Balranald – Ivanhoe Road

Pavement Condition Assessment

Cristal Mining Australia Limited

December 2013

Ref No. 20130829RA3

a better approach

Document History and Status

Rev	Description	Author	Reviewed	Approved	Date
A	Draft for Client Comment	PSC	RKE/JT	JT	27 November 2013
B	Issued to Client	PSC	RKE/JT	JT	4 December 2013
C	Minor Edits	PSC	JT	JT	6 December 2013

[Note: This document has been produced for double-sided printing]

Contents

Tables

Figures

Appendices

1 Introduction

Tonkin Consulting has been engaged by Cristal Mining Australia, to undertake an assessment of the haul road access on Balranald-Ivanhoe Road (M67) to the railway crossing, (approximately two kilometres south of Ivanhoe), a total of some 130 kilometres.

Cristal Mining has prepared an Environmental Impact Assessment looking at the issues associated with the creation of the new Atlas-Campaspe Mineral Sands Project. As part of these investigations GTA Consultants have prepared an assessment of the road transport implications for the project and have identified the Balranald Ivanhoe road as a key component of the proposed haul route from the mine.

The Balranald – Ivanhoe Road is located within the areas of the Balranald and Central Darling Shires. Both Councils have raised concerns on the impact of the performance and serviceability of the current road configuration based on the anticipated traffic that will be generated as a result of the new mine.

The objective of the Tonkin investigation is to assess the current condition of the road and estimate the likely remaining serviceable life of the pavement under both the existing and proposed traffic regimes. This will enable a strategy of road maintenance to be prepared for consideration for Cristal and the Shires to manage the serviceability of the road of the proposed life of the mine.

1.1 Background

Balranald-Ivanhoe Road (MR67) is a Regional Road which links from the Sturt Highway at Balranald, generally north-south via Hatfield to the Cobb Highway at Ivanhoe.

The NSW RMS considers Regional Roads perform a significant regional function and for which the RMS and Council contribute 50% each towards maintenance.

The Balranald–Ivanhoe Road is a low volume road that has been constructed and sealed in sections since the 1970s. From discussions with both Shires the road is considered to be in reasonable condition. The quality of construction and materials used is considered variable, however has improved in northern sections due to recent construction techniques. At present, approximately 34 kilometres of the road is unsealed. The unsealed sections are signposted as non-traversable during wet conditions.

This road is an approved route for road trains and 4.6m high vehicles. Cristal Mining has proposed to use Type 1 Double Road trains as the preferred haul vehicle.

A road safety audit has been undertaken as part of the EIS and Balranald Shire advised cattle grids, races and culverts all came under scrutiny.

Both Shires are concerned about the impact on the road with the increase in heavy traffic, specifically the increase in maintenance and the loss of pavement life, as a result of the proposed new mining activities proposed by the Atlas-Campaspe operation.

1.2 Existing Road

The typical cross section profile includes a seal width of 7.1m seal increasing to 7.2m and 7.4m in sections. The road is elevated and the table drain invert is generally 3 m from the edge of seal and extends to 5m in the northern sections of the road.

It is understood typically 150mm depth of granular pavement material was constructed on the formation, however Central Darling Shire advised that in recent times they have included a select fill layer of 150mm in depth below the pavement.

In terms of the condition of the road, the following observations were made:

- The sealed surface is in good condition with most sections having a lively binder which indicates the regular resealing program on the road is in place. Some older sections are showing signs of stripping, however only isolated sections have broken through to the pavement, which can be managed with reseals and maintenance.

Photograph 1 Typical seal condition

- The shoulders in places are heavily vegetated in sections which restrict stormwater draining from the edge of the road surface.

Photograph 2 Sections where vegetation in the shoulder restricts drainage

- The table drains, elevation and shape of the road cross section provide a sound platform for drainage, provided maintenance occurs, to ensure a free draining surface.

Photograph 3 Typical formation cross section

- There are sections of the road that provide a rough ride, however the majority of the road provides a smooth ride.

Photograph 4

Section of road surface with poor rideability due to deformation and cracking

- There is evidence of cracking in sections of the road, typically longitudinal cracking in the outer wheel path. This is generally isolated to sections rather than an extensive defect along the entire length of the road.

Photograph 5   Outer wheel path cracking

- There was little observable rutting, however when driving in the evening, there was some shadowing suggesting minor rutting in sections.

Photograph 6 Shadowing indicating some rutting in outer wheel path in sections

- The seal changes are typically 5–8km sections providing some indication of the history and the staging of construction.

Photograph 7 Typical change of seal

Figure 1 below shows the status of the Ivanhoe-Balranald Road in terms of the extent of unsealed sections (shown in yellow) and new works areas (shown in purple), with the remainder of the road being sealed. The Test Pit locations, identifying the geotechnical sample locations undertaken to date and referenced in Appendix A of this report. The change in seal or surface type is also shown by the yellow dots. This provides a clear picture of the extent of construction still to be undertaken and the aerial mapping overlay shows the variation in terrain. Of particular note is the crossing of the waterway system near TP2.

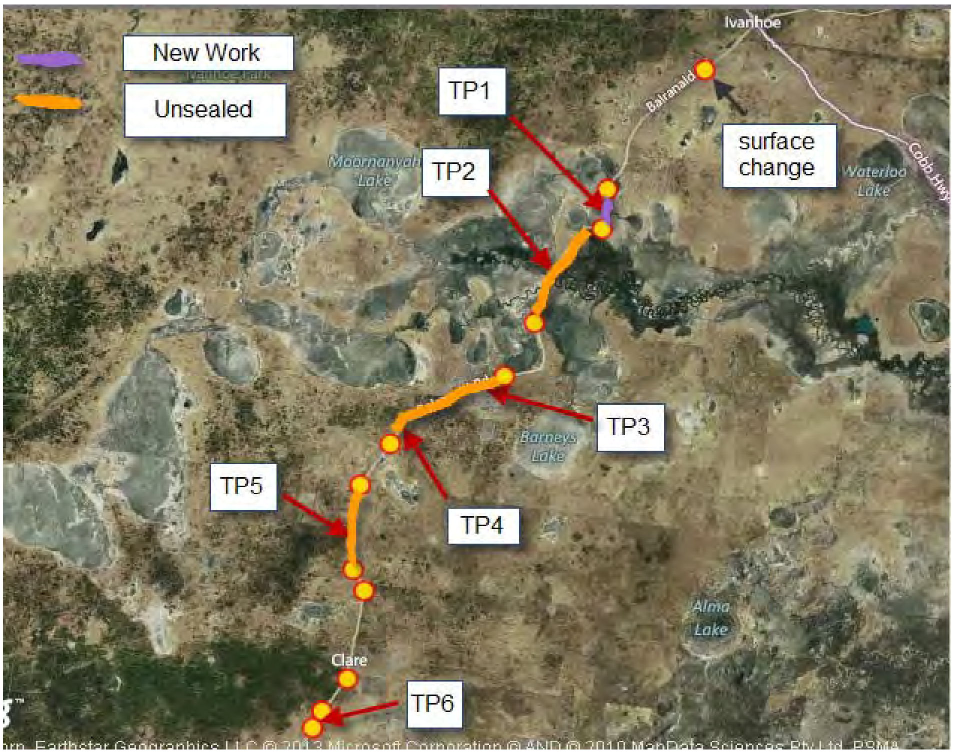

Figure 1 Map of the Balranald Ivanhoe Road from Clare to Ivanhoe

Figure 2 below shows the haul road access point in red which is 73.3km north of Balranald and the yellow dots highlight a segment length which is evident by a change in seal. The full section of the road in this section is sealed and was subjected to additional testing in the form of Falling Weight Deflectometer (FWD) testing in order to understand the pavement and subgrade conditions. No testing was undertaken in this area for pavement depth or condition.

Figure 2 Map of the Balranald-Ivanhoe Road from Haul Road Access point (73.3km North of Balranald to Clare)

2 Traffic Conditions

2.1 New Traffic Generated by Mine Haulage

2.1.1 Haul Vehicle

The vehicle proposed for haul of ore is a Type 1 Road train 36.5m with a Gross Combination Mass of 85 tonne (HML approved), which is the maximum sized vehicle currently allowed for this road.

2.1.2 Mineral Concentrate Transport

Cristal has indicated that the life of the mine will be approximately 20 years, and is expected to haul 450,000 tonnes of material per annum at peak production.

An indicative schedule of concentrate transport is included in the Cristal Atlas–Campaspe Mineral Sands Project EIS. The mine has a potential 20 year mine life over which time it is planned to transport 6.2Mt (dry tonnes) of concentrate, which equates to 124,000 trips of a fully laden (50t payload of mineral concentrate per vehicle) road train to transport all the mineral concentrate.

Based on the average production rate there it is expected there will be approximately 35 round trips each day the pavement integrity has been assessed on this basis.

2.1.3 Road Train Axle Groups

The Type 1 Road Train consists of the components having a total of 5 axle groups as shown in Figure 3 below, with each road train capable of transporting a 50t payload of mineral concentrate.

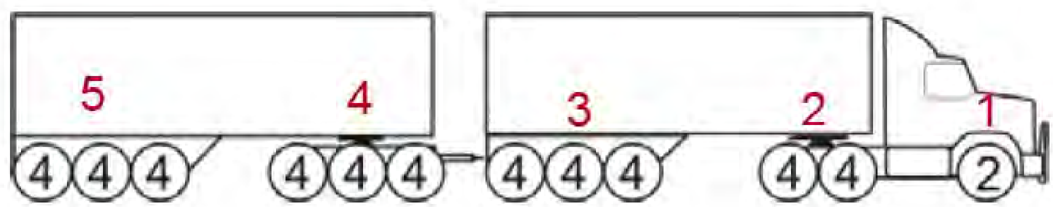

Figure 3 Type 1 Road Train Axle Groups

2.2 Equivalent Standard Axles

AUSTROADS AGPT02, Equation 7.3: Pavement design guides provide guidance to how many passes of a reference axle group called the “standard axle” (an 80kN Single Axle Dual Tyre axle) any given pavement can withstand. In order to compare the effects of various vehicles on a pavement it is industry practice to determine the number of passes of the standard load that would cause the equivalent damage to the loading in question. *Austroads Guide to Pavement Technology Part 2: Pavement Structural Design* equation 7.3 provides a method for calculating the number of passes of the standard axle that cause the same damage as a single pass common road legal axle configurations.

