11 March 2014

Management of Ballast Fouling in the Central Queensland Coal Network

A review of Ballast Management 2010 - 2017

Updated 24 February 2015 – Removal of Redactions

Table of Contents

Glossary

Aurizon Network	The subsidiary of Aurizon Holding Limited which owns and manages the Central Queensland Coal Network
Ballast	Ballast is the material that is laid on the rail bed under the sleepers, providing stability and drainage to the track structure.
Ballast bed	The track bed upon which railway sleepers are laid
Ballast fouling	The progressive intrusion of various types of fine particles into ballast layer that over time, fills ballast voids
Ballast Siding/Siding	A ballast siding is a section of track used for the supply of ballast product to the railway
Ballast Void	The spaces between ballast particles that make up the ballast profile of the track
Below Rail Transit Times (BRTT)	Below Rail Transit Time
BNSF	Burlington Northern Santa Fe Railway Company. The second-largest freight railroad network owner in North America. Its part ownership of the Powder River basin, which supplies 40% of the coal in the United States.
Clay Hole / Mud Hole	Slurry from the subgrade, together with the fine material inside the ballast that pumps through the ballast when the underlying formation is saturated
Coal Dust	Small particles of coal that are present near railways
Coal Fines	Small particles of coal, including coal dust, that penetrates the ballast and contributes to ballast fouling
Coal Fouling	refers to the progressive intrusion of coal fines into the ballast layer and subsequently filling the voids
Coal Dust Management Plan (CDMP)	The CDMP was prepared in 2010 by QR Network on behalf of QR Limited and the Central Queensland coal supply chain in response to community concerns regarding dust from coal trains
Coal Surface Veneering	The coal surface in rail wagons is treated with a chemical that effectively forms an ultra-thin layer or crust over the coal surface, minimising the amount of coal dust emanated from the train during transportation
Condition Based Assessment (CBA)	An obligation introduced within the 2010 Access Undertaking requiring Aurizon Network to undertake an end of term assessment of the condition of the Rail Infrastructure. The CBA determines whether the network infrastructure “has deteriorated by more than would have been the case had good operating practice, prudent and effective maintenance and asset replacement policies and practices had been pursued”

CQCN	Central Queensland Coal Network - Aurizon Network maintains over 2,667km of track within the Central Queensland Coal Region and has an underlying commitment to its customers to deliver coal tonnage throughput from mines to the Ports and Domestic users.
Formation rehabilitation	Rehabilitation of line sections with substructure problems
Ground Penetrating Radar	A non-destructive subsurface inspection technology that is used to measure the condition of Aurizon's Assets, in particular ballast
Kwik Drop Doors	Kwik Drop Doors are the coal wagon doors with an automatic release mechanism to allow quick unloading of the coal wagon as they pass through the coal unloader. The doors are operated by an opening and closing lever mechanism on the wagon which engages with trackside cams.
Network Strategic Asset Plan (NSAP)	Aurizon Network document that provides a strategic view the asset need for maintenance and renewals investment under current or future demand scenarios
Overall Track Condition Index (OTCI)	A measure of the quality of the geometry of the track calculated from track geometry recording vehicle outputs
Percent Void Contamination (PVC)	Calculated by dividing the volume of contaminates by the volume of voids within the ballast profile. PVC is determined in a compacted state to simulate actual track conditions
Rail Infrastructure Manager	Aurizon Network is owner and Rail Infrastructure Manager of the Central Queensland Coal Network managing the operations and maintenance of the network
Resurfacing	A term often used interchangeably with "tamping". The machines use to tamp or resurface the track are often also known as "tamping" machines or "resurfacing" machines
Tamping	A manual or mechanised process applied to the track to correct the top, cross level and line geometry of the track
Top and Line	Top and line refer to the "vertical" and "lateral" geometry of the track respectively
Turnout	A section of railway track-work that allows trains to pass from one track on to a diverging path
UT1	The period from 2001 to 2006, being the term of QR's first access undertaking
UT2	The period from 2006 to 2010, being the term of QR's second access undertaking covering the CQCR
UT3	Aurizon Network's current Access Undertaking, approved by the QCA on 1 October 2010, together with any subsequent changes approved by the QCA
UT4	The four year period commencing 1 July 2013, being the proposed term of the 2013 Undertaking, which will be the fourth access undertaking covering the CQCR

1 Introduction

1.1 Purpose and Scope

Aurizon Network welcomes the opportunity to provide this submission to the Queensland Competition Authority (QCA) detailing the ongoing management and maintenance of ballast fouling in the Central Queensland Coal Network (CQCN), following the submission of the Draft Access Undertaking (2013 DAU) to the Authority in April 2013.

The 2013 DAU included the recovery of ballast cleaning impairment charges levied against Aurizon Network in the 2010 Undertaking through an adjustment to the allowable revenue. This represented the portion of costs associated with the impairment charge incurred upon commencement of UT4 (1 July 2013).

In making the decision to apply the revenue adjustment in UT3, the QCA noted that:

"The Authority will consider re-including this deduction in the future if QR Network is able to demonstrate that its past approaches to ballast fouling have been cost effective and that it has adopted an efficient approach to maintaining a sound ballast, whether that be through ballast cleaning and/or fouling prevention[1]"

Consequently, the explanatory material provided in Volume 3 of the 2013 DAU detailed that:

- Aurizon Network had addressed the matters that were within the direct scope of its reasonability as the network provider;
- The decisions made by Aurizon Network were based on the relevant information and standards available at the time; and
- The decisions made by Aurizon Network were based on a reasonable assessment of the consequences to throughput and exposure to asset optimisation at the time.

The QCA has requested Aurizon Network to provide the following information to supplement the previously submitted 2013 DAU documentation, in particular:

- The extent of ballast fouling and a detailed assessment of preventative measures currently being undertaken
- The proposed measures being undertaken to minimise ballast fouling and the identification of possible solutions
- The proposed maintenance scope of work to achieve these outcomes
- The assessment of the allowance required

[1] Queensland Competition Authority (2010b), p.78

Further, the QCA has requested that Aurizon Network provide detailed information with regards to the previous Undertaking (UT3), specifically:

- The allowance provided during this period for planned ballast works;
- The measures undertaken to address ballast fouling, including the effectiveness of these measures; and
- The extent to which these have informed and have been applied within the UT4 submission

Aurizon Network recognises that ballast fouling is a complex issue that requires the commitment of all supply chain participants to ensure the delivery of a safe, reliable and efficient rail network. The 2008 Connell Hatch commended Aurizon Network on its practices and acknowledged that Aurizon Network as leading the Australian railway in the management of coal dust.

2 Background

2.1 Ballast

Ballast is comprised of select crushed granular rock which knits together to form a resilient bed beneath the sleepers. It is an essential structural component of the track as it transfers the forces of the train through the sub-ballast and formation.

The major function of ballast is to:

- resist vertical, lateral and longitudinal forces applied to the sleepers to retain the track in its required position;
- provide some of the resiliency and energy absorption for the track;
- facilitates maintenance surfacing and lining operations by the ability to rearrange ballast particles by tamping operations; and
- provides immediate drainage of water falling onto the track.

The ability of the ballast to perform its function is controlled predominantly by the physical characteristics of the stone. The ballast performs best when the ballast bed is free of fine fouling material as the voids allow the free flow of water as well as the movement of the ballast structure as it cushions the weight of the loaded train. Over time, fouling material will fill the void spaces, starting from between the ballast stones (from the bottom of the ballast bed where the ballast transfers its load to the formation) then upwards towards the sleeper base (where the sleeper loads are transferred to the ballast).

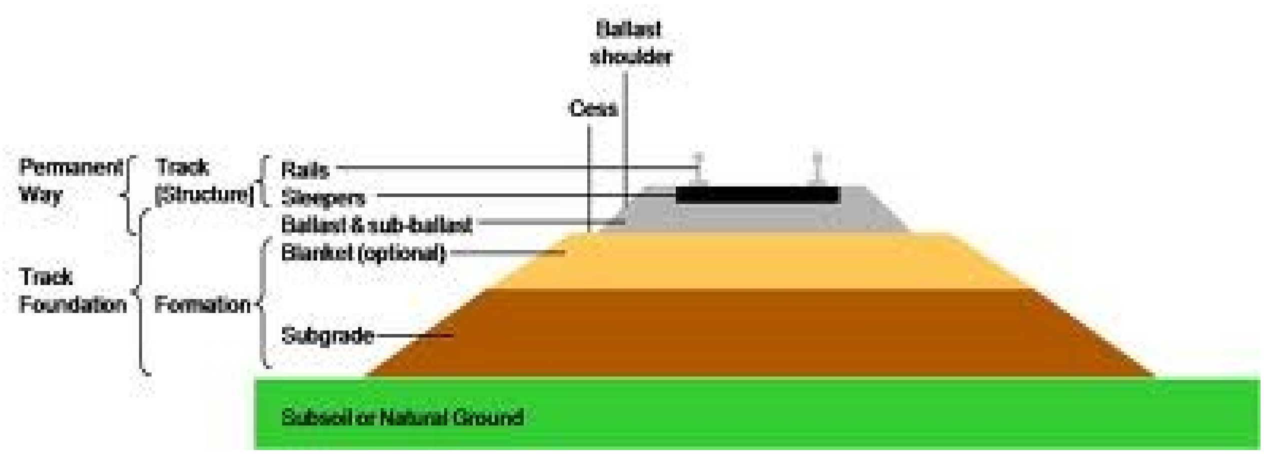

Figure 1. Major components of the rail infrastructure

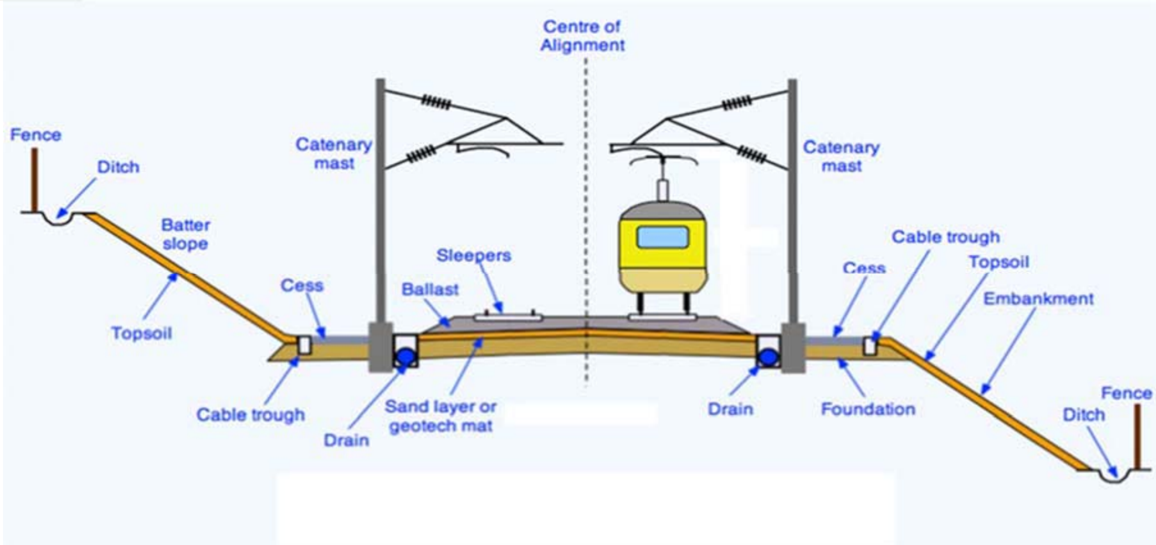

Figure 2. Major components of the rail infrastructure

2.2 Ballast fouling

Ballast fouling is the accumulation of material that resides within the ballast layer. Over time ballast deteriorates by fracturing into smaller pieces, losing its sharp edges and becoming contaminated with dirt and mud rising from below the ballast. Within the CQCN, coal spilled or blown from wagons hastens the rate of ballast fouling, with the principal degradation mechanism within the CQCN being the loss of voids and consequently poor drainage.

Based on Canadian Pacific Railroad findings published by Professor Ernest Selig (North America's leading rail geotechnical authority) the expected ballast life of 1600 million gross ton (approximately 100 million net ton) for baseline ballast life with no coal fouling is expected. The Canadian Pacific findings indicate this is at the high end of expected ballast life, based on optimal ballast design and construction that provides the required void storage capacity and abrasive strength. The intervention of point 1600 million gross ton was based on the rate at which the ballast breaks down and fouls the ballast to the point where it can no longer perform it required function resulting in structural deterioration of the ballast layer.

The most direct measurement of ballast fouling is the height to which the ballast bed is filled with fine materials (including coal dust, dirt and degraded ballast) which provides an indication the ballast is in need of renewal. The term renewal refers to the activities undertaken to significantly extend the life of the ballast asset, which may include cleaning and ballast replenishment (up to and including full replacement), with the activity depending on the characteristics and circumstances pertaining to the particular site.

Aurizon Network has a target ballast fouling rate of 5% per 100 million net tons of coal, with an intervention level of 30% Percentage Void Contamination (PVC).

2.2.1 The consequences of ballast fouling

Once ballast has reached the end of its life either through degradation or fouling or a combination of both, replacement or intensive maintenance is required to avoid the likelihood of damage to the surrounding track, environment or the rollingstock, as discussed below:

Fouled ballast prevents effective drainage and the movement of particles through the ballast

As the void spaces between the ballast stones start to fill with fine material, the drainage capacity of the ballast bed decreases. The fine material will retain the moisture which will lead to a wet ballast bed and ultimately a wet formation.

Research conducted by Professor Selig[2] demonstrates that clean ballast to full depth can drain rain water at a rate of 150mm per hour, whereas if the entire ballast bed is uniformly fouled, it would only be able to drain 1.5mm per hour. After rain, a fouled ballast bed will remain wet for a very long time as it takes much longer for the water to drain away. This has a negative consequence on the structural integrity of the ballast.

Fouled ballast leads to mud/clay holes

If the ballast bed remains wet due to the absorbed moisture by the fine material in the void spaces, the underlying formation will also become saturated. This may cause failure of the formation. When the formation fails, slurry containing clay from the formation, together with the fine material inside the ballast will start pumping through the ballast becoming visible on the surface of the ballast bed. This is called a clay hole. A clay hole usually extends down 300mm to 400mm under the ballast and can cover long sections of track. If the results of this pumping are visible for more than 100m, this would be regarded as continuous formation failure rather than a clay hole.

