2 – OK

Corbel 3 – OK **Corbel Length 3.7**

Corbel 4 – 100mm pipe dia 400mm

Concrete Pier – OK

Span 4 Girder 1 – E2 75mm pipe dia 400mm – E1 75mm pipe

Girder 2 – E2 125mm pipe dia 450mm – E1 100mm pipe

Girder 3 – E2 100mm pipe dia 450mm – E1 OK **Girder Length 9.1**

Girder 4 – E2 200mm pipe dia 400mm – E1 75mm pipe

Pier 4 Corbel 1 – OK

Corbel 2 – Badly Split

Corbel 3 – Badly split & crushing 100mm pipe **Corbel Length 3.7**

Corbel 4 – OK

Concrete Pier – OK

Span 5 Girder 1 – E2 OK – E1 OK

Girder 2 – E2 OK – E1 125mm pipe dia 450mm

Girder 3 – E2 OK – E1 OK **Girder Length 9.2**

Girder 4 – E2 OK – E1 75mm pipe dia 400mm

Pier 5 Corbel 1 – 200mm pipe badly split

Corbel 2 – OK

Corbel 3 – 100mm pipe dia 450mm **Corbel Length 3.7**

Corbel 4 – 250mm pipe dia 400mm crushing over headwall

Concrete Pier – OK

Span 6 Girder 1 – E2 160mm pipe – MS- 125mm pipe – E1 125mm pipe dia 400

Girder 2 – E2 150mm pipe – MS – 150mm pipe – E1 75mm pipe 450mm dia

Girder 3 – E2 150mm pipe – MS- OK – E1 150mm pipe dia 450mm

Girder 4 – E2 160mm pipe –MS- OK E1 125mm pipe dia 400mm cracky end 1

Girder Length 9.6

Deck worn out & perishing rotted on ends through to spiking plank

A2 Concrete Headwall – OK

BRIDGE HAS MAJOR PROBLEMS IN ALL SPANS AND IS BEYOND REPAIR AS WOULD COST MORE IN REPAIRS THEN TO REBUILD OVER EXISTING PIERS. SUGGEST CONCRETE DECK ON CONCRETE PIERS.

RECOMMEND LOAD AND SPEED LIMIT

Appendix D

In Field Bridge Inspection Form

Bridge: Jack Parr Bridge **Inspector:** T.Meredith **Date:** 7/07/2011

Bridge Length: 82.9m **Roadway Width:** 5m **No. Spans:** 9

Approximate waterway area
3*9*1.7 Total: 190m
2*9*2
2*9*4
2*9*2

Orientation of Bridge to Waterway
The bridge is perpendicular to the stream bed

Location of Bridge relative to river bed
The bridge is located at the transition point between a large radius curve and straight section

Materials Used on Bridge
Timber

Further Classification of Bridge
Simple timber beam bridge, each headstock supported by four timber piles
Timber abutments with stone pitching on approaches, concrete kerbing

Fauna found/suspected on site
Aquatic species - Was unable to see any however ideal habitat
Evidence of animals drinking from stream
Fenced on either side of the bridge with cattle in river bed

Flora found on site
A species of Bottle Brush

Description of site further upstream
Larger low flow stream
The bank on either side densly wooded
Limited trees in stream bed
Straighter river alignment

Description of site further downstream
Larger low flow stream
The bank on either side densly wooded
Location of another possible low flow channel
Dense trees in river bed

Alignment and condition of approach road

From Coonambula: Concrete causeway, relatively flat for approximately 50m before rising, combined vertical and horizontal curve, appropriate alignment, two lane bitumen seal, good condition

From Mundubbera: Combined horizontal and vertical curve, greater radius in both dimensions than other approach, vertical curve begins close to bridge, two lane bitumen seal, good condition

In Field Bridge Inspection Form

Bridge:	Flagstone Bridge	**Inspector:**	T.Meredith	**Date:**	7/07/2011
Bridge Length:	54m	**Roadway Width:**	3.6m	**No. Spans:**	6

Approximate Waterway Area:

1*9*1.5 Total: 130m

2*9*2

2*9*4

1*9*1

Orientation of Bridge to Waterway

The bridge is slightly skewed from perpendicular

Appoximately 10 degrees

Location of Bridge relative to river bed

The bridge is located on a very large radius bend. Bend is barely discernable and almost appears to be on a straight

Materials Used on Bridge

Timber

Concrete

Further Classification of Bridge

The bridge utilises a concrete peir and headstock structure with a timber superstructure including girders and corbles

Fauna found/suspected on site

Flora found on site

Eucalyptus and bottle brush

Description of site further upstream

Heavily wooded bed and bank, steep bank, similar current location

Description of site further downstream

Heavily wooded bed and bank, steep bank, similar current location

Alignment of approach road

From Mundubbera: Steep horizontal and vertical curve

From Hawkwood: Straight vertical curve

Steep approaches both sides

Condition of approach road

Two lane bitumen seal in good condition in both directions

Other

Heavy vehicle side track currently in place

Three pipe culverts approximately 600mm diameter

In Field Bridge Inspection Form

Bridge: Derrabungy **Inspector:** T.Meredith **Date:** 7/07/20011
Bridge Length: Bridge destroyed (Unmeasureable) **No. Spans** 1

Approximate Waterway Area:

Orientation of Bridge to Waterway
Perpendicular

Location of Bridge Relative to creek bed:
The bridge is located on a straigth with a large radius curve immediately upstream

Materials Used on Bridge
Steel
Concrete
Further Classification of Bridge

The bridge comprised of a large steel truss structure which supported the deck. Pre fabricated steel planks where used as the deck. The steel truss was conected to concrete abutments.

Fauna found/ suspected on site

Flora found on site

Description of site further upstream
Creek bed spreads out and is far more open
Dense tree coverage in bed
Large radius bend in stream
Description of site further downstream
Steep bank on one approach
Straight geometery
Similar bed to current location
Alignment of approach road
Large radius horizontal curve and very steep vertical curve coming towards Mundubbera
Near straight horizontal alignment and very steep vertical curve coming from Mundubbera
Conditon of approach road
Two lane gravel road in good condition in both directions
Other
All vehicle side track currently in place
Approx three 600mm pipes in place
Large ponding immediately downstream of site

In Field Bridge Inspection Form

Bridge: Waratah **Inspector:** T.Meredith **Date:** 17/07/2011
Bridge Length: 28m **No.Spans:** 4 @7m **Roadway Width:** 3.5m

Approximate Waterway Area:
3*6*7 Total:161m^2
1*5*7

Orientation of Bridge to Waterway
Perpendicular

Location of bridge relative to river bed:
The bridge is located in a small straight between two large bends

Materials used on Bridge
Timber

Further classification
It is a simple timber beam bridge which utilises fender poles upstream indicating a dirty stream. The bridge has timber abutments.

Fauna found/suspected on site

Flora found on site
Grass
Iron barks
Eculayptus
Other trees

Description of site further upstream
Large bend immediately upstream
Significant amount of trees on bank
Similar to current site

Description of site further downstream
Large bend immediately downstream
Similar amount of trees on bank
Much wider channel
Gully inlet
Small rapids section

Alignment of approach road
Small radius horizontal curve before entering steep decent - from Monto
Steep horizontal and vertical curve from other direction

Condition of approach road
Single lane bitumen each direction in good condition

Other
Tee intersection at one end with limited visibility

Appendix E

The following information was collected from road inspections of the area and from a desktop analysis of the bridge and area:

Road Description:

Coonambula Road is a Local Road of Regional Significance. It begins in Mundubbera township as a two lane bitumen sealed road. There are approximately two piggeries and three citrus orchards and several cattle properties between Mundubbera and Jack Parr Bridge. It is expected that the predominant travel route for these enterprises would not involve crossing the bridge. Just after Jack Parr Bridge there the road turns to single lane bitumen before turning into a gravel road. The name of the road changes to McCord's Road and then to Deepbank Coonambula Road before it meets the Eidsvold Theodore Road (State controlled Road). After Jack Parr Bridge there is one citrus orchard, approximately two irrigated cropping properties and several large cattle properties. There is also a rural housing development with approximately 10 allotments of approximately 100ha each. It is expected that the predominant travel route taken by the orchard, both cattle properties and some of the cattle properties would involve crossing the bridge.