To calculate number of standard axle repetitions (or passages of the standard axle) for each type of axle group at maximum axle group loads, use

$$SAR_4 = \left(\frac{L}{SL}\right)^4$$

Where:

SAR4 = number of Standard Axle Repetitions (or passages of the Standard Axle) which causes the same amount of damage as a single passage of the particular axle group type at its actual load

L = Applied load on the axle group in question

SL = Reference Load

The reference loads are provided in Table 1

Table 1 Typical Axle Types and reference Loads (Austroads)

Axle Type	SL (Axle Reference Load kN)	Axle Mass (t)
Single Axle with Single Tyres (SAST)	53kN	5.4t
Single Axle with Dual Tyres (SADT)	80kN	8.2t
Tandem Axle with Single Tyre (TAST)	90kN	9.2t
Tandem Axle with Dual Tyres (TADT)	135kN	13.8t
Triaxle with Dual Tyres (TRDT)	181kN	18.5t

2.2.1 Calculation of Loaded MCT vehicle ESA's

Table 2 shows the calculation to determine the equivalent passes of the standard axle which would cause the same damage as one pass of the fully loaded design haul vehicle (Type 1 Road Train) standard axle.

Table 2 Calculation of Loaded MCT vehicle ESA's

Axle Group	1	2	3	4	5			
Axle Group Type	SAST	TADT	TRDT	TRDT	TRDT			
Reference Load	53	135	181	181	181	kN		
Load on Axle Group	60	170	225	225	225	kN		
							Total	
Equivalent Load (Load/Reference)^4	1.64	2.51	2.39	2.39	2.39		**11.32**	ESAs

Table 3 below summaries key numbers for a Type 1 road train laden with 50 dry tonne payload of ore.

Table 3 Equivalent Standard Axles expressed as a ratio per dry tonne of payload

ESAs Per Vehicle Pass	11.3 ESA
t/ESA	4.42t/ESA
ESA/t	0.23 ESA/t

Based on 124,000 trips of a fully laden MCT vehicles to transport all the mineral concentrate equates to a total of 1,404,000 ($1.4x10^6$) ESAs.

Only the North bound lane of the Balranald-Ivanhoe Road will be trafficked by the laden vehicles the South bound lane will be trafficked by only empty haul vehicles returning to the mine.

2.2.2 Calculation of Unloaded MCT vehicle ESA's

The damage caused by a pass of the unladen Road Train has also been calculated for the South bound lane as show in Table 4.

Table 4 Calculation of Unloaded MCT vehicle ESA's

Axle Group	1	2	3	4	5			
Axle Group Type	SAST	TADT	TRDT	TRDT	TRDT			
Reference Load	53	135	181	181	181	kN		
Load on Axle Group	60	70	92	92	92	kN		
							Total	
Equivalent Load (Load/Reference)^4	1.64	0.07	0.07	0.07	0.07		**1.92**	ESAs

Based on 124,000 trips of the unladen MCT vehicles returning to the mine equates to a total of 237,000 ($2.4x10^5$) ESAs.

2.3 Other Traffic

2.3.1 Existing Traffic

GTA Consultants undertook a road transport assessment (ref# 12S1252000) which included taking traffic counts of the Balranald-Ivanhoe Road North of Hatfield-The Vale Road intersection. The count was conducted between Friday, 11 May 2012 to Thursday, 17 May 2012. The seven day, two-way traffic is shown in the Table 5 below.

Table 5 Existing Traffic

Vehicle Type	Number (AADT)	Number of Axle Groups
Light	149	NA
Rigid	45	2
Articulated	2	3
B Double	13	4
Road Train	15	5
Total	**224 (35/day)**	**Average = 2.97**

As the traffic counter data only provides the number of vehicles in each class not the configuration of each axle group and the applied load on each it is not possible to undertake the exact calculations used in determining ESAs for the MCT.

The *Austroads Guide to Pavement Technology Part 2: Pavement Structural Design* Section 7.6.2 provides an alternative method for estimating the damage caused by vehicle passes by providing indicative average number ESAs/Axle Group based on typical Australian Roads these are provided in Table 7.8 of the Guide and are reproduced below in Table 6:

Table 6 ESA / Axle Group (Australian Roads Guides Pavement Technology Table 7.8

	Urban Roads	Rural Roads
ESA/Axle Group	0.7	0.9

Based on this the Equivalent Standard Axle (ESA) based on expected traffic loading from the existing traffic assessment over the 20 year design life of the mine has been calculated as follows:

- AADT = 35
- % Heavy Vehicles = 33% (based on GTA traffic count)
- Average Number of Heavy Vehicle Axle Groups (NHVAG) = 3 (based on GTA traffic count)
- ESAs per Heavy Vehicle Axle Group = 0.9 (Austroads default for rural roads)

From this assessment a design traffic loading of **1.1 x10^{5} ESAs** can be assumed for the existing traffic and drawing comparison to the traffic loading when the mine is operational, which is covered later in this report.

2.3.2 Non MCT Mine Traffic

GTA estimated non MCT project traffic as 14 light vehicles and 2 heavy vehicles per day (2 way), it is anticipated that this will include a variety of different vehicles required from time to time for the operation of the project. As such the Austroads rural default values for vehicle loadings have been adopted.

- AADT = 16
- % Heavy Vehicles = 12.5% (based on GTA estimate)
- Average Number of Heavy Vehicle Axle Groups (NHVAG) = 2.9 Austroads default for rural roads)
- ESAs per Heavy Vehicle Axle Group = 0.9 (Austroads default for rural roads)

Giving a total of **1.9 x10^{4} ESAs** from non MCT mine traffic.

2.3.3 Non Mine Growth

The GTA report provides an estimate of the non project related traffic growth. The numbers include the estimated BMSP traffic and other growth not related to any specific project. The

BMSP traffic has been conservatively assumed to last for the whole design life, despite the fact it is expected to cease in year 14 of the project. The traffic has been calculated based on:

- AADT = 22 (GTA estimate)
- % Heavy Vehicles = 23% (based on GTA estimate)
- Average Number of Heavy Vehicle Axle Groups (NHVAG) = 3 (based on existing traffic mix of vehicles)
- ESAs per Heavy Vehicle Axle Group = 0.9 (Austroads default for rural roads)

Giving a total of **5.0 x10^4 ESAs** from non project growth.

2.4 Total Traffic

All expected traffic is summarised below in Table 7.

Table 7 Expected Traffic

Traffic Type	Traffic Loading (ESA)
Existing	1.14 x10^5
Non Project Growth	5.0 x10^4
Mineral Concentrate Transport	1.404 x10^6
Other Atlas Campaspe Traffic	1.9x10^4
Total	**1.6 x10^6**

For the purposes of the pavement analysis it has been assumed that the total traffic loading will be applied evenly throughout the life of the mine as follows:

- Existing Traffic Condition - 8x10^3 ESA's per annum, applied to each lane;
- Mine Traffic Condition - 8x10^4 ESA's per annum to north bound lane, 2.3x10^4 ESA's per annum to north bound lane.

3 Falling Weight Deflectometer Testing

3.1 Testing

In order to determine the ability of the pavement to withstand future loads, Falling Weight Deflectometer (FWD) testing was conducted on the sealed section of seal from the Magenta Wampo Road to the Railway crossing just south of Ivanhoe over a total distance of 151km. This testing was undertaken in early October 2013. The unsealed sections of the road were not tested.

The FWD drops a uniform load on pavement and measures deflection at specific distances from the point of application. The deflection bowls recorded can be used to determine the additional passes of the standard axle the pavement can be subjected to before permanent deformation occurs.The testing was undertaken in the outer wheel path at 1000m intervals and staggered in both the north bound and south bound lanes. Accordingly there is data available along the length of the sealed road at 500m intervals, with provides a basis of predicting impacts on pavement performance under existing traffic and future traffic conditions.

The reporting this data includes chainages to accurately determine the section of road in question. For the purposes of the reporting Chainage 0.0 has been identified as the intersection of the haul road from the mine to the Balranald – Ivanhoe Road, located approximately 73km North of Balranald.

3.2 Key Results

The key information provided in the FWD results is described below:

- Defections provide an indication of the suitability of pavement cover over the subgrade for different traffic loading conditions. The higher the deflection and the lower the allowable traffic to resist permanent deformation.
- Curvatures provide an indication of the stiffness of the pavement which is a combination of the thickness and material quality.
- Subgrade CBR is an estimate using the Queensland Main Roads method, and uses the deflection data to predict the subgrade CBR strength.

3.2.1 Deflection Results

Austroads(1992) Pavement Design – A Guide to the structural design of Road Pavements together with Austroads (2004) Pavement Rehabilitation – A Guide to the design and rehabilitation Treatments for Road pavement provides guidance in the use and interpretation of FWD data and provides a basis for predicting remaining life of the pavement.

For the purpose of this analysis, we have ignored correction factors that take into account such variables as temperature and utilised the raw data.

Table 8 below summarises the recommended limits for curvature and deflection, to ensure that the pavement can achieve a 20 year design life.

Table 8 Tolerable Deflections and Curvature assuming a 20 year life

Traffic	Tolerable Deflection (Figure 6.5) Austroads 2004	Tolerable Curvature (Figure 10.4) Austroads 1992
Existing	1.55mm	0.28mm
Future (South Bound)	1.28mm	0.22mm
Future (North Board)	1.08mm	0.17mm

The deflection results indicated in Figure 4 below indicates there are sections of the road above 1.55mm, which highlight that these areas may not resist permanent deformation within a 20 year design life under the existing traffic conditions.

While there are some sections of road with deflections less then 1mm, the majority of the road has deflection readings above 1.08mm, which indicates the majority of the road will not resist permanent deformation within a 20 year design life under fully loaded hauling.

It is worth noting the north section of the road, within the Central Darling Shire Council area has deflections closer to tolerable deflections and is likely to have a longer life then the majority of the road in Balranald Shire Council area. These areas correlate well with the general topography of the area, with the areas recording high deflections located adjacent low lying depressions, which are subjected to regular inundation and lower strength subgrade material.