Mud holes, which are different to clay holes, are caused by the mixing action of the fouling material, ballast and moisture from within the ballast profile under normal traffic conditions. Under the action of traffic, if a mud hole is left untreated or the site is subject to significant rainfall, the formation will be impacted as previously described. Mud holes are often observed within the CQCN and can be attributed to coal fouling.

If the formation contains clay soil, maintenance becomes ineffective and total rehabilitation of both the ballast and the formation becomes necessary. In this circumstance, the clay soil effectively becomes a binder and hardens like pottery, reducing the ability of the ballast to move

[2] Railways of Australia: Track Geotechnology and Substructure Management 1992

and cushion the load from normal train operations. Formation rehabilitation is an extensive, time-consuming and expensive process that requires track closures to complete effectively.

These types of failures contribute significantly to speed restrictions on the network particularly after extensive rain or flooding of the track which occurred both in 2011 and 2013.

Fouled ballast inhibits the elasticity of the track

Fine material in the void spaces reduces the elasticity of the ballast. In addition, if the fine material becomes wet and is allowed to dry again, the ballast bed can be cemented into a rock-hard layer (binding). The resultant lack of elasticity can cause damage to sleepers, fastenings and rollingstock as forces are reflected back through the track structure.

Fouled ballast reduces resistance against vertical, lateral and longitudinal forces

If the fine material in the ballast becomes saturated, it will have a decreased resistance to shear deformation due to coal, clay, silty particles and/or water present at the ballast contact point. The fine material will act as a lubricating agent which leads to a decrease in track support and geometry. Coal fouling is the worst contaminant from the view point of reducing track strength. This has been demonstrated by the derailments that occurred on the BNSF rail network in 2005[3] and the subsequent investigations. (Refer Appendix A).

Poor durability after maintenance inputs

The lack of void spaces due to ballast fouling will restrict the effective rearrangement of the ballast stones during tamping. This inhibits the process of tamping to level out the surface and substructure enabling track top and line configuration to return to an acceptable position. The track will revert to its unacceptable geometry in a very short time. This would require the tamping machine or work gang to return to the same spot repeatedly, thus negatively affecting train operations via a reduction in train paths and a reduction in track speed, producing inefficiencies in the maintenance process. Even if the ballast can be sufficiently rearranged to remove the track memory, the fine material clinging to the ballast surfaces will still act as a lubricant, thereby reducing the friction between the stones, resulting in poor durability of tamping input.

Saturated fouled ballast dramatically reduces the production rate of the ballast cleaning machine

International experience with ballast cleaning machines has demonstrated that at low moisture content, ballast cleaning machines achieve higher production rates. Moisture and fouling reduces the production rate dramatically. With lower production rates, unit price increases along with a

[3] BNSF Opening Statement, FD35305, p.10

dramatic decrease in the effectiveness of the ballast cleaning process. This potentially means that the ballast cleaning cycle will reduce, resulting in more track possessions for the ballast cleaner to undertake rework. Ballast Cleaning is discussed further in section 2.2.4.

Speed restrictions

Speed restrictions are required to manage the deteriorated state of the track, which for ballast fouling is normally reflected in the loss of top and line geometry, impacting the railway safety performance. Speed restrictions are also imposed to ensure that track that has been fouled does not receive further damage in significant rain events. In the latter case, blanket speed restrictions are placed on the entire network to ensure that track damage is minimized without closing the network. Blanket speed restrictions dramatically impact the network's overall capacity.

Derailments

In extreme cases, loss of track strength and support can result in derailments, which are highly disruptive to network capacity. In 2005, BNSF Railway reported track instability due to ballast fouling as a cause of two derailments on Powder River Basin coal lines. BNSF reported[4] this was contributed by coal dust accumulation in the track ballast causing moisture accumulation and decreased stability of the tracks.

2.2.2 The sources of ballast fouling

A review undertaken by Evans and Peck[5] on the CQCN, highlighted the evolving nature of understanding regarding coal loss, its impacts and effective mitigation options. Historically, investigations into ballast fouling on rail networks have been triggered by one of three drivers:

1. Rail safety impacts, particularly the increased risk of derailments;
2. Concerns regarding the impact on the environment; or
3. Revenue impacts, either through lost revenue, increased maintenance costs or material capacity impacts.

Evans and Peck[6], noted that coal loss research is seldom made available in an unrestricted form as it is quite often considered to be commercially sensitive. However, a large body of information regarding the mitigation of coal loss has become readily available in recent years.

Following a series of major rail incidents in 2005, the BNSF railway committed significant resources to understanding and addressing the sources of coal fouling.

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4 BNSF Opening Statement, FD35305, p.10
5 Evans and Peck, Aurizon Network Pty Ltd Ballast Contamination Scoping Study, March 2013, UT4 submission (Annex K)
6 Evans and Peck, Aurizon Network Pty Ltd Ballast Contamination Scoping Study, March 2013, p.4

Information on the BNSF experience has become publicly available as a result of utilities (coal power stations) disputing the reasonableness of the introduction of coal loss performance standards. The introduction of these standards required the intervention of the Surface Transport Board[7] (STB) resulting in a subsequent determination on imposing reasonable requirements on coal shippers for management of coal dust.

Aurizon Network considers that the timing and extent of BNSF's coal loss investigations and corresponding coal loss initiatives share many similarities with the CQCN. In particular, Aurizon Network considers it has the following similarities:

- While it was known that the ballast was being fouled by coal spillage the actual level of coal fouling was limited to sites that had been manually assessed
- An external influence was required to incentivise coal producers, transporters and the ports to undertake the necessary investments to modify and apply effective management practices
- At low volumes, asset reliability was not compromised and maintenance efforts to manage service standards had little impact on capacity
- Significant volume growth increased both the rate of fouling over time and placed limitations on the ability to undertake increasing levels of ballast cleaning
- Significant resources were committed and substantial time taken to investigate the sources of fouling and the effectiveness of various mitigation strategies and
- A period of time lapsed between when it became necessary to address coal loss and when coal producers, transporters and the implemented their control measures.

A summary of the BNSF experience has been compiled by Aurizon Network from verified statements and exhibits submitted to and any relevant subsequent STB determinations in relation to coal loss performance standards. Further detail on the BNSF experience is contained within Appendix A.

2.2.3 General ballast fouling

As previously mentioned, ballast will naturally breakdown as part of its normal function. However, general ballast fouling for heavy haul railways is largely being determined by the original railway design, the cumulative effect of the railway operating conditions and the prevalent environmental conditions. Connell Hatch, in the Coal Loss Literature Review[8] identified five non-coal sources contributing to ballast fouling:

- Particles entering from the surface such as wind blown sand or coal falling out of cars

[7] The STB is the economic regulatory agency in the US that has jurisdiction over (amongst other things) railroad rate and service issues and rail restructuring transactions (mergers, line sales, line construction, and line abandonments

[8] Connell Hatch, Final Report Coal Loss Literature Review, Coal Loss Management Project, Queensland Rail Limited 15 May 2008, p.6

- Products of wood or concrete sleeper tie wear
- Breakage and abrasion of the ballast particles
- Particles migrating upward from the granular layer underlying the ballast (sub ballast)
- Migration of particles from the sub grade.

In relation to rail transportation, the Environmental Evaluation undertaken by Connell Hatch in 2008 for the CQCN was identified as the source for leading best practice measures to control emissions of particulate matter from rail corridors[9].

2.2.4 Ballast Cleaning

Ballast cleaning refers to the mechanical excavation of deteriorated and/or fouled ballast from beneath the sleepers, after which fresh ballast is added to the formation and tampered to restore the track to correct track geometry and ballast depth. Ballast cleaning includes associated support activities such as resurfacing, pre and post earthworks, track protection and ballasting. Ballast cleaning can occur “on track” with a specialized ballast undercutting machine or “off track” with excavators. The ballast undercutting machine is more suited to long stretches of track whereas excavators are used around turnouts and tighter spaces.

An MFS wagon[10] is a specialized heavy track based mineral conveyor and storage unit. The MFS picks up spoil from the ballast undercutter and transports the spoil away from the site.

The current ballast cleaning operation utilises a Plasser & Theurer RM900 machine, which is regarded internationally as one of the best high production ballast cleaners at the time of purchase in 2001

[9] Katestone Environmental Pty Ltd, NSW Coal Mining Benchmarking Study: International Best Practice Measures to Prevent and/or Minimise Emissions of Particulate Matter from Coal Mining Prepared for Office of Environment and Heritage KE1006953, June 2011, p.193

[10] MFS, this term translated from German.

The two ballast cleaning methods used by Aurizon Network are the on track RM900 undercutting operations and the off track ballast undercutting as detailed below:

RM900 Undercutting Operations	Off Track Ballast Undercutting
1 x RM900 Ballast Cleaner	2 x Excavators (13T) with cutter bars
6 x MFS40 Ballast conveyor wagons (spoil wagons)	2 x Excavators with mud buckets
1 x Water & power combination wagon	2 x Track jacks (OTV-Lightweight)
1 x Water supply wagons	2 x Front End Loaders
2 x Container wagons holding critical spares & tools	1 x Grader
1 x 3 tynes pair Continuous Action Tamper	2 x 15T Rigid Tippers
1 x Dynamic Track Stabiliser	1 x Resurfacing tamper (MMA064)
1 x SSP Ballast Regulator	1 x Ballast Regulator
1 x Track lifter	
24 x VBZR Ballast Wagons Goonyella System – 20 x VBZR Ballast Wagons Blackwater System	
2 x Ballast Ploughs	

RSM900 Undercutting Operations

The RM900 and MFS40 Ballast conveyor wagons are supported by two diesel locomotives (front and rear). The ballast wagons, track lifter and ballast ploughs are set in a consist (and are supported by three diesel locomotives (2 x front and 1 x rear). This arrangement significantly improves the efficiency of the ballast operation and reduces the time to unload ballast and lifting the track in a three-pass operation by approximately 10%. The other benefit is the travel of the ballast train back to the ballast siding. Shunt movements are not required on the ballast train which allows an optimised departure off the network.

The RM900 operation is able to ballast undercut on all main line track sections, excluding turnouts and cross overs, within the CQCN. The operation provides for full section ballast cleaning and associated resurfacing, with the ability to undertake ballast cleaning that allows the section of track to be 'handed back' to the control center, without the requirement of placing a temporary speed restriction over it.

The RM900 currently operates at a controlled optimal cutting volume rate of 650m^3 of ballast per hour. The RM900 has the capability of screening moderately fouled ballast and returning this directly into the track. The density and type of ballast fouling will determine the cutting rate. The more heavily spoiled saturated ballast will reduce the cutting rate to approximately 400m^3 per hour. Heavily fouled ballast that is unable to be screened will bypass the screeners on the RM900 and be discharge directly (total dump) away from the track into the rail corridor.

Spoiled ballast can be discharged adjacent to the track and graded off within the corridor. No spoiled ballast is discharged into any waterways and spoiled ballast that is discharged into drains or cuttings is removed. In these areas where the ballast cannot be discharged, the spoil wagons need to transfer the spoilt ballast away from the worksite.

Off Track Ballast Undercutting

Aurizon Network has mobilised additional ballast undercutting capacity utilising excavators with cutter bars which are able to operate on all track sections within the CQCN. The excavator with a cutter bar will complete full section ballast cleaning, associated resurfacing and required civil works on any plain line track and turnouts. This consist has the capability to ballast clean up to changes of sections including track, signaling and overhead line sections.

Ballast will be trucked to site and placed on track with front end loaders and mini excavators. Pending access and weather conditions, this operation can ballast undercut between 15-25 metres per hour. On larger sites, additional excavators with cutter bars and supporting fleet are mobilised to increase production rates. Spoiled ballast will be discharged adjacent to the track and graded off within the corridor. Exclusions of this operation include ballast undercutting at platforms, bridges, high embankments and narrow cuttings.

2.3 Coal loss

The following information has been developed by Aurizon Network and Connell Hatch in response to an Environmental Evaluation Notice issued by the Department Resource Management. This report concluded that coal loss[11] can be emitted from the following sources in the rail system (also refer to Figure 2):

- Wagon Surface: coal surface of loaded wagons
- Door Leakage: coal leakage from doors of loaded wagons
- Spilled coal in the corridor: wind erosion of spilled coal in corridor
- Residual Coal: “carry back coal” in unloaded wagons and leakage of residual coal from doors
- Parasitic Coal: parasitic load on sills, shear plates and bogies of wagons due to poor loading practice[12]

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[11] It should be noted that whilst the Environmental Evaluation Report refers to the relative proportion of coal dust, because of the methodology used coal dust is synonymous with coal loss. For example, page 30 of the Environmental Evaluation Report explains that the coal dust estimate for wind erosion of spilled coal in the corridor is based on assuming that deposited material is eventually emitted as dust.

[12] Connell Hatch, Final Report Environmental Evaluation of Fugitive Coal Dust Emissions from Coal Trains Goonyella, Blackwater and Moura Coal Rail Systems, Queensland Rail Limited, 31 March 2008, p.1.

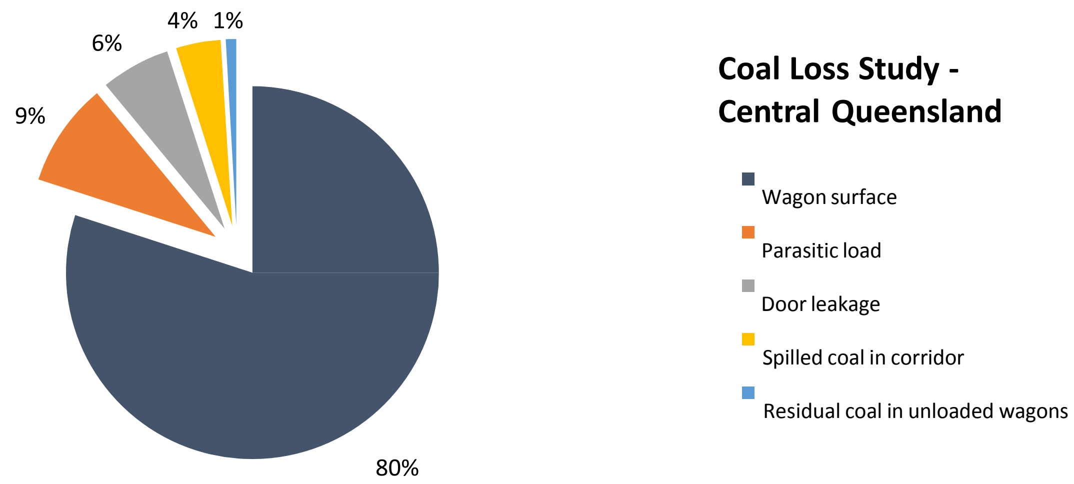

Figure 3. Sources of Coal loss

Further detail on the Environmental Evaluation Notice and the research conducted by Connell Hatch is contained within Appendix B.