Description of relative immunity of bridge:

There are no other major waterway crossings on this road. There are several smaller creek crossings which have fast rise – fast fall flooding characteristics. There are approximately two other crossings of the Burnett River in the area. These are on Grosvenor Road and Malmoe Road and have relatively similar flood immunity as Jack Parr Bridge. The Eidsvold Station Bridge is on the Eidsvold Coonambula Road between the Coonambula Road intersection and the town ship of Eidsvold. This bridge has slightly greater immunity than Jack Parr Bridge.

Industry serviced by bridge:

As mentioned previously the bridge services a citrus orchard, approximately two irrigated cropping properties and large cattle properties as well as rural residential development.

Possible future industry:

There is a significant portion of land in the vicinity of the Burnett River past Jack Parr Bridge which is not developed. It is possible that in future this could be developed for citrus or other intensive industries. There is also the possibility of further rural residential development in the area.

Waterway description:

The Burnett River is the major catchment and river system in the North Burnett region. The bridge is located between the Kirra Weir in Eidsvold and the Jones Weir in Mundubbera.

Known crashes near bridge:

The crash data for the region suggested that there have been four vehicle accidents on Coonambula Road since data collection began in 1992. The location of each crash along the road is not documented. However a process of elimination was used to determine if it was possible the accident occurred within the vicinity of the bridge. One accident occurred in a 60km/hr speed zone. The bridge is within a 100km/hr speed zone. Another accident involved a pedestrian. As there are no features near the bridge to attract people it is not expected that this accident occurred near the bridge. Another accident occurred on a straight crest. Both approaches to the bridge are curved. Another accident occurred on a causeway which suggests that it was not in the vicinity of the bridge. Taking into account the above description of each accident it is suggested that there have been no accidents on the bridge or on the approach to the bridge since recording began in 1992.

Known submersion description:

Flood data was available from a DERM river gauge within 20km of the bridge. However the relative level of the bridge is unknown and an accurate representation of the flood history could not be attained. Anecdotal evidence suggests that the bride is submerged for an average of approximately six days every year for an average of approximately 24-48 hours at a time.

Flagstone Bridge

Road Description:

Hawkwood Road is a Local Road of Regional Significance. It begins approximately 10km out of Mundubbera on the Mundubbera Durong Road and ends near Chinchilla in the Western Downs Regional Council Area. The boundary between NBRC and WDRC is approximately 100km from Mundubbera. The road is single lane bitumen sealed in either direction from the bridge. It runs into a well graded dirt road several kilometres from Flagstone Bridge.

Description of relative immunity of bridge:

This bridge has a slightly greater immunity than Dykehead Bridge which is located approximately 20km further along Hawkwood Road. To get to Flagstone Bridge from Mundubbera the driver must cross the Boyne River Bridge. This bridge is on the Boyne River and whilst the flooding patterns are different, it is also closed in a moderate to large flood event in the area. Another possible route to the bridge is from Cheltenham Road from the Eidsvold Theodore Road. Travelling from Eidsvold this requires the Burnett River to be traversed at the Eidsvold Station Bridge.

Industry serviced by bridge:

There is a citrus orchard on either side of the bridge. It is expected that traffic from one of these orchards would traverse the bridge in regular trips to Mundubbera. There is large irrigated cropping property immediately after the bridge. There is also a cattle feedlot development across the bridge. There are also several large cattle properties across the bridge which would regularly generate trips to Mundubbera requiring the bridge to be traversed.

Possible future industry:

It is expected that any of the above mentioned industries has the potential for expansion due to the water supply of the Auburn River and underground water supplies.

Waterway description:

The Auburn River is a major tributary of the Burnett River. The confluence of the two rivers is within tens of kilometres of Flagstone Bridge. This results in back up water reaching the bridge when the Burnett is in a large flood. Under free flow conditions the Auburn River is usually faster to rise and fall then the Burnett.

Known crashes near bridge:

The crash data suggests that there have been no serious accidents on Hawkwood Road since data collection began in 1992.