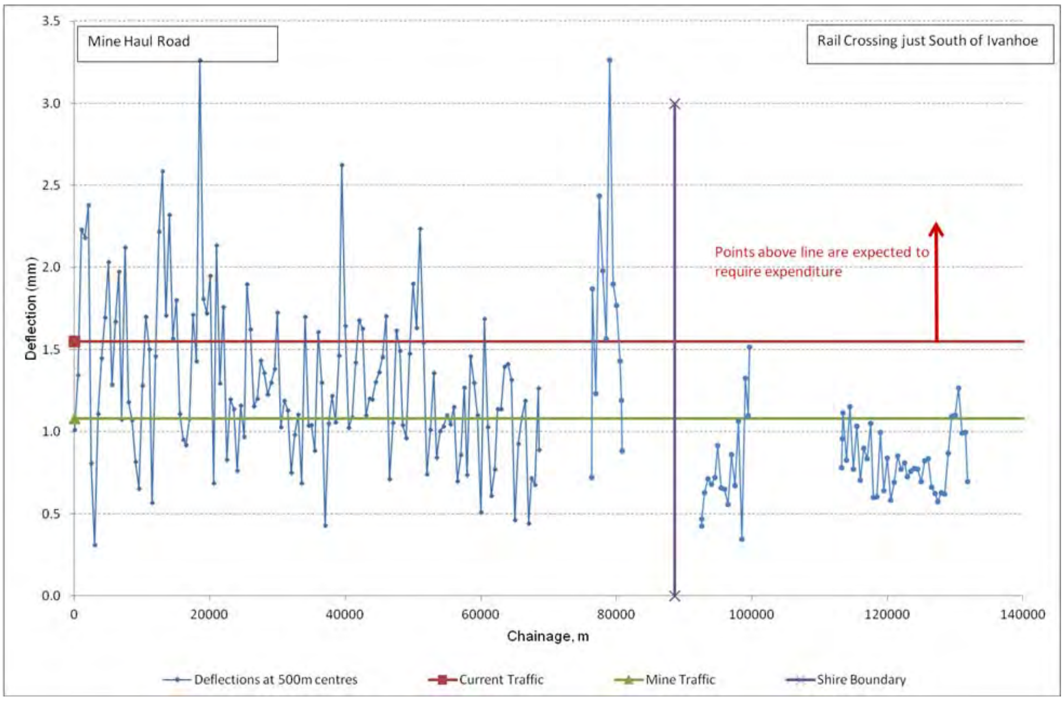

Figure 4 Deflection Results

The deflection results allow the remaining life of the pavement to be determined under various traffic conditions and has been the basis for determine the initial trigger point in implementing the adopted maintenance regime, which is discussed in further detail in later sections of this report.

3.2.2 Curvature Results

In terms of curvature the results are generally well above the tolerable limits for both the existing and the future traffic conditions. Refer to Figure 5 for curvature results. It is noted that the curvatures are a function of the overall pavement stiffness. The curvature results are relatively uniform, which suggests that the quality of the base course material is poor, or due to the relatively thin pavement layers (assumed to be nominally 150mm), the pavement performance is heavily influenced by the subgrade properties and therefore poor subgrade conditions will contribute to higher curvature results.

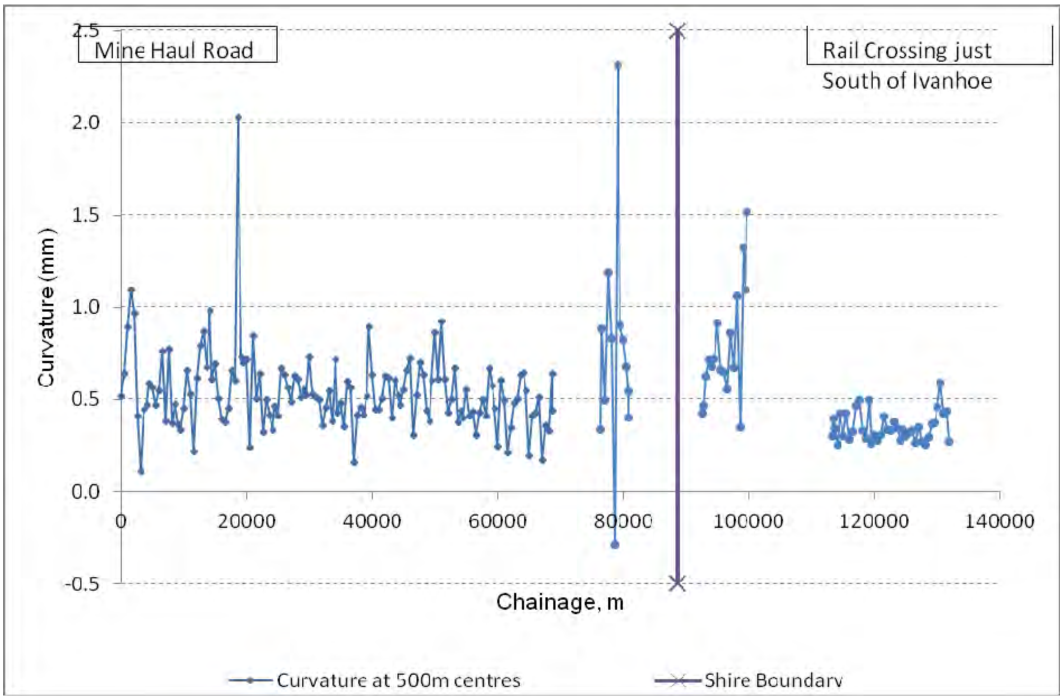

Figure 5 Curvature Results

3.2.3 CBR Results

Due to the high curvature experienced and the thin pavements there is a low bearing capacity for the pavement and it is likely to experience shear failure resulting in dig outs and replacement of the pavement in sections.

The FWD testing has provided an estimate of the subgrade CBR using the Queensland Main Roads (QMR) method. Based on these results, segments of road have been divided into three categories and presented in Figure 6.

- Poor Subgrade – CBR values <7% (design subgrade of 5% assumed for treatment cost estimates), shown in red.
- Average Subgrade – CBR values between 7% and 13% (design subgrade of 10% assumed for treatment cost estimates), shown in yellow.
- Good Subgrade – CBR Values >13% (design subgrade of 15% assumed for treatment cost estimates), shown in green.

These broad CBR categories have been used for high level cost estimates and analysis, it is anticipated that more detailed geotechnical investigation will be undertaken to specific sections of road before actual treatments are designed.

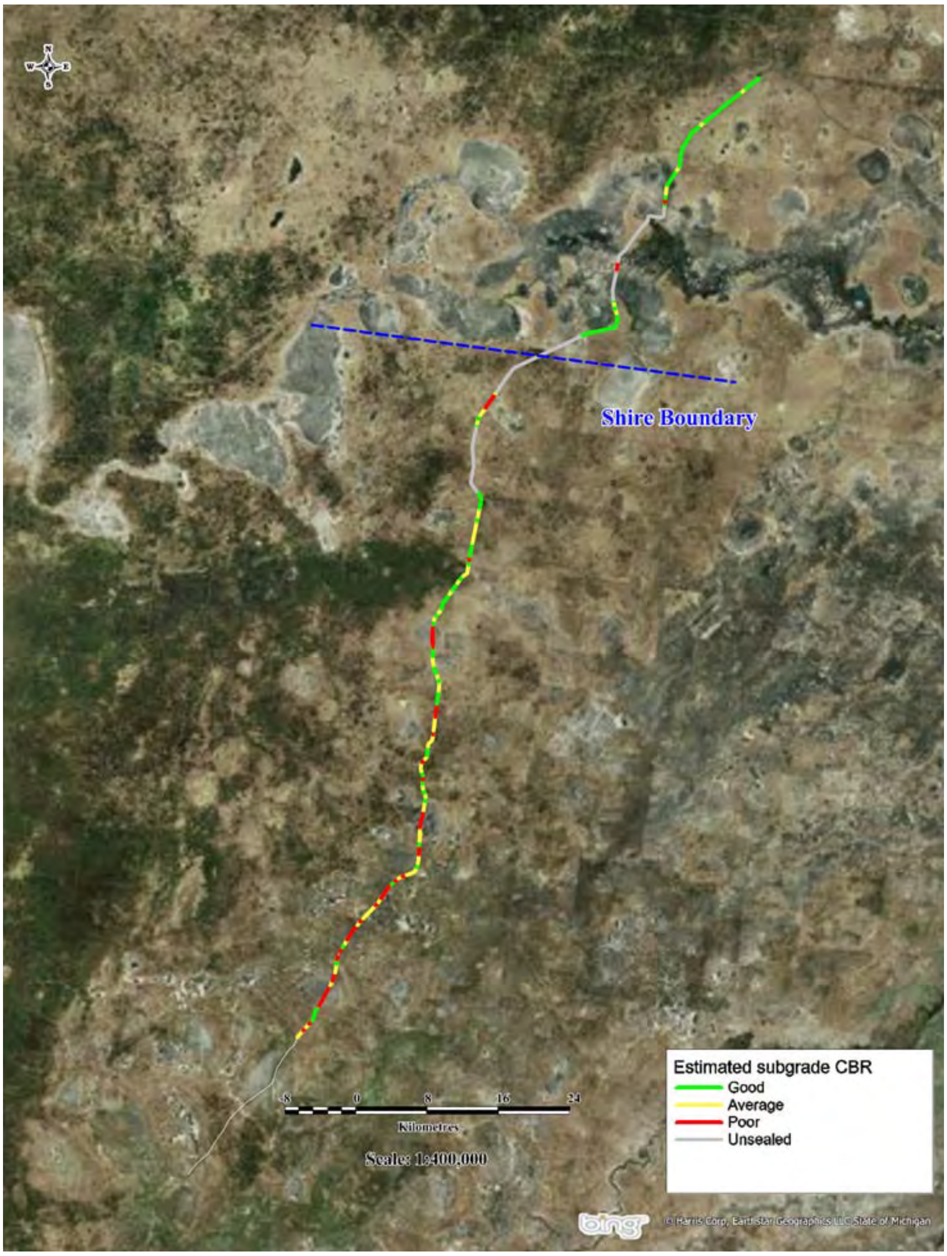

Figure 6 CBR results along Balranald – Ivanhoe Road

The areas of poor CBR appear to generally occur with low lying areas, watercourses etc. Figure 7 below shows an example.