In completing the Environmental Evaluation Report, Connell Hatch reviewed literature available at the time, conducted testing along with collating and analysing available data. Based on the relative proportions of coal spillage a range of measures were recognised as potentially reducing the rate of emission of coal, the most practical and cost-effective identified were:

- Coal surface veneering using chemical dust suppressants at the mine
- Improved coal loading techniques at the mine to reduce parasitic load on horizontal wagon surfaces and reduce over-filling and hence spillage during transport
- Load profiling at the mine to create a consistent surface of coal in each wagon. To be implemented at the mine, and
- Improved unloading techniques to minimise coal ploughing and parasitic load on wagons

A subsequent investigation by Aurecon Hatch in 2009[13], determined that coal loss from Kwik Drop doors on the CQCN is estimated to be 1,900t per annum within the Goonyella system and 1,750t per annum within the Blackwater system.

In order to determine the root cause of coal spillage data would need to be sourced from a combination of field measurements and computerised models such as the Computerised Particle Dynamic ('CPD') models run by CSIRO would be required. The following diagram represents graphically the interrelation of ballast and coal fouling. While a more comprehensive representation can be found in Appendix C.

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13 Connell Hatch, Final Report Environmental Evaluation of Fugitive Coal Dust Emissions from Coal Trains Goonyella, Blackwater and Moura Coal Rail Systems, Queensland Rail Limited, 31 March 2008, p.3.

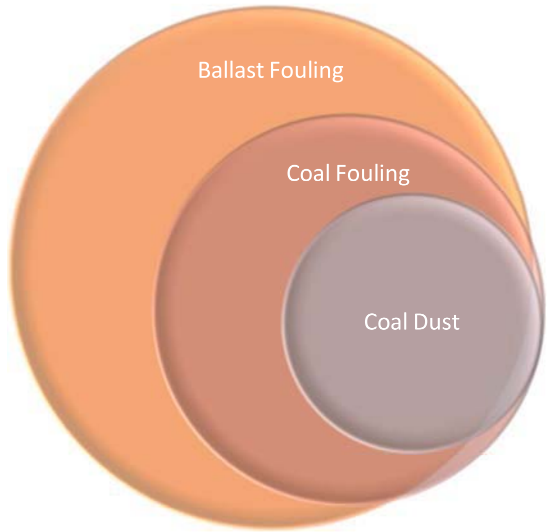

Figure 4. Ballast fouling

2.4 Coal dust

The terms coal dust and coal loss are sometimes used interchangeably, however, coal loss is the loss of all sizes of coal particles from a train and coal dust refers to the coal particles that are suspended in the air and are a subset of coal loss. Coal dust is generated when coal particles are blown from the top of the surface of a coal load, from coal spilled on the surface of rollingstock wagons or spilled on to the railway. After the coal dust is deposited in the corridor it is repeatedly disturbed and redistributed on passing trains and the prevailing winds. Coal loss includes particles of coal greater than what is suspended in the air as dust. Coal dust impacts on air quality and coal loss, including coal dust, which contributes to ballast fouling. In addition to the factors identified earlier, coal dust has the following impacts on rail infrastructure:

- Coal dust has similar properties to clay, which affects the strength of the ballast and formation when coal dust becomes saturated with water
- Coal dust can hold excessive amounts of moisture, thereby preventing free draining of the ballast
- Coal dust acts as a lubricant between ballast stones, causing movement and track instability
- The chemical consistency of the coal dust has caustic effects on the concrete and steel structures of the CQCN.

Additionally Huang, Tutumluer and Dombrow[14] conducted a detailed study on the effect of different fouling agents as a part of the laboratory program initiated by the University of Illinois. The change in shear strength with increasing weight percentage of different fouling agent was observed in this study. The results showed that coal dust was the worst fouling agent among the

[14] H. Huang, E. Tutumluer and W. Dombrow, "Laboratory Characterisation of Fouled Railroad Ballast Behaviour," *Journal of the Transportation Research Board,* no. 2117, pp. 93-101, 2009.

fine particles tested and drastically decreased shear strength. The ballast reached the critical level of contamination at 15% by weight and the strength decreased to the equivalent level of coal dust itself at 35% by weight.

2.4.1 Opportunities to prevent coal loss

The Coal Dust Management Plan outlined in Appendix B was a coordinated response to better manage coal loss in the CQCN and received unanimous agreement from the supply chain participants. The plan is comprised of six suites of proactive activities to be undertaken by the:

a) Coal producer sector
b) Coal train operator sector
c) Network Manager sector
d) Capricornia Domestic Terminal sector
e) Goonyella Export Terminal sector and
f) Capricornia Export Terminal sector.

A summary of the action plan is contained with Appendix D.

Although there has been progress against the plan, there remains more work to be undertaken by all parties to ensure that the supply chain is collaboratively progressing toward a solution. One of the more significant improvements implemented by the supply chain participants has been the installation of improved load profiling and veneering stations. This decision represented a real benefit to the supply chain and was supported by earlier research into the effectiveness of chemical binders in controlling coal dust undertaken by the Canadian Environmental Protection Service[15].

The timing of, and mitigation options for coal loss management, are dependent on a range of variables specific to each railway, including:

- coal properties: dustiness, moisture content and particle size
- load specifics: amount of exposed coal surface, evenness of profile
- specifics of the train trips: frequency of train movements, train speed, load jostling or vibration in route, total journey length
- climatic conditions: exposure to wind, wind flow characteristics and precipitation
- wagon design: wagon dimensions; wagon payload as compared to tonne axle load of infrastructure; surface areas, door design, aerodynamic design
- infrastructure standard: track geometry and design.

The United Kingdom competed a detailed review of its coal loss practices and as a result, implemented mitigation activities which included the installation of the facilities shown in Figure 5.

[15] Guarnaschelli, C., In-Transit Control of Coal Dust from Unit Trains, Environmental Protection Service – Fisheries and Environment (Canada), 1977, p.3

Figure 5. Example of UK coal rudimentary profiling facility

These facilities perform basic profiling and brush the raves (the wagons vertical sidepieces) to clear them of any residual coal. It is noted in the report to the Office of Rail Regulation in 2013 that as a result of the installation of these facilities, coal spilled outside of terminals has been reduced by 75%[16].

3 Delivering best practice in ballast management

Aurizon Network's approach to ballast management is consistent with other heavy haul rail networks in Australia and around the world.

Aurizon Network is regarded as a leader in this area as evidenced below:

- In recent correspondence from the Department of Environment and Heritage Protection to a supply chain participant it was outlined that Central Queensland now leads Australia in the management of train related coal loss
- The QRC testimony in the Senate Inquiry, "Based on the information now available, the Queensland Resources Council (QRC) is able to report to the Senate Inquiry into the impacts on health of air quality in Australia and that the coal loss mitigation activities have reduced coal dust from trains by up to 90 percent through veneering"[17]
- Evans and Peck 2012 Report on Operating and Maintenance Costs determined that "Aurizon Network and a number of Class 1 US railways now lead the industry in the research and strategies to deal with ballast fouling"
- The ballast cleaning program represents an integrated approach between Aurizon Network, the Rail Industry Safety Standards Board (RISSB), the Australian Railway Association (ARA)

16 ARUP, Office of Rail Regulation, Part A Independent Reporter Framework, Mandate: Review of Coal Spillage Charge (CSC), Final | 17 April 2013, p.13

17 The Queensland Resources Council Submission to the Federal Senate Standing Committee on Community Affairs, Inquiry into the impacts on health of air quality in Australia, 8 March 2013, p.12

and Engineering standards approved by the Rail Safety Regulator as part of Aurizon Network's Safety Management System

Outlined in the following sections is the current practices that Aurizon Network currently undertakes to manage its coal fouling practices.

3.1 Percent Void Contamination intervention

Once the issues relative to ballast fouling have been established, Aurizon Network uses an intervention level based on Percent Void Contamination (PVC). The Percent Void Contamination percentage value is calculated by dividing the volume of contaminates by the volume of voids within the ballast profile, and is determined in a compacted state to simulate actual track conditions. The volume of voids within new/clean ballast on the CQCN constitutes approximately 40-45% of the total volume of ballast within track.

Coal fines generally migrate to the base of the ballast layer by rain or vibration from rail traffic. Accumulation of these coal fines at the base of the ballast layer results in a reduced clean ballast depth below the base of sleepers. Once the depth of clean ballast below the base of sleepers is less than 100mm (approx.), more rapid deterioration of the track top and line can occur.

Testing and observations over many years of experience in the CQCN have identified not only that the ability of the ballast to function becomes gradually more impaired as fouling increases, but when the level of contamination has reached the bottom side of the sleeper, the ballast loses its strength, resiliency and drainage capabilities. As a result, the track structure has started to fail or is in imminent risk of failure under traffic loadings particularly when precipitation or inundation occurs. In an environment such as Queensland's central coast this is not a sustainable condition. A measure of 50% PVC means the fouling has reached the bottom of the sleepers.

Aurizon Network's Percentage Void Contamination intervention level is 30%

This critical fouling point of 30% PVC has been empirically based on original research in the CQCN and with consideration of the fouling measurements and intervention limits adopted by other railways. For the CQCN environment, a minimum clean competent and free ballast depth of 100mm is required. Independent of the measurement technique or index, the maximum limit of contamination needs reflect this requirement.

The adoption of a 30% PVC critical fouling point is supported by international experience from North America, South Africa and Europe, with more detailed information contained within Appendix E. However, as discussed above rail organisations have different ways of measuring the level of fouling within the track structure. Aurizon Network has led the world in recognition and research into coal fouling issues related to coal fouling impacts and the inappropriateness of weight based indices due to the low Specific Gravity of coal dust.

The PVC measure is a volumetric test, whereas the European method is to use a weight based test. These tests (or measures) only align when the fouling material has similar specific gravity to the ballast (ie. crushed ballast). By contrast, coal has a much lower specific gravity using weight based tests (as per the European method) providing a false result (indicating no issues). In the CQCN, the better test is the volumetric PVC test.

The European Rail Research Institute Criteria has been adopted in both European and North American Railways. This fouling Index generally quoted is 30% (by weight) and although relevant to operating conditions on general freight and passenger railways, where the dominant fouling material is not coal this is appropriate. However, in coal networks where the contribution to coal fouling by coal with a lower specific gravity (around one-third of ballast) understates the intervention level. It was not until around 2005 when two major derailments occurred in the BNSF that the University of Illinois in conjunction with BNSF identified and demonstrated that the European Rail Research Institute Index was inappropriate for use in a coal railway. It was shown that a fouling index of 25% represented the full fouling of the ballast profile with resultant loss of track function.

To maintain the 100mm below sleeper threshold, when the fouling material is of a similar specific gravity to the ballast material, a PVC index of 30% is similar to a fouling index of 30% by weight using the European Rail Research Institute Criteria, in that the height of competent free draining material below the sleeper is of a similar size using both measures. This height is approximately 75-100mm and it can be seen in the references below how for an appropriately designed track structure this is the important determining factor that ensures the sustainable functionality of the track.

Aurizon Network's Asset Policy for Maintenance and Renewals reflects these findings and will deliver the network in a "fit for purpose" state whilst meeting our 30% PVC targets. The Asset Policy Maintenance and Renewal is designed to balance the need for high cost capital replacement against maintaining the asset whilst managing the risk of any asset failure. This has been Aurizon Network's mandate since becoming a Rail Manager for the CQCN.

3.2 Ballast recycling

Aurizon Network's ability to recycle high volumes of ballast is restricted when the ballast has lost its required physical characteristics where the ballast is heavily fouled and cannot be screened by the RM900. This situation is further exasperated when the ballast is wet and becomes covered with sticky materials such as clay or coal contaminants. The screening decks on the RM900 ballast cleaner cannot effectively separate this material from the ballast and as a result the ballast is discharged from the RM900 ballast cleaner into the rail corridor and is subsequently utilised as fill. This process and its inherent issues which introduce increased cost and can affect the drainage performance of the track infrastructure.

During the UT3 regulatory period Aurizon Network endeavoured to establish a relationship with a third party to provide a ballast recycling program. Several attempts were made with different parties to achieve this objective, however, due in limited suitable resources in the CQCN at the time of the program this relationship was not established. With the some easing on the resources demand in the region Aurizon Network is now reinvestigating the feasibility for a mix of internal and external resources to recycle fouled ballast which is currently unscreenable.

Aurizon Network is also currently evaluating locations where this unusable material can be stockpiled to dry and screen with purpose built screening equipment. This will allow suitable ballast to be recycled and replaced back into the track with new ballast.

Ballast recycling will become more feasible and cost effective with the deployment of the fleet of ballast spoil wagons into the ballast cleaning operations. These ballast spoil wagons will enhance the process through better management of the material and thereby facilitate a cost effective "off track" screening operation.

3.3 Ground Penetrating Radar

Ground Penetrating Radar is a non-destructive subsurface inspection technology that is used to measure the condition of Aurizon Network’s assets, in particular ballast. Ground Penetrating Radar is the primary means of measuring ballast fouling through advanced radars.

Ground Penetrating Radar works by transmitting short pulses of radio frequency electromagnetic energy into a physical medium.

Changes in the electrical properties (conductivity and dielectric permittivity) of different materials affect the speed of the transmitted wave and cause part of the wave’s energy to be reflected. The amplitude of the reflected signal is determined by the contrast in the dielectric constants of the various materials. The dielectric permittivity is the electromagnetic property that governs the speed at which the Ground Penetrating Radar signal moves through a material.

The strength and return time of the reflected signal is recorded and processed to create an image of the subsurface over the depth of radar penetration. A pulse moving from dry ballast to wet clay will produce a strong, brightly visible reflection while one moving from contaminated ballast with moist fines into an underlying moist silt layer will produce weaker reflections. Water saturation increases the dielectric and sometimes the conductivity of a material. Materials which are conductive absorb the signal rapidly and prevent any further penetration.