Known submersion description:

No accurate flood data could be provided for this bridge. There is a flood gauge on the Auburn River however it is upstream of the confluence of a major creek system and hence the data is not accurate for this situation. Anecdotal evidence suggests that when taking into account the flooding from the back up of the Burnett River this bridge is isolated for on average approximately 12 days every year.

Derrabungy Bridge

Road Description:

Beeron Road could be described as a collector road. It is not a through road. The bridge is approximately 25km from the start of Beeron Road at the intersection of Beeron Road and the Mundubbera Durong Road.

Description of relative immunity of bridge:

There is another similar creek crossing approximately 2km further along Beeron Road from Derrabungy Bridge. This crossing has a lower immunity. To get to Beeron Road from Mundubbera the driver must traverse the Boyne River Bridge which is submerged in a moderate to large flood event.

Industry serviced by bridge:

There are cattle properties on the far side of the bridge and an earthmoving contractor. There are approximately three residences. Most of the property entrances are past the second creek crossing.

Possible future industry:

It is not considered that there is a large chance of further industry development further along the road due to minimal surface water supply.

Waterway description:

Derrabungy Creek is a fast rise fast fall creek. It is a tributary of the Boyne River. It has limited, if any permanent flow.

Known crashes near bridge:

An analysis of the crash data suggests that there have no serious accidents on Beeron Road since data collection began in 1992.

Known submersion description:

There is no flood data for Derrabungy Creek. Anecdotal evidence suggests that due to its rapid rise and rapid fall it is never submerged for greater than one day at a time.

Waratah

Road Description:

Cahalane Road begins just off the state controlled Monto Gladstone Road with an intersection with Monal Road. Waratah Bridge is located approximately 2km from this intersection. The road ends with another intersection with Monal Road. It begins as a single lane bitumen road and moves to a graded gravel road past the bridge.

Description of relative immunity of bridge:

There are no other major low level crossings on this road. There are waterway bed crossings on two other roads which come off Cahalane Road and connect to other major roads. There is a low level crossing on Monal Road between the two intersections with Cahalane Road. It is expected that this bridge has a lower immunity than Waratah Bridge.

Industry serviced by bridge:

There are irrigated cropping properties and dairy farms in the area serviced by the bridge as well as beef cattle properties.

Possible future industry:

It is expected that there is further potential for expansion of the above mentioned intensive industries in the area.

Waterway description:

Monal Creek is a tributary of Three Moon Creek which in turn is a tributary of the Burnett River. The flow characteristics of this creek are not known.

Known crashes near bridge:

An analysis of the crash data suggests that there have been no serious accident on Cahalane Road since data collection began in 1992.

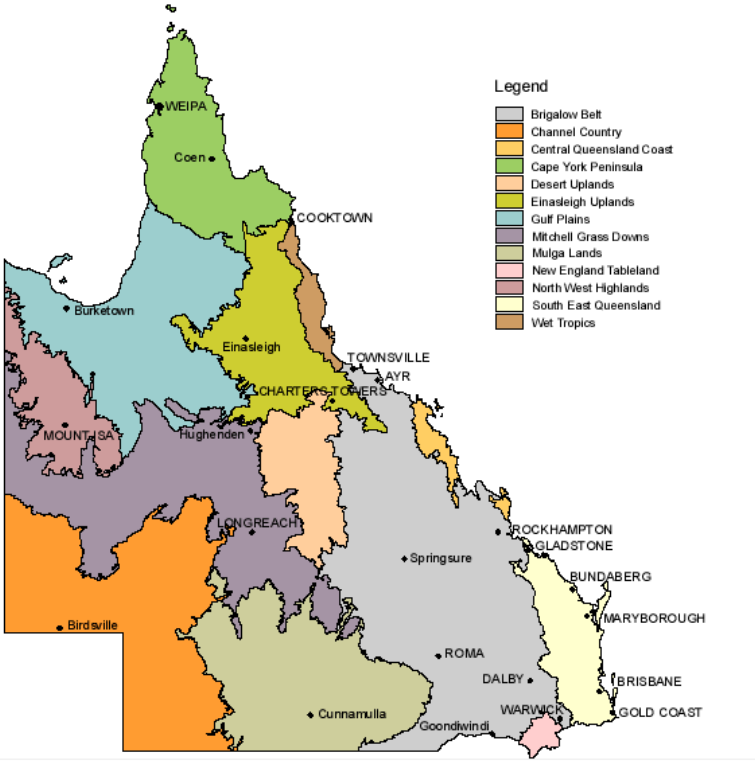
Known submersion description:

Accurate flood data for this bridge is not known. However anecdotal evidence suggests that the bridge is never submerged.