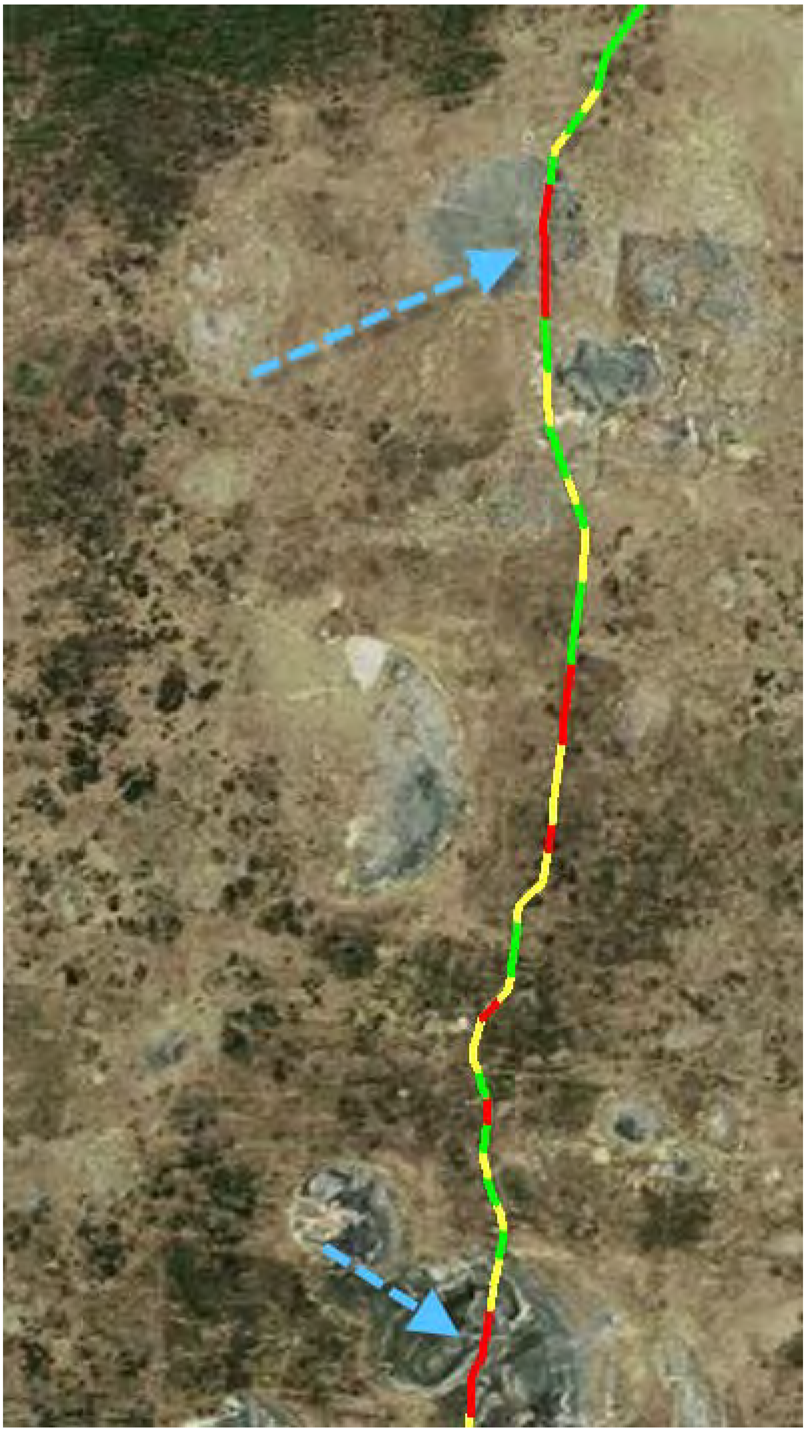

Figure 7 Poor CBR values within areas in lake crossings

3.3 Anticipated Failure Modes

The results of the FWD testing give some insight into the likely modes of failure that will be experienced as a result of current and increased traffic conditions.

It is likely the outer wheel path will have the lowest bearing capacity, which results in shear failure which is evident as shoving in the pavement layers and the inner wheel path may be more indicative of rutting failure. If significant winter rains occur then the extent of shear failure may increase. In addition to this it is likely the where softer base material is used that the stone in the spray seal will be pushed into the base leaving the binder exposed with the potential for flushing in the wheel paths.

In addition areas with low CBR's are likely to deteriorate at a rate quicker than the average or good zones, which will trigger the requirement intervention and implementation of the adopted maintenance regime.

4 Managing the Road

4.1 Maintenance Strategy

Once the pavement has been subjected to the number of passes of the standard axle to achieve the remaining pavement life indicated by the deflection results, it is expected that permanent deformation will begin to occur resulting in ruts, potholes, shoving and edge damage etc. It is anticipated that maintenance measures will be applied to correct these defects to increase the pavement's serviceable life. There will come a time however at which maintenance will not be economically viable and the pavement will need to be reconstructed.

4.1.1 Adopted Maintenance Regime

For the purposes of the analysis, we have adopted a maintenance regime that seeks to prolong the life of the existing pavement .The regime is consistent with typical philosophies in regional locations including local and state road authorities to prolong the serviceable life of the road in a cost effective manner.

The approach consists of a period of light patching within any segment of road followed by heavy patching, prior to pavement reconstruction by reusing existing materials and possibly adding a powder binder to stabilise the pavement.

The process of determining when any segment of the road requires intervention and implementation of the maintenance regime has been assumed to be a function of the deflection results in conjunction with the estimated CBR of the segment.

The assumed maintenance regimes for pavements with various remaining lives are provided in Appendix B. Details of each of the maintenance operations have been described below.

4.1.2 Light Patching

It is assumed that once the first pavement defect begins appearing that light patching will be undertaken. Light patching corrects defects at the top of the pavement layer and will not provide the structural rehabilitation. These patches simply serve to provide a short term repair to prevent moisture ingress and maintain the service level of the road and it is likely that the areas subject to light patching will fail again in the near future (1-2 years). In addition it is assumed these failures will be isolated in nature.

4.1.3 Heavy Patching

Once larger areas of pavement are suffering distress or the light patching continues to deteriorate quickly, a heavy patching regime will be undertaken. This operation will include excavation of the pavement material to subgrade level and patching with imported gravel and resealing. This may also involve adding a powder binder like quick lime.

For the purposes of the analysis and costings, it is assumed that once 12% of a road segment has been treated, any further heavy patching will not be economically viable. The amount of heavy patching undertaken in any one year has been adjusted within the model based on the assumption that certain sections of road (typically areas of poor CBR) are deteriorating faster than others.

4.1.4 Reconstruction/Stabilisation Treatments

Due to the lack of a reliable, good quality rubble source in the region, it is likely that when a road is reconstructed it has been assumed that in- situ stabilisation techniques will be adopted to minimise the amount of rubble/gravel to be imported. In addition the preferred stabilisation treatment differs depending on the subgrade quality in that area. It is assumed that the binder for all stabilisation operations will be a 70% slag 30% lime blend. Three options have been considered and are as follows:

Poor Subgrade

For areas identified as poor, 50mm of new gravel will be added to the road and this new gravel, the existing 150mm pavement layer and 100mm of subgrade material will be stabilised with 2% binder to form a 300mm stabilised layer. This layer will then have an additional 150mm of compacted gravel placed on top of it and a 2 coat spray seal.

Austroads Guide to Pavement Design Figure 8.4 indicates that 400mm cover of pavement material is required over a CBR 5% to withstand traffic loading of 1.6×10^6 ESA. It is assumed that a 300mm stabilised layer and 150mm granular overlay (450mm) thick will provide an adequate pavement, equivalent to a 400mm depth pavement with high quality material, as assumed in the Austroads charts.

Average Subgrade

Areas identified as average, the existing 150mm of pavement and 150mm of subgrade will be stabilised with 2% binder to form a 300mm stabilized layer. This layer will then receive a 2 coat spray seal.

Good Subgrade

For areas identified as good, the 150mm pavement layer and 100mm of subgrade material will be stabilised with 2% binder to form a 250mm stabilized layer. This layer will then receive a 2 coat spray seal.

4.1.5 Reseals

It is assumed that roads will be resealed approximately every 12 years, which has been based on the approach historically adopted by each Shire. It is assumed that for resealing a previously sealed road, a single coat 10mm spray seal is sufficient.

For areas in poorer subgrade the resealing frequency has been modified to occur at intervals not more than 9 years. The reduction of seal life recognises that the gravel material used in these areas is of lower quality and therefore more susceptible to deterioration due to flushing of the surface, which occurs when the sealing aggregate is pushed into the underlying softer granular pavement material resulting in a matt, smooth surface.

Further the model has incorporated the assumption that if no reconstruction work is undertaken on a segment of road, that a reseal will be undertaken when the seal reaches the end of its life. Based on the liveliness of the binder encountered during the initial inspection of the road Table 9 identifies the estimated remaining seal life for the purposes of cost model assumptions.

Table 9 Estimated Seal Change Locations and Remaining Seal Lives

Chainage (km)	Estimated Remaining Seal Life
0-3	6 years
3.5-10.5	3 years
11-35	5 years
3.5-39	4 years
39.5-45.5	5 years
46-56	7 years
56.5-60	9 years
60.5-104	10 years
104.5-End	12 years

For segments resealed in the first 7 years it is assumed a second reseal will be needed in the 20 year design life period and has been scheduled 9-12 years after the first.

For road segments that have undergone stabilisation treatments, reseals have been allocated 12 years prior or after this treatment, which is consistent with the approach adopted by the Shires.

It has been assumed the frequency of reseal is no different for loaded and unloaded scenarios

5 Costings

The costs of maintaining the Balranald – Ivanhoe Road have been estimated based on the assumed adopted maintenance regime as previously described, for both the current and future traffic conditions

In determining the costs for each of the maintenance operations we have sought advice from the local Shires, Contractors that have previous experience in the region and our own previous experience. The rates adopted for the various treatments are summarised below.

All costs assume treating one lane (4m wide) of the 500m segment. Where segment lengths are not 500m, for example approaching the change to the unsealed sections, the rates have been adjusted accordingly.

5.1 Light Patching Costs

It has been assumed that 5% of the area of the road segment will undergo light patching each year prior to heavy patching commencing. A rate of $20/m^2 has been assumed for light patching based on the assumption that it will be approximately a third of the cost of heavy patching.

- Light Patch 5% of Road Segment - $2,000 per segment.

5.2 Heavy Patching Costs

Balranald Shire has indicated that heavy patching typically costs between $60 and $70 per m^2. A rate of $65/m^2 has been adopted for heavy patching. Assuming a 4mx500m (2000m^2) segment this results in the following treatment costs:

- Heavy Patch 3% area of Road Segment - $3,900 per segment
- Heavy Patch 4% area of Road Segment - $5,200 per segment
- Heavy Patch 6% area of Road Segment - $7,800 per segment
- Heavy Patch 12% area of Road Segment - $15,600 per segment.