When ballast becomes fouled, the average aggregate size decreases and the size of associated air voids also decrease.

In the past, before the use of Ground Penetrating Radar technology, ballast fouling conditions where determined using manual, destructive techniques. Manual methods known as point sampling included taking ballast samples from track and sending them to a laboratory for analysis. This was done by excavating trenches at nominated distances. This method was not only inefficient but destructive. Additionally because of the testing frequency, and locations the ballast fouling conditions of individual trenches were extrapolated over the distance between trenches. Compared to manual methods, Ground Penetrating Radar provides a number of benefits:

- simpler identification of sites requiring ballast cleaning;
- non-intrusive, efficient and cost effective means of measuring ballast condition network wide;
- near continuous measurement every 5m at three offsets (compared to every 500m – 1km sampling previously used)
- ability to develop ballast fouling rates and proactive ballast renewal plans

3.4 Ballast condition on the network

There have been two Ground Penetrating Radar runs across the network, one in 2011 and the second in 2012. For the efficacy of this report we have provided data for sections of the Goonyella track. A more comprehensive suite of data is available.

Figure 10 below show individual fouling levels at 1km intervals for both Ground Penetrating Radar runs for a section of the Goonyella Up track. The pink line is 2011 and the red is 2012. These two lines show an overall decreasing trend in fouled ballast.

The data has then has been normalised to quantify the fouling levels for the section of track over time. You will notice that both trend lines are declining and remain below the intervention level of 30% PVC.

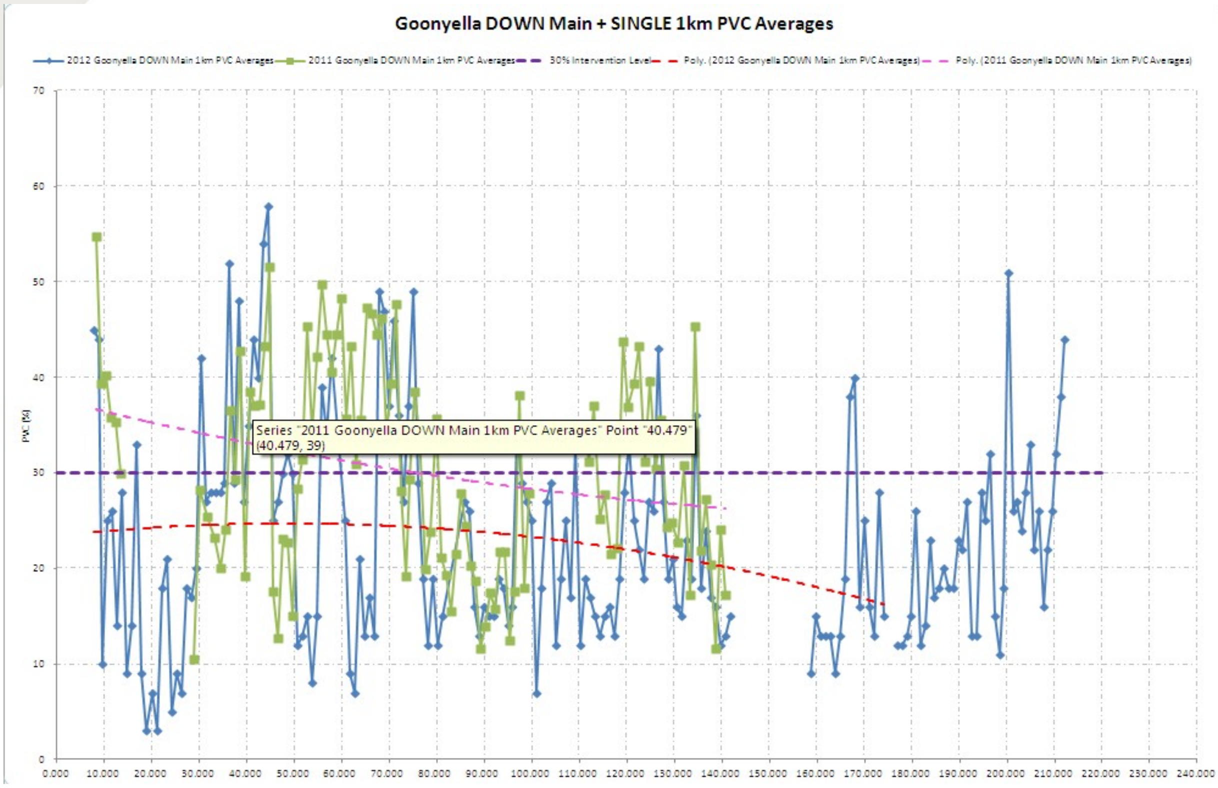

Figure 6. Normalised PVC for Goonyella Up track

Notes:
Pink Line = 2011
Red Line = 2012

SYSTEM	LINE	TRACK	START KM	END KM	GPR Date	PVC (LEFT)	PVC (CENTRE)	PVC (RIGHT)	LAST CLEANED	Remaining 13/14 Scope	Proposed 14/15 Scope	Mnt Since Last Cleaned	Current Mnt Per Year	Years Until Next Clean (600Mnt)	Average PVC (Profile)	Fouling Rate (%/Mnt)	Years Until Next Clean (30%)
Goonyella	Main	UP	94.700	94.800	Jun-12	32	11	12	31-Jul-13			18.144	52.559	11.071	22	0.909	0.178
Goonyella	Main	UP	94.800	94.900	Jun-12	27	9	7	31-Jul-13			18.144	52.559	11.071	18	0.712	0.323
Goonyella	Main	UP	94.900	95.000	Jun-12	23	7	7	31-Jul-13			18.144	52.559	11.071	15	0.566	0.496
Goonyella	Main	UP	95.000	95.100	Jun-12	36	11	8	29-Jul-13			18.432	52.559	11.065	23	0.997	0.126
Goonyella	Main	UP	95.100	95.200	Jun-12	11	5	6	29-Jul-13			18.432	52.559	11.065	8	0.148	2.867
Goonyella	Main	UP	95.200	95.300	Jun-12	12	9	11	29-Jul-13			18.432	52.559	11.065	10	0.292	1.280
Goonyella	Main	UP	95.300	95.400	Jun-12	21	27	15	29-Jul-13			18.432	52.559	11.065	24	1.012	0.119
Goonyella	Main	UP	95.400	95.500	Jun-12	45	18	49	28-Jul-13			18.576	52.559	11.062	34	1.540	-0.044
Goonyella	Main	UP	95.500	95.600	Jun-12	33	10	24	28-Jul-13			18.576	52.559	11.062	21	0.884	0.185
Goonyella	Main	UP	95.600	95.700	Jun-12	23	19	38	28-Jul-13			18.576	52.559	11.062	28	1.253	0.026
Goonyella	Main	UP	95.700	95.800	Jun-12	20	21	38	28-Jul-13			18.576	52.559	11.062	30	1.327	0.005
Goonyella	Main	UP	95.800	95.900	Jun-12	29	54	47	28-Jul-13			18.576	52.559	11.062	50	2.439	-0.158
Goonyella	Main	UP	95.900	96.000	Jun-12	58	61	56	27-Jul-13			18.720	52.559	11.060	60	2.921	-0.193
Goonyella	Main	UP	96.000	96.100	Jun-12	21	45	28	27-Jul-13			18.720	52.559	11.060	36	1.679	-0.073
Goonyella	Main	UP	96.100	96.200	Jun-12	43	65	32	27-Jul-13			18.720	52.559	11.060	54	2.629	-0.175
Goonyella	Main	UP	96.200	96.300	Jun-12	31	52	23	27-Jul-13			18.720	52.559	11.060	42	1.964	-0.114
Goonyella	Main	UP	96.300	96.400	Jun-12	52	43	44	27-Jul-13			18.720	52.559	11.060	47	2.288	-0.146
Goonyella	Main	UP	96.400	96.500	Jun-12	38		40	27-Jul-13			18.720	52.559	11.060	20	0.804	0.235
Goonyella	Main	UP	96.500	96.600	Jun-12	28		17	21-Aug-13			15.120	52.559	11.128	14	0.580	0.532
Goonyella	Main	UP	96.600	96.700	Jun-12	83	100	62	21-Aug-13			15.120	52.559	11.128	82	5.730	-0.205
Goonyella	Main	UP	96.700	96.800	Jun-12	48	15	24	21-Aug-13			15.120	52.559	11.128	32	1.762	-0.018
Goonyella	Main	UP	96.800	96.900	Jun-12	31	29	22	25-Jul-13			19.008	52.559	11.054	30	1.297	0.005
Goonyella	Main	UP	96.900	97.000	Jun-12	34	74	36	25-Jul-13			19.008	52.559	11.054	55	2.614	-0.180
Goonyella	Main	UP	97.000	97.100	Jun-12	66	80	56	25-Jul-13			19.008	52.559	11.054	73	3.589	-0.229
Goonyella	Main	UP	97.100	97.200	Jun-12	35	62	48	24-Jul-13			19.152	52.559	11.051	55	2.611	-0.182
Goonyella	Main	UP	97.200	97.300	Jun-12	28	34	37	24-Jul-13			19.152	52.559	11.051	36	1.597	-0.067
Goonyella	Main	UP	97.300	97.400	Jun-12	62	58	39	24-Jul-13			19.152	52.559	11.051	55	2.604	-0.182
Goonyella	Main	UP	97.400	97.500	Jun-12	27	63	43				-	52.559	-	53	-	-
Goonyella	Main	UP	97.500	97.600	Jun-12	21	65	51				-	52.559	-	58	-	-
Goonyella	Main	UP	97.600	97.700	Jun-12	32	61	38				-	52.559	-	60	-	-
Goonyella	Main	UP	97.700	97.800	Jun-12	80	100	92	13-Nov-06			388.654	52.559	4.021	96	0.234	-5.363
Goonyella	Main	UP	97.800	97.900	Jun-12	20	37	21	13-Nov-06			388.654	52.559	4.021	29	0.063	0.216
Goonyella	Main	UP	97.900	98.000	Jun-12	28	42	18	13-Nov-06			388.654	52.559	4.021	35	0.077	-1.217
Goonyella	Main	UP	98.000	98.100	Jun-12	18	19	11		24-Jul-13		-	52.559	-	19	-	-
Goonyella	Main	UP	98.100	98.200	Jun-12	54	26	27	12-Nov-06	24-Jul-13		388.792	52.559	4.018	40	0.090	-2.125
Goonyella	Main	UP	98.200	98.300	Jun-12	39	13	28	12-Nov-06	24-Jul-13		388.792	52.559	4.018	26	0.053	1.544
Goonyella	Main	UP	98.300	98.400	Jun-12	24	26	20	12-Nov-06	24-Jul-13		388.792	52.559	4.018	25	0.051	1.861
Goonyella	Main	UP	98.400	98.500	Jun-12	35	45	32	12-Nov-06	24-Jul-13		388.792	52.559	4.018	40	0.089	-2.052
Goonyella	Main	UP	98.500	98.600	Jun-12	27	16	16	11-Nov-06	24-Jul-13		388.930	52.559	4.016	22	0.042	3.812
Goonyella	Main	UP	98.600	98.700	Jun-12	35	30	38	11-Nov-06	24-Jul-13		388.930	52.559	4.016	33	0.071	-0.679
Goonyella	Main	UP	98.700	98.800	Jun-12	16	32	38	11-Nov-06	24-Jul-13		388.930	52.559	4.016	35	0.077	-1.192
Goonyella	Main	UP	98.800	98.900	Jun-12	13	22	17	26-May-13	24-Jul-13		27.648	52.559	10.890	19	0.524	0.383
Goonyella	Main	UP	98.900	99.000	Jun-12	14	18	11	26-May-13			27.648	52.559	10.890	16	0.382	0.720

PVC Category	Description	PVC Range (%)
5	Clean	0 to <10
4	Moderately Clean	10 to <20
3	Moderately Fouled	20 to <30
2	Fouled	30 to <50
1	Severely Fouled	>=50

Figure 7. Shows individual data sets for the Goonyella Up track

Figure 12 shows the range of metrics used by Aurizon Network to plan its ballast cleaning program. The results of the two runs have been further broken down to delineate the left, right and centre areas of the track. Historical and future interventions have also been captured in the data base which is used for ongoing comparisons.

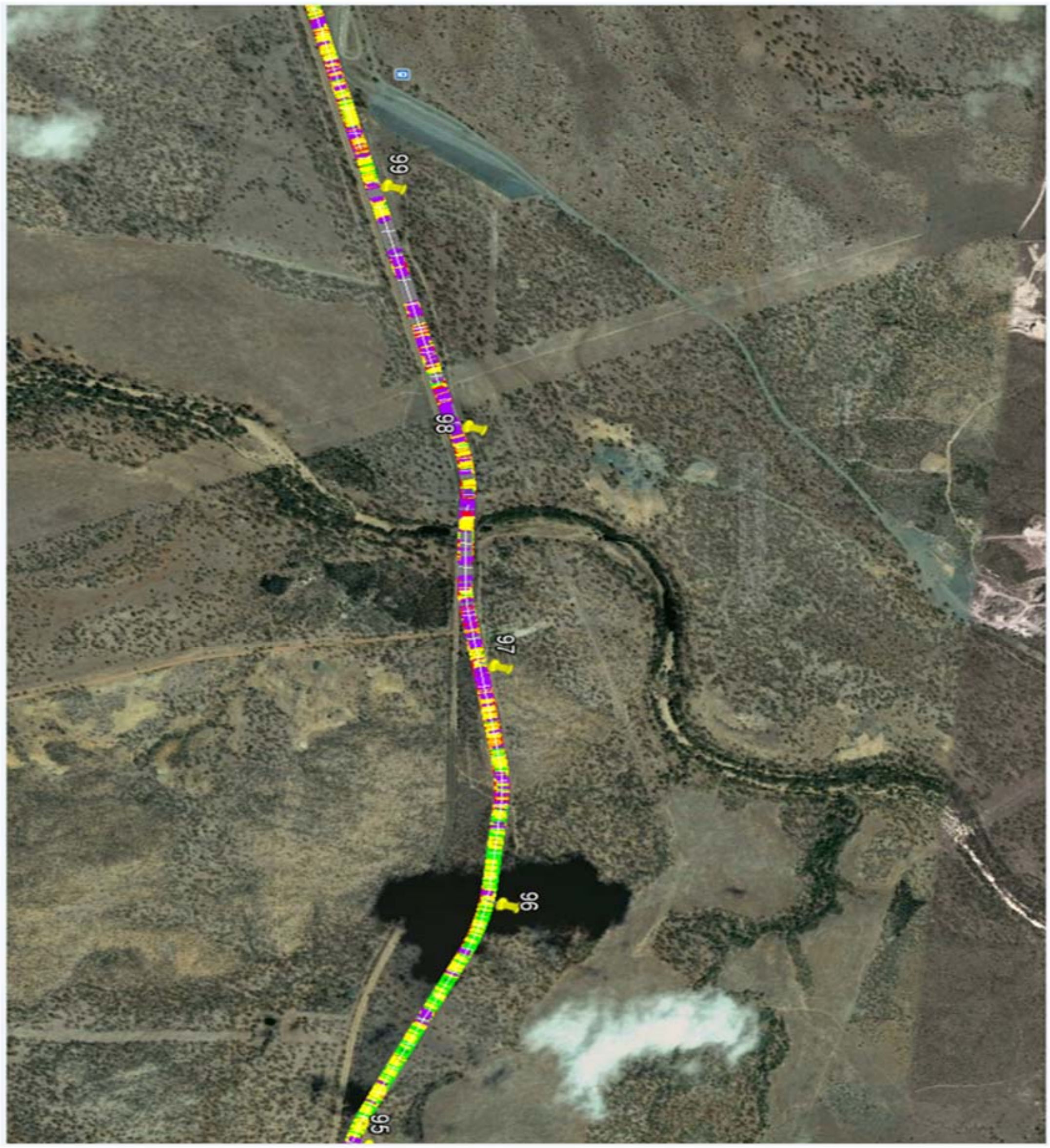

Figure 8. Overlay of a section of track onto a Google Earth image

To enable Aurizon Network to take a more holistic view when assessing the condition of the ballast and to easily identify clusters of areas of concern across the network the data sets have been overlayed and coded to a Google Earth map. This provides an opportunity to quickly identify any potential risk areas (refer to Figure 12) with different colours indicating the extent of fouling along different track sections.