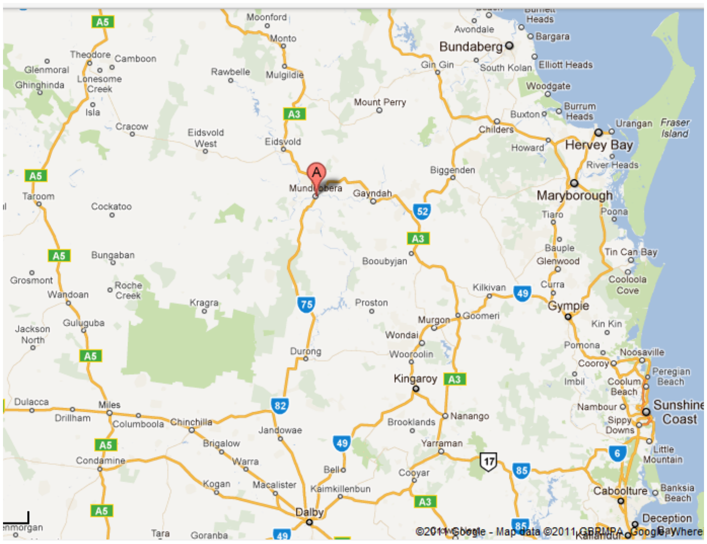
Appendix F

Regional Ecosystems

The first parameter required for the search was the biogeographic region where the bridges are. A map of all the regions of Queensland is shown below.



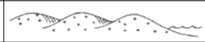
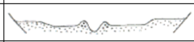
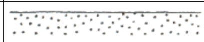
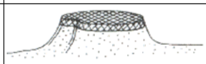
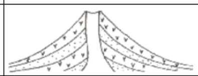
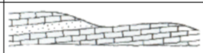
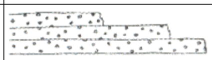
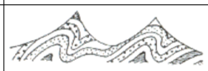
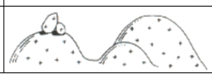
Biogeographic regions of Queensland. Source: Department of Environment and Resource Management 2011



North Burnett Region and surrounds.

The above map shows that Mundubbera is located nearly directly north of Dalby and west of Maryborough. This suggests that a portion of the North Burnett Region is in the Brigalow Belt whilst the rest of it is in South East Queensland. As the case study bridges used are in Mundubbera and Monto, the search focus will be placed on the Brigalow Belt.

The next phase of the search required focussing on specific land zones. The figure below shows the specified land zones in the region.

Land zone	Land zone name	
Zone 1	Tidal flats and beaches	
Zone 2	Coastal dunes	
Zone 3	Alluvium (river and creek flats)	
Zone 4	Clay plains not associated with current alluvium	
Zone 5	Old loamy and sandy plains	
Zone 7	Ironstone jump-ups	
Zone 8	Basalt plains and hills	
Zone 9	Undulating country on fine grained sedimentary rocks	
Zone 10	Sandstone ranges	
Zone 11	Hills and lowlands on metamorphic rocks	
Zone 12	Hills and lowlands on granitic rocks	

Land zones within the Brigalow Belt biogeographical region (Department of Environment and Resource Management 2011)