5.3 Stabilisation Costs

The costs for the stabilisation works have been based on information provided by contractor specialising in stabilisation.

The cost of mobilising a stabilisation crew is currently estimated to be $11,605, with a rate of $7,000 per day (including plant and operators). The cost to stabilise 1m^3 of material with 2% binder is currently $21.50. A productivity rate of 3,000m^3/day is assumed regardless of stabilisation depth. These rates were combined with Council's rate for grading, watering and rolling and a 2 coat spray seal.

For the purpose of apportioning the mobilisation cost it is assumed that the equipment will be mobilised for a minimum of 5 days, to achieve some cost efficiencies in the mobilisation of the plant and crew.

- Stabilising poor subgrade sections - $94,434 per segment
- Stabilising average subgrade sections - $60,940 per segment
- Stabilising good subgrade sections - $58,780 per segment.

5.4 Sealing Costs

Balranald Shire has indicated the following sealing costs:

- Single Coat Spray Seal $7.15/m^2$ (Rate assumed for reseals)
- Two Coat Spray Seal $12.15/m^2$ (Rate assumed for sealing after reconstructions).

These rates equate to the following costs per segment:

- Single Coat Spray Seal = $14,300 per segment
- Two Coat Spray Seal = $24,300 per segment (incorporated into the stabilisation costs).

6 Modelling and Expected Costs over 20 Years

In order to calculate the expected costs of maintaining the road the year that each segment will have been subjected to the cumulative allowable ESAs, (based on an average rate of ESAs per year) has been determined from the FWD deflection results.

6.1 Costs for Existing Traffic Condition

It is assumed that if the mine did not go ahead the road is subjected to following average annual traffic loading, which included an allowance for growth as previously described in the Traffic Condition section of this report.

- North Bound Loaded Lane 8.0x10^3 ESAs/annum
- South Bound Unloaded Lane 8.0x10^3 ESAs/annum

This results in the following cumulative loadings as shown in Table 10.

Table 10 Cumulative Loadings

Year	Northbound Lane	Southbound Lane
1	8.00E+03	8.00E+03
2	1.60E+04	1.60E+04
3	2.40E+04	2.40E+04
4	3.20E+04	3.20E+04
5	4.00E+04	4.00E+04
6	4.80E+04	4.80E+04
7	5.60E+04	5.60E+04
8	6.40E+04	6.40E+04
9	7.20E+04	7.20E+04
10	8.00E+04	8.00E+04
11	8.80E+04	8.80E+04
12	9.60E+04	9.60E+04
13	1.04E+05	1.04E+05
14	1.12E+05	1.12E+05
15	1.20E+05	1.20E+05
16	1.28E+05	1.28E+05
17	1.36E+05	1.36E+05
18	1.44E+05	1.44E+05
19	1.52E+05	1.52E+05
20	1.60E+05	1.60E+05

Based on this traffic loading condition the remaining life for each segment of road can be determined and has been expressed in terms of total length in Figure 8.

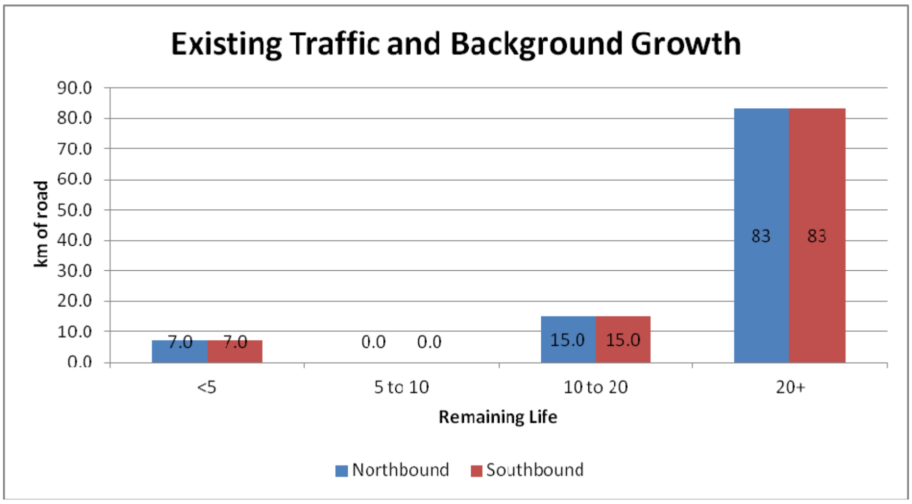

Figure 8 Remaining life of pavement expressed in kilometres for existing traffic condition

As the traffic is currently assumed to be equal in both directions both the North and South bound lanes are expected to begin to fail at the same time.

Figure 9 displays this information graphically, with the sections in red requiring treatment in the first five years, yellow representing 10 to to years and green 20+ years.

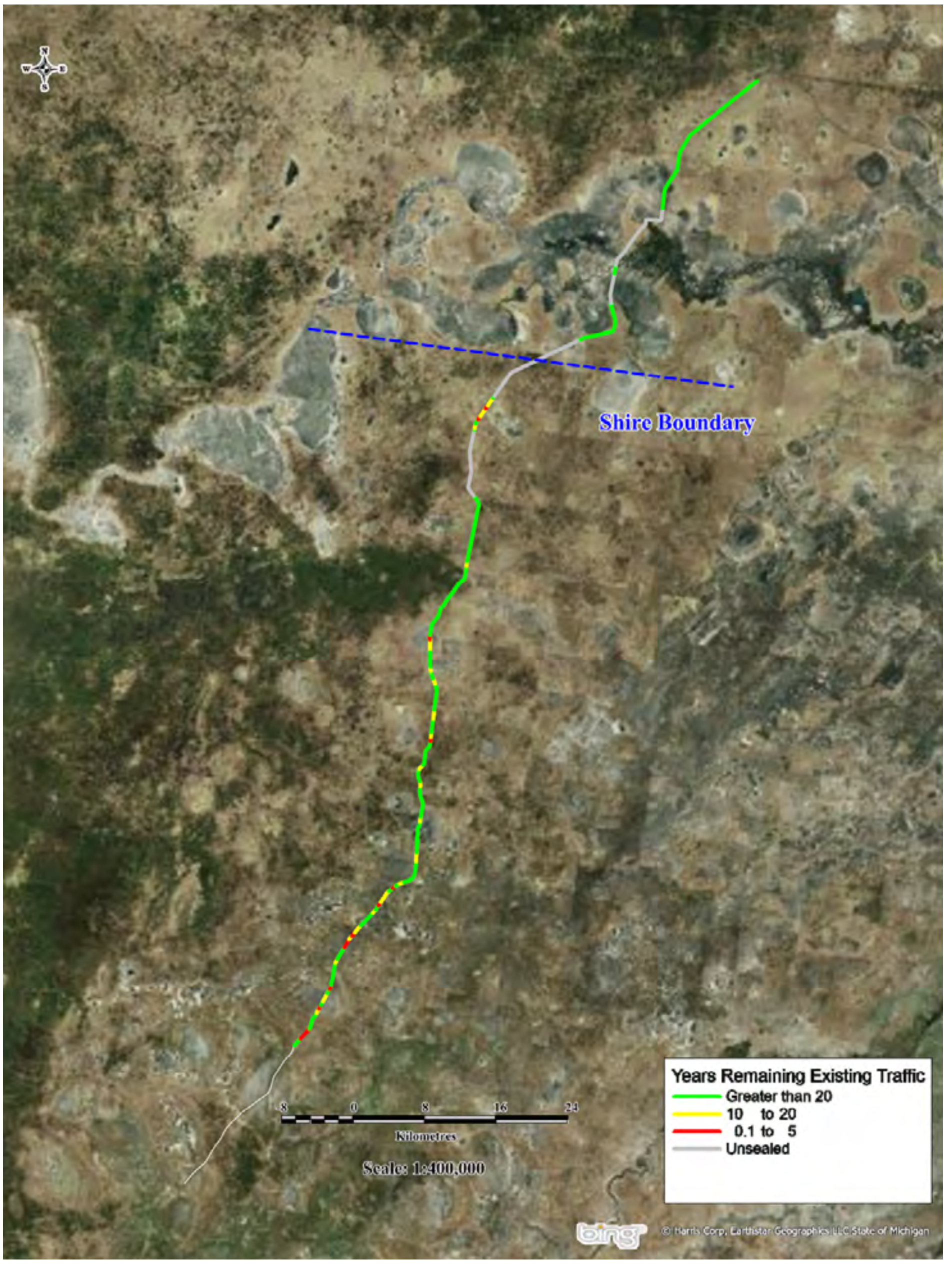

Figure 9 Remaining Pavement Life existing traffic with growth

6.2 Mine Traffic Condition

It is assumed that in the mine scenario the road is subjected to following average annual traffic loading. Refer Table 11:

- North Bound Loaded Lane $8.0x10^4$ ESAs/annum
- South Bound Unloaded Lane $2.3x10^4$ ESAs/annum

Table 11 Mine Traffic Condition

Year	Northbound Lane	Southbound Lane
1	8.00E+04	2.30E+04
2	1.60E+05	4.60E+04
3	2.40E+05	6.90E+04
4	3.20E+05	9.20E+04
5	4.00E+05	1.15E+05
6	4.80E+05	1.38E+05
7	5.60E+05	1.61E+05
8	6.40E+05	1.84E+05
9	7.20E+05	2.07E+05
10	8.00E+05	2.30E+05
11	8.80E+05	2.53E+05
12	9.60E+05	2.76E+05
13	1.04E+06	2.99E+05
14	1.12E+06	3.22E+05
15	1.20E+06	3.45E+05
16	1.28E+06	3.68E+05
17	1.36E+06	3.91E+05
18	1.44E+06	4.14E+05
19	1.52E+06	4.37E+05
20	1.60E+06	4.60E+05

As the North bound lane is more heavily loaded segments on this side of the road reach their allowable ESAs before the South bound lane. This is displayed in Figure 10 below.