With the improved understanding of the fouling levels of the ballast throughout CQCN can now proactively manage the ballast cleaning operation. Currently the planning window has been extended out for 12 months. However, with two further Ground Penetrating Radar runs planned for 2014 and 2016, Aurizon Network is confident that its understanding of the ballast fouling issue will be greatly enhanced and deliver a more focussed and effective ballast cleaning program.

3.5 Condition Based Assessment results

In a collaborative effort between the Queensland Competition Authority, Aurizon Network and the consulting firm Evans and Peck, a Condition Based Assessment (CBA) of the network was undertaken. The comprehensive report provides the reader with a thorough insight into the structural components and performance criteria for the network. More importantly it provides an assessment of the performance of the network by the key performance indicators, BRTT and oTCI. The result was:

System	Operational KPI BRTT	Operational KPI oTCI
Newlands	3 Months above BRTT*	Overall Condition Good
Goonyella	1 Month above BRTT	Overall Condition Good
Blackwater	0 Months above BRTT	Overall Condition Good
Moura	0 Months above BRTT	Above median threshold

Figure 9. Results from Condition Based Assessment

*This non-conformance was due to signalling and train control delays, combined with additional culvert inspections on the Goonyella to Abbott Point Expansion

Condition Coding	Description
Green	Asset performing at or better than specified
Yellow	Minor non-conformance
Amber	Non conformance
Red	Major non conformance
Grey	Unavailable or insufficient data

Figure 10. Coding for the Condition Based Assessment results

As determined by Evans and Peck the systems where the BRTT were recorded as either a minor non-conformance or a non-conformance were a consequence of signalling system issues. Causal factors relating to oTCI for the Moura system can be mapped back to the above average rainfall in the early part of 2012 and the negative impacts the black soil base has on the track foundations.

4 Aurizon Network's UT3 Maintenance Submission

The UT3 Maintenance Submission for ballast cleaning was based on the utilisation of the RM900 and 50 MFS40 Spoil Management Wagons to complete approximately 90-130 km of ballast cleaning within the existing possession plan of 160 x 8 hour closures.

The fleet in the UT3 Maintenance Submission, comprised of the following:

Fleet
Plasser&Theurer RM900 ballast cleaner
50 MFS Wagons and 3 Power cars
Plasser&Theurer 3 tyne pair tamping machine, with another older machine as back up
Ballast Cleaning System reliability level of 95%
Provision of the existing stabling points throughout the system to enable storage/movement of the machine
Ballast handling facilities that are able to load and empty the 50 MFS wagons at Hatfield, Saraji, Blackwater and Bajool

At the time of preparing the UT3 Maintenance Submission it was intended to expand the ballast cleaning fleet with 50 new MFS wagons, 3 power cars and the a new 3 tyne pair Tamping machine. It was assumed that the MFS wagons could be purchased for $1.25m per wagon and the power cars at $4.0m per car in Financial Year (FY) 2007/08 dollars.

The additional MFS wagons were considered necessary as they:

- allowed the ballast cleaner to operate continuously in areas where there it is unsuitable to deposit spoil
- reduced the amount of tamping required from 3-4 passes to 1-2 passes
- removed the requirement to use ballast trains on most sites by allowing the ballast cleaner to use the fresh ballast to leave the track at design level.

At the commencement of UT3 spoil management had become a critical issue on a number of key sections within the network. In some areas there was a 100% rejection of the existing ballast and no adjacent ground to deposit the spoil, the existing 6 wagon operation could only operate for 80m before the MFS wagons had to be taken away to be emptied. This meant that while the MFS wagons were being emptied the ballast cleaning operation would be forced to halt production.

The delivery of the scope also provided for a range of matters including:

- where single line track areas were heavily fouled shoulder cleaning only was to be undertaken
- the establishment of a ballast screening facility

- additional ballast loading/unloading facilities to be built across the network
- 75% of the recycled ballast fit for reuse as track ballast.

4.1 Cost assumptions

A detailed cost build up for the ballast cleaning scope of works for the UT3 period is detailed in QR Network's Access Undertaking (2009) Maintenance Cost Submission and is summarised below:

	50 MFS Option*			
	2009/10	**2010/11**	**2011/12**	**2012/13**
Direct wages etc	$5.6	$5.8	$6.0	$6.2
On-costs	$0.9	$0.9	$1.0	$1.0
IT, HR etc	$0.1	$0.1	$0.1	$0.1
Plant maintenance	$5.0	$6.8	$8.2	$8.2
Consumables	$13.5	$15.7	$17.6	$18.0
Asset charges	$1.8	$9.9	$14.8	$14.2
Margin	$4.0	$5.9	$7.1	$7.1
Total	**$30.9**	**$45.1**	**$54.7**	**$54.7**

Figure 11. Estimated Ballast Cleaning Costs UT3 Period ($M) from the UT3 Maintenance Cost Submission

*This data was originally redacted. It is no longer current or correct as the MFS wagon project has subsequently been re-scoped.

4.2 Scope delivery

The following table is a summary of Aurizon Network's performance for ballast undercutting as reported in the Annual Maintenance Costs reports.

Scope in km	**09/10**	**10/11**	**11/12**	**12/13**
Total Undercutting Forecast	108	130	150	150
Total Undercutting Actual	111	120	107	94
Mechanised Undercutting Forecast	83	105	125	125
Mechanised Undercutting Actual	83	86	78	85
Undercutting Other Forecast	25	25	25	25
Undercutting Other Actual	28	34	29	9

Figure 12. Ballast Undercutting scope for UT3 Maintenance Cost Submission

Cost	09/10	10/11	11/12	12/13
Total Undercutting Forecast	28,493,053	39,144,312	48,449,667	50,147,704
Total Undercutting Actual	30,183,058	39,998,777	45,513,456	48,608,352
Mechanised Undercutting Actual	-	33,366,134	38,587,647	42,182,066
Undercutting Other Actual	-	6,632,643	6,925,809	6,426,286

Figure 13. Ballast undercutting costs for UT3 Maintenance Cost Submission

Please note the above figures (figure 6 and 7) have not been adjusted for the reduced CQCN volumes nor the reduction to the maintenance allowance due to AT1 (incremental maintenance tariff).

4.3 Detailed Performance Analysis

As part of the performance analysis, it is important to outline that the UT3 Maintenance Submission was prepared where there had been 10 years of drought, as such the production assumptions did not consider the impacts of wet weather and flooding. Wet weather impacts both the amount of ballast that can be recycled as well as restricting access to the track. Further, fouled ballast storage and removal became much more difficult due to environmental implications than was envisaged in the production assumption modelling, in particular, two major review events involving substantial flooding within the CQCN, namely the 2011 and 2013 flood review events, resulted in approximately 17,000m^3 of ballast (2011) and $1,224,776 (2013) being replaced across the Blackwater and Moura systems respectively .

As such, there were no ballast cleaning works carried out as these resources were directed to flood repair works. This equated to a loss of 18 shifts with an average production of 300m, which equals a scope delivery of 5.4km. The significant increase in sites where ballast was unable to be returned to the track due to the heavily fouled condition (wet ballast) substantially increases the unit cost of the ballast cleaning operation.

In the FY2013 when required to "totally reject" non screenable ballast (50% contamination) the business incurred $6M of additional costs.

In addition to the above, the following summary of the performance for ballast cleaning operations in which aspects of both the cost and production assumptions are reviewed in further detail:

4.3.1 Ballast Return Rates

- The scope assumptions were based on a range of 70% to 90% of the cleaned ballast being able to return to the track, supplemented by a range of 10% to 30% of clean ballast. Return rates were much less at 49% for FY2012 and 48% for FY2013. This resulted in a slower and more expensive operation;
- Ballast return rates for the UT3 Maintenance Submission assumed a return rate of between 70 to 90%. However, actual return rates were much lower at 49% for the FY2012 and 48% for the FY 2013. These percentages confirm that greater quantities of ballast had to be replaced resulting in greater levels being removed;

4.3.2 Ballast Scope Change

- The scope of ballast to be cleaned assumes a standard ballast depth of 300mm. However, this can vary, with evidence of depths of up to 700mm. This has a direct impact on costs and ability to deliver to a lineal ballast undercutting scope;
- As outlined above, the volume of ballast cleaned was more than the lineal distance scope of ballast required. While there are no detailed records of the depth of ballast cleaned covered by the UT3 regulatory period, we do know that in FY2013, more than 40% of the ballast cleaned was greater than the standard depth. By way of comparison, in FY2013, 94km of ballast was cleaned which equates to 235,000m^3 if the ballast was at standard depth. If the assumption is made that 70% was at standard depth and 30% non-standard at 500mm deep, then the ballast cleaned would have been 391,000 cubic metres, which equates to a 20% difference in the two scenarios. This equates to a lineal conversion of 113km of cleaned ballast

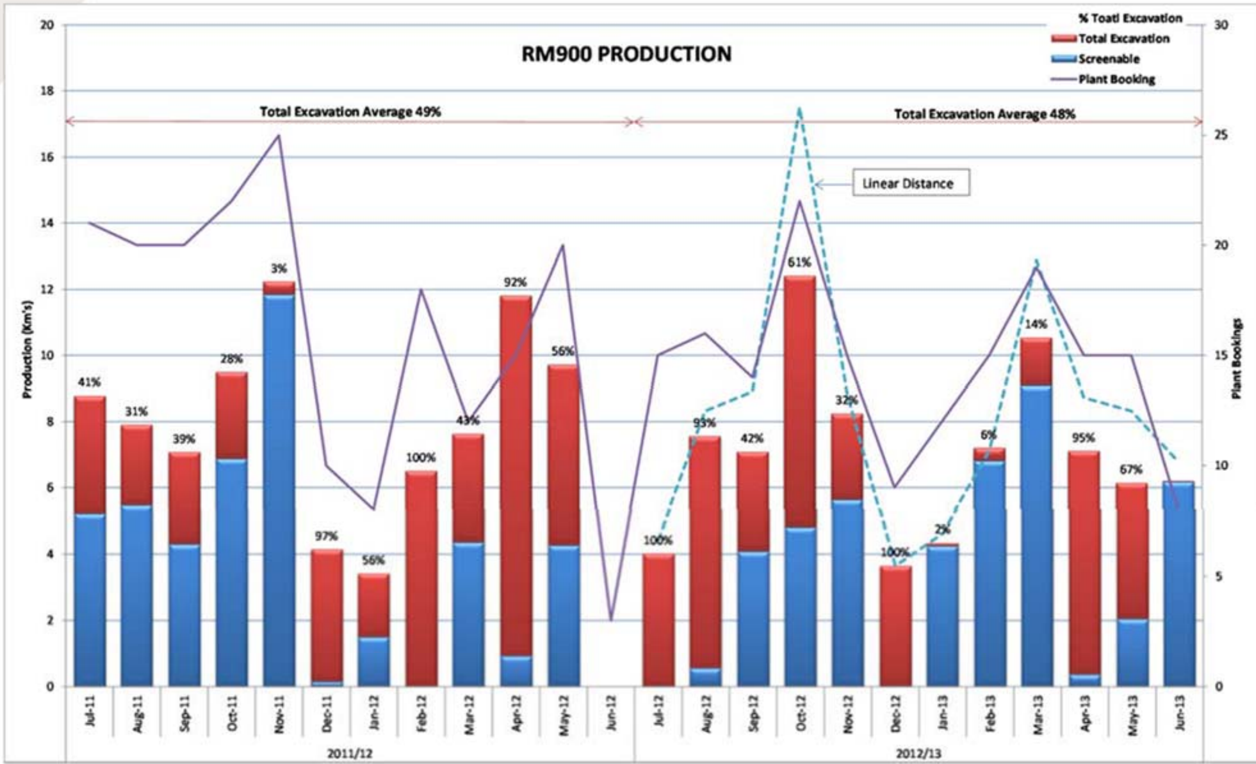

Figure 14. Ballast recycle rates for FY 2011/2012 and FY 2012/2013

4.3.3 Labour Rates

- The UT3 ballast cleaning scope forecast did not provide for any reduction in production for local conditions, for example, due to the difficult terrain encountered at Black Mountain on the Goonyella system, a production rate of 150m per shift was achieved
- UT3 assumed a standard award rate of $100k per worker, however, the realised wage rates were on average $140k;
- The original UT3 maintenance submission provided for staff numbers of 70. The actual staff number realised over the UT3 period were on average 100 full time equivalent employees (FTE). This increase in FTE, was due to slower than expected progress on ballast undercutting as a result of high level of moisture and subsequent fouling within the ballast;
- No provision was made in the UT3 submission for the impacts of the introduction of the new Rail Safety and Workplace Health and Safety legislation. This additional cost has been assessed at $1M per year;
- Plant maintenance costs, both labour and materials, escalated as a result of resource demands in the coal regions which saw an additional cost of $1.8m in the FY2013.