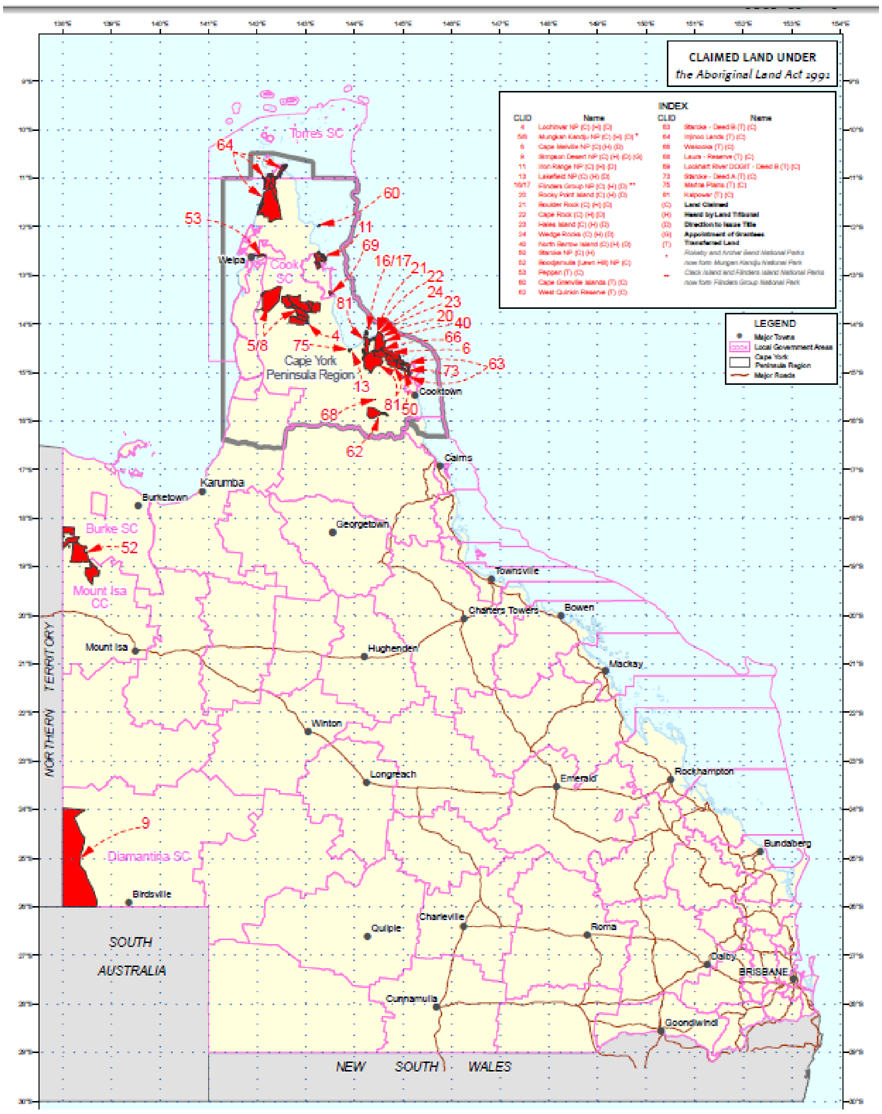
As the case study bridges all cross waterways, the alluvium land zone was selected.

This search (Department of Environment and Resource Management) resulted in 39 documented regional ecosystems in the region. The status of each of these ecosystems is noted in the database and the search was further focussed by only considering the ecosystems which have been noted as being of concern or endangered. There are 25 of concern or endangered ecosystems in the area. Each of these ecosystems was further researched to determine if they are known to be located near any of the case studies. Within the database there is a section which lists the areas where the ecosystem is protected. The assumptions was made that if the protected area was within the North Burnett Region or close surrounds, there is possibility that the ecosystem could be represented at the bridge site and further investigation would be required. Of the 25 ecosystems three where found to be represented in the North Burnett Region. These are discussed below.

RE Identification	Protected Areas within NBR or nearby	Brief Description	Status
11.3.25	Auburn River NP, Cania Gorge NP, Kroombit Tops NP	Two varieties of Eucalyptus – woodland fringing drainage lines	VMA – Least Concern Biodiversity Status – Of Concern
11.3.27	Kroombit Tops NP	Freshwater wetlands	VMA – Least Concern Biodiversity Status – Of Concern
11.3.4	Kroombit Tops NP, Cania Gorge NP	Two varieties of Eucalyptus – flood plains	VMA – Of Concern Biodiversity Status – Of Concern

Cultural Heritage

The map below shows the location of Native Title claims in Queensland.



Claimed land in Queensland under the Aboriginal Land Act 1991. Source: Department of Environment and Resource Management 2011.

This shows that there is no claimed land in the vicinity of North Burnett Regional Council.