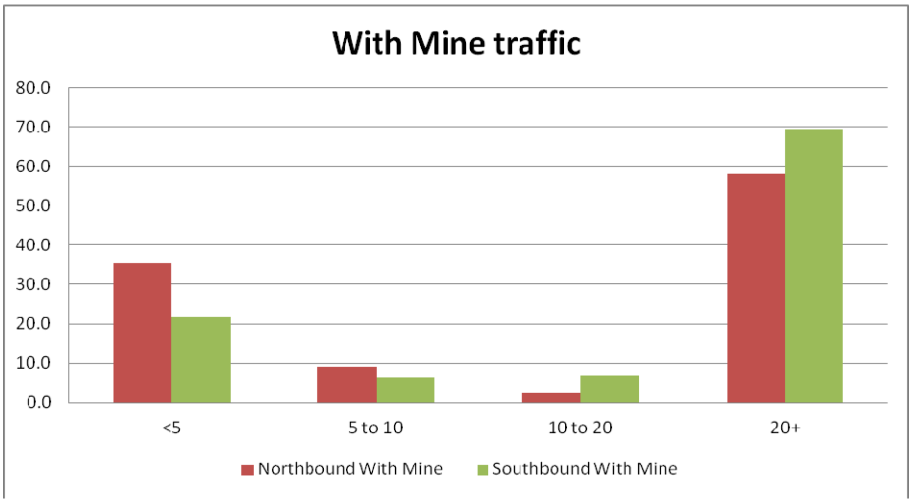

Figure 10 Remaining life of pavement expressed in kilometres for mine traffic condition

Figures 11 and 12 displays when segments fall due for treatment for both the north and south bound lanes.

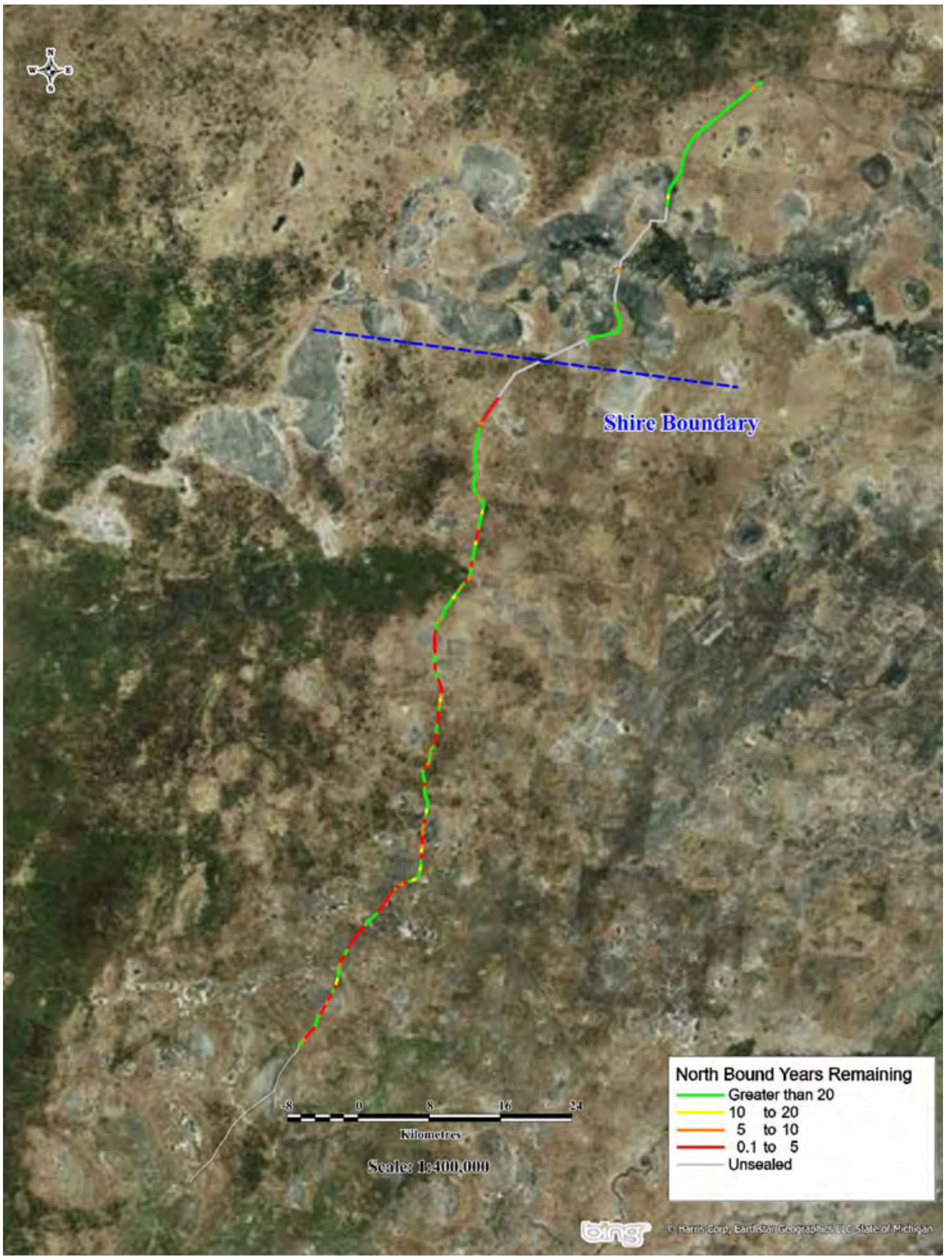

Figure 11 Remaining Pavement Life for Mine traffic Condition (North Bound)

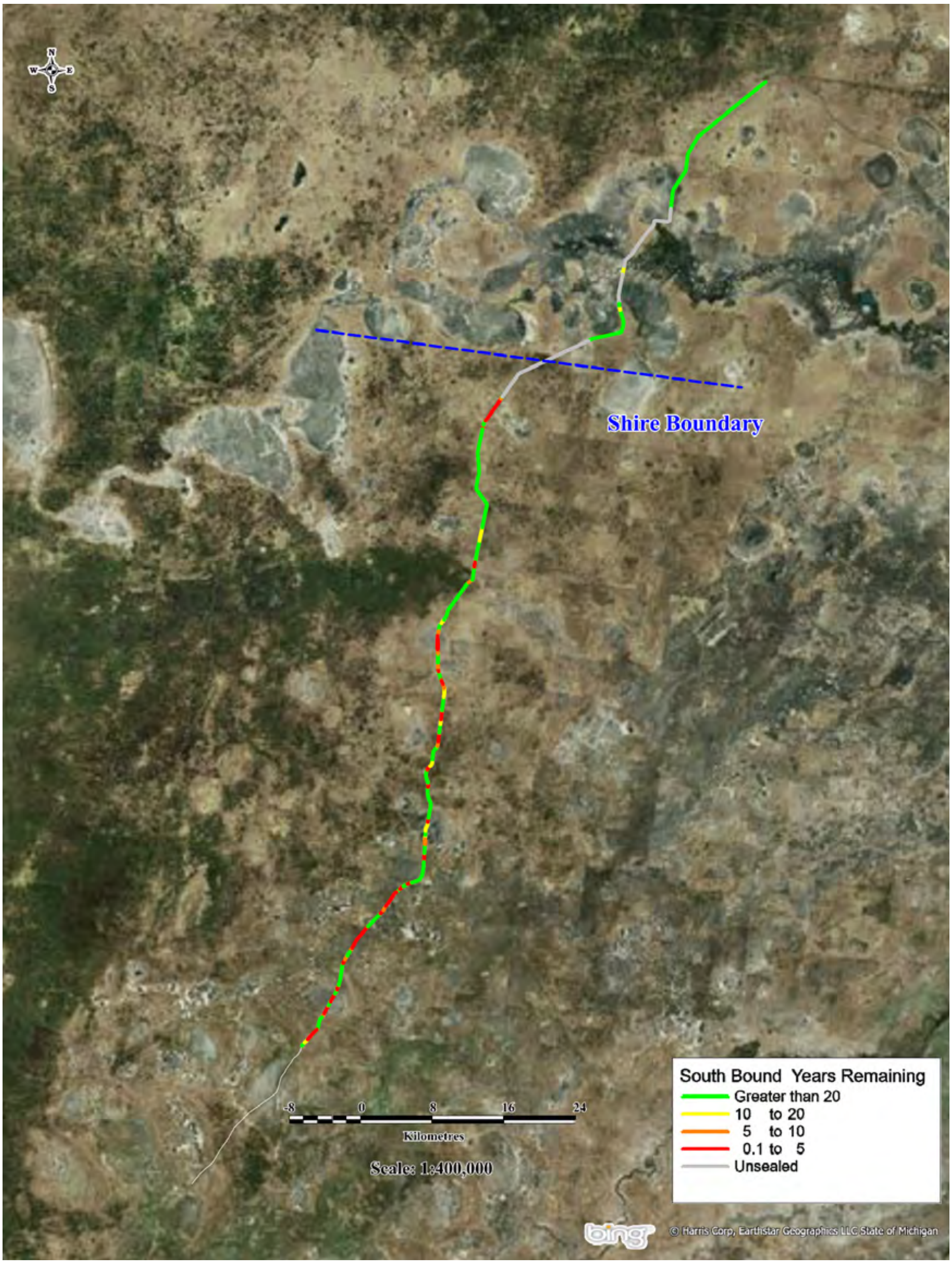

Figure 12 Remaining Pavement Life for Mine traffic Condition (South Bound)

6.3 Estimated Required Expenditure

The required expenditure based on both the current condition and mine traffic scenarios has been calculated. The calculated expenditures are determined for each year but have been grouped into 4 yearly intervals reflect that the model is only approximate as to the year segments will need treatment.

6.3.1 Current Traffic Condition

Table 12 below provides an indication to the expected expenditure for each activity required in each for year block for the scenario for the current traffic regime, including an allowance for future growth, but without the mine traffic.

Table 12 Expected Expenditure

	Reseal	Light Patching	Heavy Patching	Stabilisation / Reconstruction
Year 1-4 Total	$257,400	$167,520	$0	$0
Year 5-8 Total	$2,775,344	$111,680	$290,368	$0
Year 9-12 Total	$1,297,010	$0	$145,184	$2,502,621
Year 13-16 Total	$1,322,750	$480,000	$0	$0
Year 17-20 Total	$2,259,400	$480,000	$0	$0
Total	**$7,911,904**	**$1,239,200**	**$435,552**	**$2,502,621**

It is likely that this work will be staged over multiple years and as such the total expenditure has been averaged and allocated over the 4 year blocks (i.e. costs for the first four years is total required over that period divided by 4). This is displayed graphically below in Figure 13.