4.4 Maintenance allowance for additional plant and scope

The UT3 Maintenance Cost Submission included in its scope assumptions improved production through the procurement of an additional 50 MFS Wagons at $1.25m per unit, three Power Cars at $4m per unit and a 3 tyne pair Tamping machine. The MFS wagons and Power Cars were not purchased during the term of UT3, however, the existing 3 tyne pair Tamper was refurbished at a cost of $1m. Within the cost assumptions of the Maintenance Cost Submission provision was made also for the additional asset charges to be recovered. Refer to the table below and page 175 from the UT3 Maintenance Cost Submission.

Estimated Machine Asset Charges – UT3 Period ($m)

50 MFS wagons*	**2009/10**	**2010/11**	**2011/12**	**2012/13**
Opening Asset value	6.9	56.5	84.7	78.4
Depreciation	0.9	4.2	6.3	6.3
MV lease charges	0.3	0.3	0.3	0.3
Total asset charges	**$1.8**	**$9.9**	**$14.8**	**$14.2**

Figure 15. Asset costs derived from UT3 Maintenance Cost Submission

*This data was originally redacted. It is no longer current or correct as the MFS wagon project has subsequently been re-scoped.

Both the scope and the cost build up for the ballast cleaning function within UT3 was based on assumptions previously outlined. Additionally, 90% of the scope was delivered (once a volumetric conversion was applied) and was delivered at 4% less than the maintenance allowance. The production was achieved by better utilising existing resources (double shifting during extended track closures, modifying work rosters and increasing the output from existing asset).

The subsequent result was that the business concluded that the additional “Asset Charges” funding provided for in the Maintenance Allowance which was to be spent on the spoil wagons, was instead to be consumed by the business to deliver the ballast cleaning program through other mechanisms.

4.5 System Review during UT3

In the QCA’s final decision in 2010 it was determined that Aurizon Network should undertake a Condition Based Assessment of the systems within the CQCN during the term of the 2010 AU. This was driven by the need to confirm that the maintenance and renewals practices deployed by Aurizon Network were delivering a “fit for purpose asset”. The major points of concern with industry stakeholders were couched in the notion that Aurizon Network would under maintain the asset and there were concerns over the ballast cleaning program.

In relation to ballast cleaning it is understood that the impacts of an inappropriate ballast cleaning program would manifest in various forms and as such the key performance indicators of Below Rail Transit Time (BRTT) and Overall Track Condition Index (OTCI) degraded performance over the term. Aurizon Network, in a tripartite arrangement with the QCA and Evans and Peck

undertook a Condition Based Assessment in 2012. The results of the CBA confirmed that there were no issues with Aurizon Network Maintenance and Asset management practices.

4.6 Impairment from the RAB for ballast fouling

Aurizon Network, in Volume 3 of its 2013 DAU submission, outlined the consequences associated with the impairment charges of the ballast undercutting levels.

Aurizon Network has included within this paper, evidence that Aurizon Network has of adopted efficient maintenance practices in the management of ballast during the UT3 term. Aurizon Network, proactively works as a member of the coal supply change within the Central Queensland Coal Region, to positively influence the impact of coal fouling on the network.

Aurizon Network's position on the impairment charge has not changed.

5 Aurizon Network's 2013 UT4 Maintenance submission

5.1 UT4 approach to ballast

Within the 2013 DAU, Aurizon Network has included two PVC options to measure the levels of contamination within the CQCN. These methods include:

1. Point Sampling – This has been used historically by Aurizon Network
2. Ground Penetrating Radar (GPR)

Previously, to understand the required scope of ballast cleaning, Aurizon Network conducted an assessment of the condition of the ballast on a network-wide basis using Point sampling method. This method was time consuming, costly and provided limited information due to the infrequent sampling process (the assessment process was physically limited and provided a very localised, invasive sample every 500m – 1km). In order to address this issue and provide a better understanding of the extent of the fouling of the CQCN, Aurizon Network has adopted the use of Ground Penetrating Radar in its approach to scope under UT4.

Prior to establishing this new approach, Aurizon Network developed a specific calibration formation test bed with graded coal fouling to ensure that the Ground Penetrating Radar results could be customized and validated for the CQCN environment

Aurizon Network has tested and analysed a significant proportion of the CQCN using Ground Penetrating Radar. This testing selected the most highly trafficked sections of track on the four systems including North Coast Line, Central Line, the Goonyella trunk and the Oaky Creek Branch. This selection, represents about 90% of the ballast cleaning requirements of the CQCN.

To assist with the calculation of the rate at which the network is fouled by ballast, the Ground Penetrating Radar data is calibrated for PVC. Ballast fouling rates have then been determined in terms of PVC per 100million net ton of coal carried. These rates range between 1% and 15%, depending on local infrastructure configuration, per 100million net ton. Based on these network wide findings, an average fouling rate of 5% per 100million net ton has been established. To manage ballast fouling at the average fouling rate requires ballast undercutting intervention with a frequency of every 600 million net ton.

The Network Strategic Asset Plan model forecasts scope for ballast undercutting requirements through the UT4 period and beyond. The scope is based on the current condition of the network to maintain an average fouling rate of 5% per 100 million net ton and the forecast tonnage profile across the network.

Based on these forecast scopes the actual annual ballast undercutting programs are determined and prioritized from the actual ballast condition relative to the ballast critical fouling point for intervention (30% PVC) and known fouling rates.

Based on the Aurizon critical fouling point (of 30% PVC) and given the results to date from the Ground Penetrating Radar analysis, there is a very high level of confidence that the scope of ballast undercutting and renewal, both in the past and as included within the UT4 program, is prudent and required. If this were not the case the Ground Penetrating Radar results would not indicate the required scope for UT4 to maintain fouling below the critical fouling point. The Ground Penetrating Radar has also confirmed the appropriate average intervention frequency for such work.

5.2 UT4 Scope and price implications

The production and cost assumptions for ballast cleaning for the UT4 Maintenance Cost Submission have been based on actual cost and performance achieved for the activity for the FY2011/FY2012. Ballast cleaning products were costed by reference to the resources required to complete the requisite scope, given certain production assumptions.

The nature of the mechanised function is such that resources are somewhat fixed, until the scope increase reaches a certain point. When scope is at the point of requiring an additional labour resources and/or another machine is needed then a step change approach to price is required. Efficiency improvements have already been built into the mechanised products via increases in production rates of those achieved in FY2012.

Production assumptions contained within 2013 DAU include:

- Significant scope increase on FY2012 actual ballast replacement production; 39% for FY2014 and 65% to FY2017.
- Vast majority of mainline scope being performed by the RM900, with an annual 4.7km of the minor works being performed by Asset Maintenance teams, where the works are not suitable for the large machine; e.g. near turnouts and short runs
- Mechanised undercutting scope can be achieved by combining:
  - the existing RM900 plant capability;
  - the acquisition of additional 18 spoil and the upgrade of 60 ballast wagons from Q1 2014/15; and
  - The acquisition of an off-track solution from Q1 2013/14
- Work is scheduled to be performed in closures specifically assigned to the ballast cleaning function
- Redaction removed and Correction: Based upon new data, Aurizon Network would expect to gain further efficiencies commencing FY2015 when the additional spoil and ballast wagons are to hand. The ballast wagons will also assist with the geographically challenging sites.
- The RM900 and off-track consist are totally dedicated to the CQCN. Given specific off-track consist and procurement approach was not confirmed at time of the UT4 Submission, a "wet hire" allowance has been included. Costs includes ballast, fuel, plant hire, plant maintenance, Track Protection Officers and off-track logistics
- Assumed continuation of minor support provided by relevant Asset Maintenance area primarily the overhead isolations.

6 Proposed Next Steps

Aurizon Network recognises that ballast fouling is a complex issue that requires the commitment of all supply chain participants to ensure the delivery of a safe, reliable and efficient rail network.

Aurizon Network will work collaboratively with participants within the supply chain. Aurizon Network proposes to demonstrate this commitment through the following activities:

6.1 Coal Dust Management Plan

Aurizon Network is committed to continued engagement with all supply chain participants to support the commitments contained within the Coal Dust Management Plan being closed out effectively or alternatives solutions development. It is recognised that industry participants must undertake their respective obligations and should continue to collaborate across the supply chain.

6.2 CQCN Ballast Fouling Investigation

In recognition of the complexity of Ballast Management and the implication and contribution by the supply chain, Aurizon Network would like to engage with industry to facilitate a comprehensive research program and quantify the impact of the different sources of coal fouling on the network. The comprehensive approach is proposed to incorporate a review of literature to assess the differing conclusions drawn by the authors and to better understand Ballast fouling impacts onto the CQCN. The programme would include :

- Formal academic review of existing practices and procedures both internationally and domestically
- A regular progress report delivered quarterly on the investment and procurement of Ballast cleaning plant to the QCA and Industry
- A continued review and analysis of fouling rates and general Ballast Condition through the use of Ground Penetrating Radar
- The establishment of an industry committee to oversee the implementation of effective controls for all participants in the supply chain
- A defined commitment to best practice study tour with delegates from industry and the QCA
- Collaboration with industry for the development and publication of the Central Queensland Coal Fouling Master Plan
- To undertake directed subsequent research and analysis as agreed by the industry committee on such things as:
  - Economic analysis across the supply chain for proposed controls
  - University engagement for specific research and analysis

- Assess and quantify the natural degradation of ballast under normal operating conditions and environmental factors
- Establish measures for base line and rate of fouling for CQCN as affected by various controls established by the supply chain
- Enhance industry understanding and knowledge of Ballast Management
- Detailed assessment of the size and nature of the various sources of coal ballast fouling using Computerised Particle Dynamic model
- Further assessment on air quality impacts due to Coal Dust
- Partner with national and international experts and rail managers interested in supporting enhancing coal fouling management

6.3 Implementation of Ballast Undercutting Machinery Program

Aurizon Network have committed to a suite of logistical support enhancements and productivity improvements to the current undercutting programme which will enable the delivery of the full maintenance scope for the regulatory period. The following is a summary of the programme including completion dates:

- Spoil wagons, eight sets of three wagons to be delivered by December 2015;
- Ballast wagon upgrades, fourteen sets of four to be delivered by December 2014;
- RM900, the existing undercutting machine, system upgrades to be completed by December 2014;
- Upgrades to storage and loading facilities at four sites, three sites have be completed and the last site is to be completed by June 2015.

To provide comfort to industry and the QCA, Aurizon Network can confirm that the Investment Approval Request for the procurement of Ballast Upgrade Programme was authorised in 2013, which confirms that this program is fully supported, funded and being implemented..

6.4 QCA Engagement

Aurizon Network will continue to work closely with the QCA towards the timely and efficient approval of UT4, and to further an understanding of ballast management within the CQCN. Aurizon Network's approach to ballast management remains consistent with other Australian and international railways, and is regarded as a leader in best practice.

Appendix A

It should be noted that in the following sections the terms coal dust describe what is referred to as coal loss in the body of this report.

Comparison of Aurizon Network Coal Loss Management with BNSF Developments in the Powder River Basin

The Powder River Basin in north-eastern Wyoming produces the largest volume of coal of any coal producing region in the United States and provides approximately 40 percent of the coal consumed in the country. A critical artery accessing the Powder River Basin mines that produce the majority of Powder River Basin coal is the 103 mile segment of railroad owned jointly by BNSF and Union Pacific[18]. Volumes on the joint line have increased from 76 million tons in 1984, when the line began operating as a joint facility, to 375 million tons in 2008[19]. This growth in coal volumes is considered the primary reason why coal dust emerged as a major problem on the railroad. Greater volumes transported over the rails meant more coal dust emissions and the faster build-up of coal dust along the right of way[20].

The Implications of coal loss were not clearly understood at this time

BNSF have stated that whilst they were generally aware that coal dust caused problems, up until September 2002 they had not intensively studied coal dust, were not aware of the magnitude of the adverse impact to the track structure, nor had they adopted specialised programs to deal with the coal dust problem. However, by late 2002, coal dust had become a source of heightened concern with regard to the long term stability of the roadbed. In December 2003 and throughout 2004, BNSF undertook a study to quantify the magnitude of the problems associated with coal dust on the roadbed. The study monitored the rate of coal dust accumulation, the magnitude of the deposits, and the seasonal and locational impacts of coal dust accumulation on operations and maintenance[21].

While BNSF were concerned about the increasing accumulations of coal dust, rail operations on its coal lines were satisfactory through the early spring of 2005. The Joint Line had accommodated record volumes in 2004 and the first four months of 2005. BNSF had increased its inspection and maintenance activities to deal with coal dust and it was considered that the expanded maintenance activity would be adequate to support Joint Line operations until long term solutions could be implemented to address the problem of coal dust accumulations[22].

After thorough investigation and study, Union Pacific Corporation (UPRR) also concluded based on what it has learned about the pernicious nature of coal dust, that (1) BNSF was adequately

18 VS Stevan B.Bobb, BNSF Opening Statement, FD35305 p.2-3
19 VS Stevan B.Bobb BNSF Opening Statement, FD35305 p.3
20 VS Stevan B.Bobb BNSF Opening Statement, FD35305 p.3-4
21 VS Gregory C.Fox BNSF Opening Statement, FD35305 p. 3
22 VS Gregory C.Fox BNSF Opening Statement, FD35305 p. 3

maintaining the Joint Line prior to the May 2005 derailments, (2) the accumulation of coal dust at levels that could threaten the integrity of the ballast throughout the Joint Line was not readily detectable prior to the 2005 derailments, and (3) the potential for sudden and widespread deterioration of the track following heavy precipitation was neither known nor knowable prior to the 2005 derailments[23].

May 2005 derailments

On May 14, 2005, a BNSF coal unit train derailed on the Joint Line. On May 15, 2005, less than eighteen hours later, a UPRR coal trait train derailed on the Joint Line a few miles away from the first derailment. These derailments and the work required to repair the affected lines severely disrupted coal operations in the Powder River Basin[24].

Over the next several months, BNSF undertook a comprehensive rehabilitation of the Joint Line which reduced track availability and coal shipments[25].

BNSF studied the causes of the derailments and concluded that the derailments had resulted from a confluence of events. An extraordinary amount of rain and snow had fallen at the same time that the frozen ground was thawing and additional sub-surface moisture was rising up through the roadbed. Coal dust accumulations in the rail ballast had exacerbated the drainage problems caused by the excessive moisture in the roadbed. The mixture of coal dust and water caused the ballast to weaken to the point that the roadbed no longer provided adequate support for the rails[26].

As a result maintenance intervention increased considerably

During BNSF's study of the coal dust problem, BNSF was surprised to see how quickly coal dust accumulated in the ballast. In one area of new track construction, BNSF discovered a few months after the new track had been installed that the ballast had already become fouled. BNSF carried out a coal dust cleaning effort in 2008, focused on gathering visible deposits of coal dust along the right of way, in creek beds next to tracks, and along bridge abutments, and filled over 300 railcars with coal dust for disposal at a landfill[27].

In the Powder River Division, BNSF determined that certain segments of the Joint Line must be undercut every 2 to 3 years as a direct result of coal dust accumulation in the ballast. Other segments of the Joint Line where the coal dust may not accumulate as quickly must be undercut at least every 5 to 6 years, at least three times as often as the majority of BNSF's high density Transcon line through New Mexico that services only a small number of coal trains[28].

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23 VS David Connell, UP Opening Statement, FD35305 p.10
24 VS Gregory C.Fox, BNSF Opening Statement, FD35305 p. 4
25 VS William Vanhook, BNSF Opening Statement, FD35305 p. 3
26 BNSF Opening Statement, FD35305, p.10
27 BNSF Opening Statement, FD35305, p.13
28 VC Craig Sloggett, BNSF Opening Statement, FD35305 p.7

Coal loss investigations and studies

BNSF concluded that it had to take measures to prevent a recurrence of the derailments and the severe service disruption caused by these outages. BNSF had been studying the problem of coal dust and possible dust suppression measures before the derailments, but BNSF substantially expanded its efforts to understand the scope and causes of the coal dust problem in the Powder River Basin and to investigate possible ways to address the problem of coal dust emissions. BNSF gave the highest priority to the study[29].

BNSF sought to understand the science of coal dust in various different dimensions, including:

- the monitoring and measurement of coal dust levels
- the effect of coal dust on ballast and track structure and
- the identification of effective measures for limiting coal dust emissions[30].

BNSF set up an extensive data gathering network after the derailments that consisted of three basic parts.

First, a network of dust fall collectors was installed to keep track of overall coal dust deposition rates along the Powder River Basin lines and at varying distances from the track. However, these dust collectors did not measure dust emissions from individual trains.

Second, BNSF engaged Simpson Weather Associates (SWA) to set up Trackside Monitors ("TSMs") to measure the total amount of coal dust emitted by a passing train.

Third, SWA assisted BNSF in monitoring coal dust emissions from certain instrumented trains so as to test the effectiveness of various dust suppression measures introduced since 2005[31].

In addition to these data gathering efforts, BNSF sought to understand better the physical impact of coal dust on rail infrastructure. Since 2006, BNSF has worked with Dr. Erol Tutumluer, a Professor of Civil and Environmental Engineering at University of Illinois at Urbana-Champaign, who has done extensive studies of railroad track structure and the causes of track failures. Dr. Tutumluer advised that while coal dust had not previously been identified as a significant ballast contaminant, it actually has characteristics that make it one of the worst possible fouling agents. He found that coal dust has a very high water holding capacity which limits drainage in ballast fouled by coal dust. His tests also showed that ballast contaminated by coal dust has a much lower load bearing capacity than ballast fouled with other contaminants, which is an obvious problem for Powder River Basin lines that carry a greater volume and annual tonnage of freight than any other rail lines in the United States[32].

[29] BNSF Opening Statement, FD35305, p.10
[30] VS Stevan B.Bobb BNSF Opening Statement, FD35305 p.5
[31] BNSF Opening Statement, FD35305, p.11
[32] BNSF Opening Statement, FD35305, p.12

Additional studies at the request of miners

From 2005 through 2009, BNSF worked with consultants, coal shippers, shipper associations, and Powder River Basin mines to get a handle on the scope of the coal dust problem and to identify ways to substantially eliminate coal dust losses. BNSF has spent more than $6 million dollars on it study of in-transit coal dust losses since 2005[33].

Studies were undertaken:

- To determine whether coal dust emissions could be substantially reduced by crushing coal to 3 inch pieces instead of 2 inch pieces, at the request of one of the mines. It was found that there was a notable reduction in coal dust emissions, about 30%, from the use of 3 inch coal[34].
- At the suggestion of National Coal Transportation Association (NCTA) members, BNSF carried out several analyses to determine whether brake shoe dust was present in the ballast in significant quantities. These tests showed that the contamination in the ballast was attributable to coal dust and not brake shoe dust[35].
- Tests were carried out to determine the relative amount of coal lost through bottom dump cars. It was concluded that on average, about 12 pounds per 100 miles per car per trip was lost through the bottom of the car. BNSF and UPRR both took action by repairing their steel bottom dump rail cars to ensure adherence to maintenance standards for bottom dump cars and to minimize any losses of coal through the bottom of cars.
- Further analysis measured the difference in the elevation of the coal in the car before and after the train moves a certain distance and determined that somewhere between 250 and 750 pounds per car are lost in transit[36].

The analyses on which these estimates are based made it clear that substantial volumes of coal are blown out of coal cars in transit and that the volume of coal emitted from the top of coal cars substantially exceeds the amount of coal escaping from the bottom of the cars[37].

BNSF and its consultants carried out numerous laboratory and field tests on the effectiveness of various surfactants in reducing coal dust emissions. BNSF found that the use of surfactants, particularly with properly groomed coal cars, can substantially eliminate coal dust emissions[38].

SWA also determined that the mine load-out operator plays an important part in the proper grooming of a loaded coal car, even when a modified [compliant] loading chute is used. SWA found that operator training and experience have a significant impact on the quality of the load

33 BNSF Opening Statement FD35557, p.6
34 VS William Vanhook, BNSF Opening Statement, FD35305 p. 9
35 VS William Vanhook, BNSF Opening Statement, FD35305 p. 10
36 VS William Vanhook, BNSF Opening Statement, FD35305 p. 11
37 VS William Vanhook, BNSF Opening Statement, FD35305 p. 12
38 BNSF Opening Statement, FD35305, p.15

profile grooming. Therefore, [SWA] also spent a large amount of time in the last few years on behalf of BNSF working directly with Powder River Basin mines to help them implement appropriate procedures in the loading process for the most effective use of the modified loading equipment[39].

Introduction of a loading performance standard

BNSF first established its coal dust emissions standard as an operating rule under the Joint Line Agreement and communicated the new rule to UPRR on November 7, 2008. BNSF subsequently published its coal dust emissions standards in BNSF's Rules Publication 6041-B on April 30, 2009 and expanded the rule to cover BNSF's Black Hills Subdivision on May 27, 2009. The coal dust emissions standards in BNSF's Rules Publication had an effective date of November 1, 2009[40].

BNSF elected to adopt a performance-based standard because it believed that that approach would give shippers the leeway to determine on an individual basis the method of complying with the standard that best suits each shipper's. The performance based approach not only allowed shippers to choose how they would comply with the emissions standards, but it was thought it would also encourage market-based innovations in coal dust emission control techniques that will result over time in reduced costs and improved methods of dust suppression[41].

Unreasonableness of the performance standard

In October 2009, the Arkansis Electric Cooperative Corporation petitioned the STB for a declaratory order that the performance standard is unreasonable and that the standard be unenforceable. The premise of the petition being that:

> *The tariff would unilaterally impose on Powder River Basin coal shippers using the Joint Line an obligation to ensure that the emission of coal dust from the cars does not exceed an arbitrary level established in the tariff. Effective November 1, 2009 if a shipper fails to meet BNSF's coal dust emission standard, BNSF threatens to refuse to allow trains handling the shipper's cars to operate of these lines or otherwise penalize the shippers*[42]*.*

The STB endorsed the principle that BNSF has the right to address the problem of coal dust losses from trains in transit by adopting reasonable coal loading rules that require shippers to take measure when loading trains to ensure their coal remains in the loaded cars during transit. However, it concluded that the challenged tariff in this case created too much uncertainty to be deemed a reasonable practice. In particular, the challenged tariff did not explain what consequences coal shippers would face if they were found to have tendered loaded coal cars to the railroad that subsequently released coal dust during transport. Nor did it acknowledge any

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39 VS E.Daniel Carre and Mark Murphy, BNSF Opening Statement, FD35557 p.5
40 BNSF Opening Statement, FD35305, p.15
41 BNSF Opening Statement, FD35305, p.23
42 Arkansis Electric Cooperative Corporation (2009) Petition for a Declaratory Order FD35305, p.1

steps that, if taken by a shipper before coal cars are tendered to the railroad, would guarantee that the shipper would be deemed in compliance with the tariff[43].

The STB recommended the implementation of a 'cost effective safe harbor to provide shippers with a method of compliance that does not depend on the monitoring system'[44].

Conduct of the Super Trial

In 2010, BNSF undertook a large scale test of topper agents – the Super Trial. The testing protocol was thoroughly vetted with participating shippers and the data collected was shared with the participants in several open meetings. The topper agents testing in the Super Trial were shown to reduce coal dust losses by 73 to 93 percent. Three of the topper agents reduced coal dust losses by at least 85% and those three toppers were approved for use in BNSF's safe harbor. Subsequent tests showed that two additional topper agents could reduce coal dust losses by at least 85% and those toppers have also been added to the safe harbor list of approved toppers[45].

BNSF also found that load profile grooming has only a modest impact on coal dust losses in transit. Therefore, in addition to the grooming of loaded coal, the safe harbor provisions require that coal shipper apply an approved topper chemical to the loaded coal[46].

The Super Trial and follow up tests also looked at the effectiveness of two alternate in-transit coal dust suppression methods, the use of body treatments and compaction. Several shippers have their mine agents apply a body treatment chemical to all of the shipper's coal before it is loaded into rail cars. The purpose of the body treatment is to reduce coal dust in the handling of coal when the coal arrives at the plant, particularly in the unloading of coal. There was no statistically significant reduction in coal dust losses in transit where the coal had been treated with the tested treatment chemicals as compared to the untreated coal[47].

Several Super Trial participants also wanted BNSF to assist in testing the effectiveness of compaction technology, where coal that has been loaded in a rail car is compacted into a smaller denser volume using a combination of vibrating plates and a profiling pillow. The results of the tests demonstrated that compaction was not effective in reducing in-transit coal dust losses. Compacted cars actually had more in-transit coal dust losses compared to uncompacted costs. The problem appeared to be that the compaction process itself created substantial additional amounts of coal dust by crushing coal lumps, concentrating much of the dust at the top of the loaded car, which was therefore susceptible to the wind[35].

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43 Surface Transportation Board (2011) Decision on FD 35305, March, p.14
44 BNSF Opening Statement, FD3557, p.2
45 BNSF Opening Statement, FD3557, p.18
46 BNSF Opening Statement, FD3557, p.15
47 VS William Vanhook, FD35557, pp. 14-15

Introduction of safe harbour provisions

On July 14, 2011, BNSF issued a revision to its tariff which made several changes to the requirements regarding the control of coal dust emissions from trains loaded at mines in the Powder River Basin. First, BNSF changed the measurement standard to a requirement that shippers "take measures to load coal in such a way that any loss in transit of coal dust from the shipper's loaded coal cars will be reduced by at least 85 percent as compared to loss in transit of coal dust from coal cars where no remedial measures have been taken. Second, BNSF added a "safe harbor" provision under which shippers would be in compliance with the tariff regardless of actual coal dust release. To come within the safe harbor, shippers must apply one of BNSF's five approved suppression methods, consisting of application of certain topper agents to their cars after loading them pursuant to the tariff's profiling requirement. Alternatively, shippers may submit a different suppression method for approval by BNSF for inclusion in the safe harbor. The request must include evidence showing that the alternative method reduces coal dust emissions by at least 85%[48].

On November 22, 2011, the STB issued a decision that denied requests to reopen the first Coal Dust proceeding and order mediation, but instituted this proceeding to allow parties to address issues related to the reasonableness of the safe harbor provision[36].

In arguing against the reasonableness of the tariff the shipper parties argued that topper agents are not effective in suppressing coal dust emissions from open-top railcars. Coal Shippers argued that topper agents are intended for use on stationary coal piles, and their performance on moving railcars has not been verified. In addition shipper parties argue that the safe harbor is not cost effective. AECC and Coal Shippers argued that the 85% standard on which the safe harbor is based is excessive because other measures, primarily profiling combined with use of three-inch coal and maintenance, can achieve significant reductions for a much lower cost than the safe harbor[49].

On December 17, 2013, after considering evidence and arguments by coal producers and electric utilities, the STB found that coal shippers had not shown that the safe harbor was unreasonable, and was persuaded that the tariff was not unreasonable (except for the liability provision)[50].

One of Coal Shippers' major concerns appears to be the way in which BNSF will enforce the revised tariff. Given that full compliance with the tariff has not yet begun, the STB has noted that shippers will have 60 days to bring complaints to the Board before BNSF takes enforcement action and it would be prudent to assess how the enforcement works in practice before making a decision on it[51].

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48 Surface Transportation Board (2013) Decision – FD3557, December, p. 3.
49 Surface Transportation Board (2013) Decision – FD3557, December, p. 17.
50 Surface Transportation Board (2013) Decision – FD3557, December, p. 21
51 Surface Transportation Board (2013) Decision – FD3557, December, p. 17.

Appendix B

In July 2007, in response to community concerns regarding increased coal dust in populated areas, the Department of Environment and Resource Management now the Department of Environment and Heritage Protection issued QR with an Environmental Evaluation Notice under section 323 of the *Environmental Protection Act* 1994. The Notice required the identification of potential sources of coal dust emissions from trains in CQCN, the quantification of the potential risk and the factors and circumstances that contribute to dust emissions, identification of the locations where proximity of communities to rail lines may give rise to a higher risk, and identification of ways to reduce that risk taking into consideration the practicability, effectiveness and cost[52].