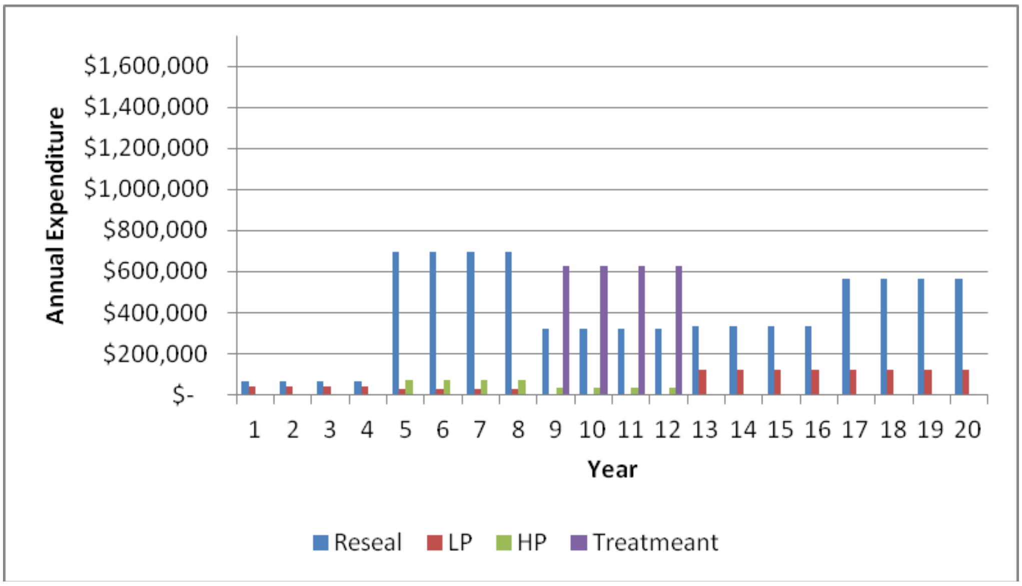

Figure 13 Average cost of pavement rehabilitation per year for existing traffic condition

6.3.2 Mine Traffic Condition

Table 13 below provides an indication to the expected expenditure for each activity required in each for year block for the scenario with the mine.

Table 13 Expected Expenditure

	Reseal	Light Patching	Heavy Patching	Stabilisation / Reconstruction
Year 1-4 Total	$379,837	$326,008	$903,552	$1,251,311
Year 5-8 Total	$1,565,507	$197,080	$726,367	$7,345,779
Year 9-12 Total	$1,157,728	$195,248	$278,408	$1,079,410
Year 13-16 Total	$1,836,978	$134,784	$262,267	$1,397,173
Year 17-20 Total	$1,625,081	$310,384	$213,429	$608,968
Total	**$6,565,130**	**$1,163,504**	**$2,384,023**	**$11,682,640**

Again this is displayed graphically below in Figure 14:

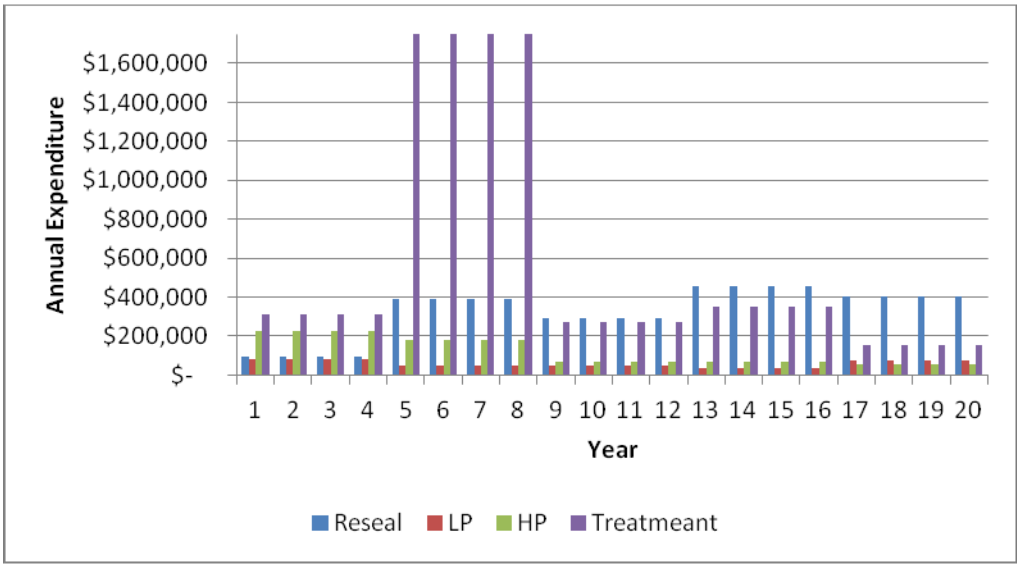

Figure 14 Average cost of pavement rehabilitation per year for mine traffic condition

It can be seen that under the mine scenario that the cost on period reseals decreases. This is as a result to more pavement segments requiring full reconstruction. The segments that are reconstructed will no longer need their periodic reseal.

All the other costs increase as the pavement deteriorates more rapidly due to the increased loading.

6.4 Comparisons

A summary of the estimated costs of each activity for both scenarios is provided in Table 14.

Table 14 Estimated Costs

Maintenance Activity	Estimated Cost without Mine Traffic	Estimated Cost with Mine Traffic	Difference
Reseals	$7,911,904	$6,565,130	-$1,346,774
Light Patching	$1,239,200	$1,163,504	-$75,696
Heavy Patching	$435,552	$2,384,023	$1,948,471
Stabilisation Reconstruction	$2,502,621	$11,682,640	$9,180,019
Total	**$12,089,277**	**$21,795,297**	**$9,706,020**

Further these costs have been broken up between the two shires and are shown in Table 15.

Table 15 Works within Balranald and Central Darling Shire

	Balranald Shire		Central Darling Shire	
	Existing	Mine	Existing	Mine
Reseals	$6,069,492	$4,794,218	$1,842,412	$1,770,912
Light Patching	$1,039,200	$965,200	$200,000	$198,304
Heavy Patching	$435,552	$2,384,023	$0	$0
Stabilisation Reconstruction	$2,191,873	$10,003,784	$310,748	$1,678,857
Total	**$9,736,117**	**$18,147,225**	**$2,353,160**	**$3,648,073**

In addition the cost of the upgrades have been summarised relative to the CBR conditions recorded as part of the FWD testing and shown below in Table 16.

Table 16 Cost of rehabilitation relative to subgrade condition

	Existing Traffic with future growth	Mine Traffic
CBR5	$5,322,069	$11,378,071
CBR 10	$3,474,833	$6,590,268
CBR15	$3,292,375	$3,826,958
Total	**$12,089,277**	**$21,795,297**

It is estimated that the total additional expenditure required to maintain the road over a 20 year life of the mine is approximately $9.7M.

The additional costs attributed to the mine traffic can also be expressed as a function of the total dry tonnes of concentrate hauled over the mine life (6.2Mt), giving an average of approximately $1.60 / dry tonne.

6.5 Summary

The increase in traffic is considerable and the performance of the existing road to withstand the increase in loading is highly dependent on the consistency and strength of pavement material and subgrade.

Based on the traffic loading estimates the Equivalent Standard Axles (ESA) will increase from the existing 1.14 $x10^5$ to 1.6 $x10^6$.

The areas identified as poor subgrade are likely to be the areas that will suffer an increase in the rate of deterioration and will require early intervention once haulage operations commence.

The maintenance regime adopted has been developed with the objective to maximise the existing serviceable life of the pavement prior to major rehabilitation works taking place. Once major rehabilitation works have been undertaken, the reconstructed areas of pavement have been assumed to have sufficient integrity to withstand the anticipated traffic loadings for the reminder of the mine life, without any re-treatment.

This philosophy results in a large cost component of the initial road upgrades occurring in areas where poor subgrade has been identified, indicating that the original road pavement construction in sections has insufficient strength to resist the traffic loads anticipated in the future. This applies regardless of whether the mine proceeds or not, however it is the extent of the road that requires reconstruction that varies.

It should be noted that these cost estimates excludes the regular, routine maintenance that is undertaken by the Shires in maintaining their road network, which would include verge and drainage maintenance, weed spraying and the like.

Other mitigation measures, which are seen as regular maintenance should be implemented, these include:

- Edge linemarking to reduce edge damage;
- upgrading cattle grids;
- shoulder widening.

In addition we would recommend that the construction of the sections of unsealed road need to consider the future anticipated traffic conditions and ensure that the pavement thicknesses are increased substantially to cater for these loads and provide for a 20 year design life which will not rely on such a substantial maintenance strategy in the future.

This will include consideration to the subgrade strengths in setting pavement depths and providing quality base material.

The investigation and costs prepared in this report have not included the portion of unsealed road, which equates to approximately 30 kilometres.

6.6 Cost Contribution

The report provides a cost estimate for one scenario based on certain assumptions that have been developed as part of the investigation. This cost will vary depending on the actual performance and response of the existing pavement to the increase in load and the preferred maintenance regime that is adopted. Hence there will be a range to consider for the actual cost contribution.

This report provides the basis for estimating a percentage impact and percentage cost sharing when comparing the existing analysis to any future assessment or rehabilitation works.

It is recognised that the actual contribution may vary depending on the ability of the Shire to commit the required expenditure. As such we would suggest that negotiations for Cristal's contribution should consider a proportional value of funding contributed by the Shires.

With reference to the totals in Table 14, this would equate to a contribution by Cristal of $0.80 for every dollar committed by the Shires, to accommodate the additional costs due to the mine traffic. However this ratio varies considerably when compared to the costs attributed to each Shire, with $0.86 for every dollar spent by Balranald and $0.55 for every dollar spent by Central Darling Shire.

This philosophy will ensure that the contribution remains equitable for all parties and any reduction in spend should recognise that a lower standard of performance or service standards of the road must be accepted.

Based on the cost model presented, any cost contribution should be capped at a maximum of $9.7Million over the life of the mine.

Appendix A

Geotechnical Testing

Geotechnical Testing Investigation

An initial in situ road material sampling exercise was undertaken on 23 August 2013 and included the following:

- Excavation of five test pits (TP1 to TP5), as located in Figure 1, to a maximum depth of 0.5m below the surface level within the unsealed sections of the road where the road surface showed signs of rutting; and
- Excavation of one test pit (TP6) to a maximum depth of 0.5m below the surface level adjacent to the sealed section of the road showing edge break.

Test pits were excavated using a rubber tyred Case 580 Super LE backhoe using a 600 mm wide toothed bucket provided by Sunraysia Land Developments. Traffic management and road reinstatement was also provided by Sunraysia Land Developments.

The investigations were directed by a senior geotechnical engineer from Tonkin Consulting who inspected the test pits and logged the materials exposed, using visual and tactile techniques. Logs of the test pits and boreholes are in a Table below. A dynamic cone penetration test was undertaken at each test pit location to a depth of 900 mm below the surface, apart from TP 5 which stopped and 200 mm below the surface due to the equipment failure, resulting in TP6 being unable to be tested.

Bulk samples of any road formation materials and subgrade were retrieved from the test pits for laboratory analysis. The samples were sent to Lab SA for a combination of the following tests;

- Particle size distribution (PSD)
- Atterberg Limits (AL)
- Soaked/unsoaked California Bearing Ratio (CBR)

CBR samples were prepared at optimum moisture content and at approximately 98% of their maximum dry density under modified compaction for pavement materials and standard compaction for subgrade samples. Samples were soaked for 4 days and subject to a 9kg surcharge load.

Laboratory Test Certificates are attached with a summary of the conditions found at each location discussed below.

Estimated CBRs were calculated using Department of Planning, Transport and Infrastructure Method for Estimation of CBR from Classification Tests, TP 133, dated May 2012.

TP1

Distance from Ivanhoe (km)	Depth interval (m bgl)	Description	Estimated CBR	Soaked CBR	Unsoaked CBR
24.5	0 – 0.1	Clayey SAND, fine to coarse grained, orange brown, low plasticity fines	13	NA	NA
	0.1 – 0. 4	Clayey SAND/Sandy CLAY, fine to coarse grained, orange brown, low plasticity fines	10	8.4	8.9

The surface at TP1 appeared to be reworked subgrade with a minor gravel component observed. The DCP results indicate a dense to very dense pavement surface overlying a dense subgrade. The laboratory analysis results indicate a subgrade CBR of between 8% and 10%, with soaking making only a minor impact on its performance.

TP2

Distance from Ivanhoe (km)	Depth interval (m bgl)	Description	Estimated CBR	Soaked CBR	Unsoaked CBR
30.8	0 – 0.3	Clayey Gravelly SAND, orange, fine to coarse grained, orange, fine to coarse grained gravel, low plasticity fines	NA	49	56
	0.3 – 0.5	CLAY, medium plasticity, pale brown	6	3.1	4.5

TP2 observed a 300 mm thick pavement layer of likely imported material, which measured a relatively high soaked and unsoaked CBR value exceeding 40%. DCP results indicated the pavement materials were in a very dense state. The underlying clay subgrade of medium plasticity indicated a CBR of 3% to 6%, and was observed to be of vey stiff consistency with a field moisture greater than plastic limit.

TP3

Distance from Ivanhoe (km)	Depth interval (m bgl)	Description	Estimated CBR	Soaked CBR	Unsoaked CBR
40.3	0 – 0.1	Clayey SAND, fine to coarse grained, brown, low plasticity fines	14	25	26
	0.1 – 0.4	Sandy CLAY, medium plasticity, pale brown	6	NA	NA

The surface materials at TP3 were assumed to be reworked subgrade materials which have had some addition of granular materials sourced from off site. The pavement materials appeared to be very dense based on DCP results with a CBR value exceeding 14%. The subgrade materials observed are considered consistent with those observed in TP2, with a slightly higher sand content.

TP4

Distance from Ivanhoe (km)	Depth interval (m bgl)	Description	Estimated CBR	Soaked CBR	Unsoaked CBR
50.6	0 – 0.3	Clayey SAND, fine to coarse grained, red brown, low plasticity fines	10	12	16

At TP4 there was no distinguishable difference between the pavement and subgrade materials. DCP results indicated that the materials were of very dense state. Laboratory analysis indicate the materials achieved a CBR in the order of 10% to 16%, with some variation observed due to soaking.

TP5

Distance from Ivanhoe (km)	Depth interval (m bgl)	Description	Estimated CBR	Soaked CBR	Unsoaked CBR
61.6	0 – 0.1	Clayey Gravelly SAND, fine to coarse grained, red brown, fine to coarse grained gravel, low plasticity fines	19	37	38
	0.1 – 0.4	Clayey SAND, fine to coarse grained, red brown, low plasticity fines	13	25	32

The surface materials at TP5 are assumed to be reworked subgrade materials with some inclusion of granular materials sourced from off site. DCP results indicated a very dense surface until the DCP equipment failed. Soaked and unsoaked CBR results of the surface materials indicate a reasonable material with a CBR greater than 35%. The subgrade observed is similar to the subgrade observed in TP4 with a CBR expected to be greater than 10%.

TP6

Distance from Ivanhoe (km)	Depth interval (m bgl)	Description	Estimated CBR	Soaked CBR	Unsoaked CBR
82.5	0 - 0.16	Clayey Gravelly SAND, fine to coarse grained, brown, fine to coarse grained gravel, low plasticity fines	>20	45	46
	0.16 - 0.5	CLAY, medium plasticity, pale brown	5	3.5	12

TP6 was excavated adjacent to the failed seal due to edge break. A pavement thickness of 160 mm was observed. The pavement material is considered to be of good quality with a CBR exceeding 40%. The subgrade materials encountered appear similar to subgrade materials observed in TP2 and TP3 consisting of a medium plasticity clay, at a moisture content greater than its plastic limit.

The measured soaked CBR of 3.5% is much lower than the unsoaked value of 12% indicating its potential poor performance under wet conditions.

Based on the results obtained from the limited sites investigated, there appears to be some correlation between materials observed.

- The granular pavement materials observed at TP2 and TP6 appeared to achieve a relatively good CBR value generally exceeding 40%.
- The subgrade materials can be grouped into two distinct materials
  - red brown/orange clayey sand/sandy clays providing CBR values in the order of 8% to 16%, depending on proportion of clay, and
  - brown medium plasticity clays of low CBR, generally 3% to 6%, which are significantly impacted by moisture changes.
- The pavement materials consisting of reworked subgrade varied considerably potentially due to the proportion granular materials added and the existing subgrade materials that have been incorporated. The variability of these reworked pavements may also be due to their age and frequency of regarding, potentially losing stone each time, or the availability and quality of granular materials at each site at the time of construction or maintenance activities.

As shown in Figure 1 the sampling and testing to date is not representative of the entire road network and potentially may be the worst case scenario. However further testing to cover areas in Figure 2 is needed to complete the assessment. This is discussed further in later sections of this report.

As shown in the above table, there is variability in the various methods used to determine CBR. The estimated CBR calculation has been developed using the soil characteristics and empirically derived formula. It is only applicable to samples with greater than 75% passing the 2.36 mm sieve. It is considered a generally a fast, easy and cheaper method of assessing the soils CBR, and is considered to have an equivalent value to a laboratory four day soaked test prepared at optimum moisture content and 95% of maximum dry density with modified compaction. It is more suited to subgrade materials rather than granular materials.

Soaked and unsoaked CBRs are prepared in the same way at the moisture and compaction ratio specified. The unsoaked value is from the sample prior to soaking and the soaked value is from the sample after soaking. The unsoaked condition is considered the best scenario in a free draining location with the material placed at the requirements, whereas the soaked condition is a more conservative value if the subgrade and or pavement materials were to be inundated. Judgement is needed in assessing which result best reflects site conditions.

The DCP results provide an indication of the relative density of the soil at the time of investigation. This can be greatly impacted by the moisture content of the soils at the time, so whilst the soils observed were considered dense to very dense, they were also relatively dry and so under inundation the relative density could possibly reduce.

In addition to this a sample of material used for base construction was sampled from the Ivanhoe stockpile site. This particle size distribution (PSD) for this material is out of DGB20 specification for the 425µm sieve, however seems to fit reasonably into the remainder of the grading envelope. The PI of 4% is within requirements as is liquid limit of 23 and linear shrinkage of 2. The CBR is estimated at 60 which is a little low for base course, however provides an indication of what is achievable in the region.

Appendix B

Adopted Maintenance Regimes

ESAs	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1.0E+04 Poor	LP5%	HP12%	Treat									Reseal								
1.0E+04 Good	LP5%	HP12%	Treat												Reseal					
1.0E+05 Good		LP5%	LP5%	HP12%	Treat												Reseal			
1.0E+05 Poor		LP5%	LP5%	HP12%	Treat									Reseal						
2.0E+05 Poor			LP5%	LP5%	HP6%	HP6%	Treat									Reseal				
2.0E+05 Good			LP5%	LP5%	HP6%	HP6%	Treat												Reseal	
3.0E+05 Good				LP5%	LP5%	LP5%	HP4%	HP4%	HP4%	Treat									Reseal	
3.0E+05 Poor				LP5%	LP5%	LP5%	HP4%	HP4%	HP4%	Treat									Reseal	
4.0E+05 Good					LP5%	LP5%	LP5%	LP5%	HP4%	HP4%	HP4%	Treat								
4.0E+05 Poor					LP5%	LP5%	LP5%	LP5%	HP4%	HP4%	HP4%	Treat								
5.0E+05 Poor						LP5%	LP5%	LP5%	LP5%	HP4%	HP4%	HP4%	Treat							
5.0E+05 Good						LP5%	LP5%	LP5%	LP5%	HP4%	HP4%	HP4%	Treat							
6.0E+05 Good							LP5%	LP5%	LP5%	LP5%	HP4%	HP4%	HP4%	Treat						
7.0E+05 Good			Reseal						LP5%	LP5%	LP5%	LP5%	LP5%	LP5%	HP4%	HP4%	HP4%	Treat		
7.0E+05 Poor			Reseal						LP5%	LP5%	LP5%	LP5%	LP5%	LP5%	HP4%	HP4%	HP4%	Treat		
8.0E+05					Reseal					LP5%	LP5%	LP5%	LP5%	LP5%	LP5%	HP3%	HP3%	HP3%	HP3%	Treat
9.0E+05					Reseal						LP5%	LP5%	LP5%	LP5%	LP5%	LP5%	HP3%	HP3%	HP3%	HP3%
1.0E+06					Reseal								LP5%	LP5%	LP5%	LP5%	LP5%	LP5%	HP3%	HP3%
2.0E+06							Reseal										LP5%	LP5%	LP5%	LP5%