In recognition of the projected volume increases and the associated community and economic consequences of coal loss, QR Network established the Coal Loss Management Project[53]. The project was tasked with working with QR Network's supply chain partners to quantify the impacts of coal loss and investigate any remediation activities that may be required to address the Notice terms of reference. Importantly it was recognised that a co-ordinated effort was required to reduce the impact of environmental, social, and commercial consequences associated with coal loss.

The Coal Loss Management Project became the seminal study on coal loss in Australia. In 2010, the New South Wales Office of Environment and Heritage commenced an environmental review to benchmark the performance of the New South Wales coal mining industry against international best practice measures to prevent and/or minimise particle emissions from all activities associated with coal mining. This review was in response to growing community concern regarding both the health and amenity impacts associated with particle emissions from coal mining in the Greater Metropolitan Region of New South Wales. In relation to rail transportation, the Environmental Evaluation undertaken by Connell Hatch in 2008 for the CQCN was identified as the source for leading best practice measures to control emissions of particulate matter from rail corridors[54].

[52] Connell Hatch, Final Report Environmental Evaluation of Fugitive Coal Dust Emissions from Coal Trains Goonyella, Blackwater and Moura Coal Rail Systems, Queensland Rail Limited, 31 March 2008, p.7.
[53] QR Network, Project Update Number 1, Coal Loss Management Project, October 2007, p.1
[54] Katestone Environmental Pty Ltd, NSW Coal Mining Benchmarking Study: International Best Practice Measures to Prevent and/or Minimise Emissions of Particulate Matter from Coal Mining Prepared for Office of Environment and Heritage KE1006953, June 2011, p.193

Coal Loss Management Project

Environmental Evaluation

The final report was completed in March 2008. It found that "coal dust [loss][55] can be emitted from the following sources in the coal rail system:

- Coal surface of loaded wagons
- coal leakage from doors of loaded wagons
- wind erosion of spilled coal in corridor
- residual coal in unloaded wagons and leakage of residual coal from doors
- parasitic load on sills, shear plates and bogies of wagons."[56]

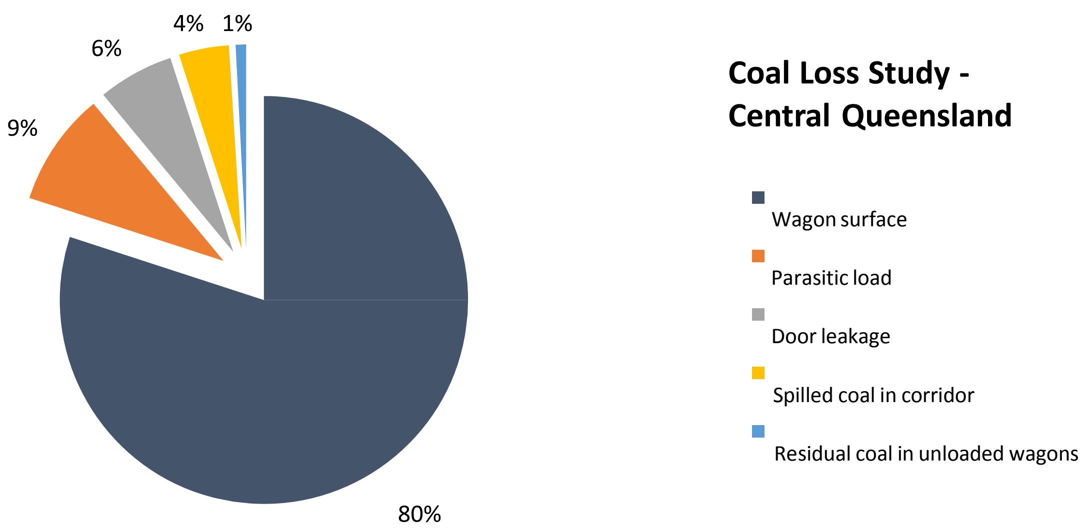

Figure 16. Coal loss study

In completing the Report, the authors, Connell Hatch, reviewed literature available at the time, conducted testing, and collated and analysed available data. Based on the research, the relative proportions of coal spillage within the coal transport network were identified. Notably, 80% of the coal loss was shown to have come from the surface of coal in the wagons.

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55 It should be noted that whilst the Environmental Evaluation Report refers to the relative proportion of coal dust, because of the methodology used coal dust is synonymous with coal loss. For example, page 30 of the Environmental Evaluation Report explains that the coal dust estimate for wind erosion of spilled coal in the corridor is based on assuming that deposited material is eventually emitted as dust.

56 Connell Hatch, Final Report Environmental Evaluation of Fugitive Coal Dust Emissions from Coal Trains Goonyella, Blackwater and Moura Coal Rail Systems, Queensland Rail Limited, 31 March 2008, p.1.

Whilst a range of measures were recognised as potentially reducing the rate of emission of coal, the most practical and cost-effective identified were:

- Coal surface veneering using chemical dust suppressants at the mine
- improved coal loading techniques at the mine to reduce parasitic load on horizontal wagon surfaces and reduce over-filling and hence spillage during transport
- load profiling to create a consistent surface of coal in each wagon. To be implemented at the mine, and
- improved unloading techniques to minimise coal ploughing and parasitic load on wagons[57]

Transitional Environmental Program

The Department of Environment and Heritage protection accepted the Report and in June 2008 issued QR Network with a notice to draft a Transitional Environmental Program. As part of the Transitional Environmental Program, QR Network and its supply chain partners were required to develop a Coal Dust Management Plan, which included the recommendations of the Environmental Evaluation Report. In addition, the Transitional Environmental Program included the requirement for:

- Further studies regarding coal leakage from Kwik-Drop doors and the effectiveness of veneering;
- development of a system of managing and responding to future complaints about dust; and
- Implementation of a dust monitoring program that aligns sources of peak dust events with coal trains and load characteristics, tests for slippage failures, and the effectiveness of veneering.

The Coal Dust Management Plan published in 2010, included summaries of studies and activities undertaken and fulfilled the requirements of the initial Transitional Environmental Program.

Coal Dust Management Plan

In February 2010, QR Network published the Coal Dust Management Plan and was prepared by QR Network on behalf of QR Limited and the Central Queensland coal supply chain. The Coal Dust Management Plan outlined a range of activities available to address coal dust and provided “a high level plan for the Central Queensland coal supply chain participants to manage coal dust from trains transporting coal”[58].

The Coal Dust Management Plan acknowledged the accountability of each sector within the coal supply chain for certain coal dust mitigation activities. It provided indicative timeframes for implementation of those mitigation activities in existing and new operations and included the

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[57] Connell Hatch, Final Report Environmental Evaluation of Fugitive Coal Dust Emissions from Coal Trains Goonyella, Blackwater and Moura Coal Rail Systems, Queensland Rail Limited, 31 March 2008, p.3.

[58] QR Network, Coal Dust Management Plan, 22nd February 2010, p.2

short, medium and long-term activities for the mitigation of coal dust from trains in transit in the CQCN.

Whilst the Coal Dust Management Plan included a commitment from each sector to implement within three years the key recommendations from the Environmental Evaluation Report, it was acknowledged that a number of factors would contribute to the implementation of dust mitigation strategies such as:

- the prevailing business conditions
- effectiveness of the particular mitigation approaches
- timeframes required to implement mitigation strategies
- overall strategy undertaken given the specific characteristics underlying the contribution to dust
- consideration of the impact on other coal supply chain participants[59]

The Coal Dust Management Plan also included a summary of additional research and development undertaken since the 2008 Environmental Evaluation.

- Laboratory testing was undertaken on an additional ten coal types using the veneering products identified in the Environmental Evaluation. It was concluded that coal wagons should be loaded with coal moisture content at or near the relevant Dust Extinction Moisture level (DEM) to achieve the most satisfactory and cost effective surface veneer performance[60].
- Field trials were conducted to investigate the potential impact of slip failures in the loaded coal. These field trials confirmed the application of surface veneer to coal surfaces to reduce dust emission. In addition, and contrary to practice that existed at the time, the recommended profile of the coal load included as much flat surface as possible and that the slope of the coal loads should be reduced below the angle of repose, which is below the natural settling angle[61].
- Aurecon Hatch was engaged to investigate coal leakage from Kwik-Drop Doors. The Report was finalised in July 2009. The study determined that coal loss from Kwik Drop doors is estimated to be 1,900t and 1,750t per annum for the Goonyella and Blackwater systems.

The Coal Dust Management Plan is widely supported by the coal industry, and is recognised as best practice. For example, in 2013, the Queensland Resources Council gave evidence to a Senate Standing Committee which identified the Coal Dust Management Plan as the voluntary

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[59] QR Network, Coal Dust Management Plan, 22nd February 2010, p.6
[60] QR Network, Coal Dust Management Plan, 22nd February 2010, p.21
[61] QR Network, Coal Dust Management Plan, 22nd February 2010, p.22

industry-driven, leading practice[62] to ensure that coal dust emissions from coal trains are adequately managed.

Transitional Environment Program 2

Subsequent to the publication of the Coal Dust Management Plan, the Department of Environment Resource Management issued a second Transitional Environmental Program notice in April 2010 to regulate certain activities. In keeping with the Coal Dust Management Plan, the second Transitional Environmental Program notice required:

- installation of veneering stations to all Central Queensland mines by December 2013;
- negotiation or update of all Transfer Facility Licences to include coal dust mitigation and profiling measures
- to plan and work with mines to implement loading practices to mitigate slippage
- develop and trial a wagon cleaning system reporting to Department of Environment and Heritage Protection on results
- collect, monitor and report the level of dust produced by coal trains and
- monitor, review and maintain the complaints system.

In December 2013, Aurizon Network provided an update to Department of Environment Heritage Protection advising the substantial completion of the tasks listed in the Transitional Environmental Program 2. In particular, the probable execution of all Transfer Facility's Licences by the end of January 2014 which in turn requires the installation of veneering stations within certain timeframes. As at the end of December 2013, 32 out of 36 veneering stations were installed with a planned installation of the remainder by mid-2014.

[62] Queensland Resources Council, Submission to the Senate Standing Committee on Community Affairs Inquiry: "The impacts on health of air quality in Australia", 8 March 2013, p.4

Appendix C

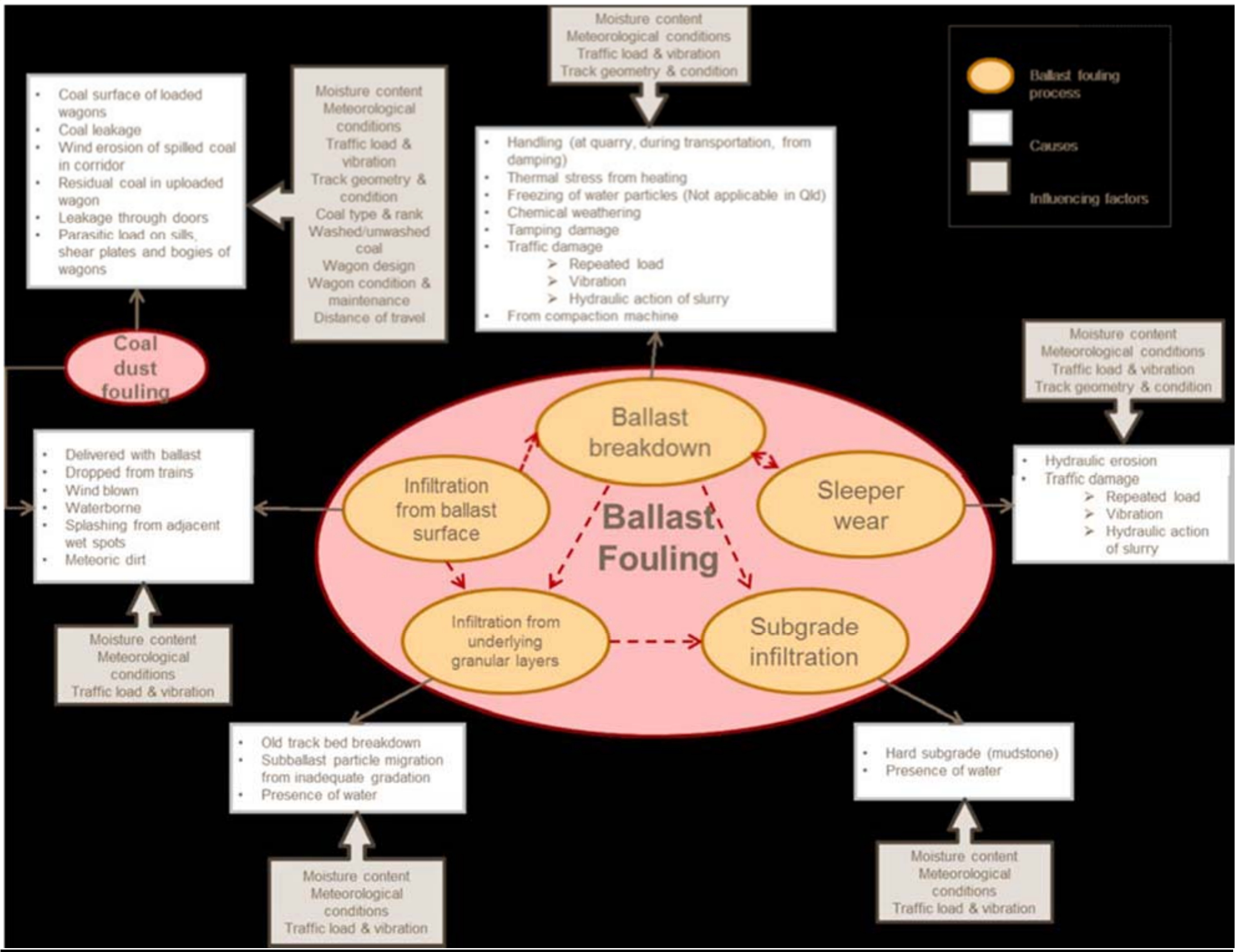

Figure 17. Ballast fouling inter-relationships

Appendix D

a) Coal Producer sector Coal Dust Mitigation Activities:

- Veneer spray stations
- Wagon loading practices and profiling
- Coal type testing for dustiness
- Load-out facility infrastructure
- Coal moisture regulating system
- Sill brushes
- Internal communications
- Batch weighing load out systems

b) Coal train operators sector – Coal Dust Mitigation Activities

- Train Speed Indicator (QR National Coal only)
- Overloaded Wagon Charge (QR National Coal and Pacific National)
- Wagon design (QR National Coal and Pacific National)
- Modified Kwik-Drop-Doors (QR National Coal only)
- ECP Brakes (QR National Coal and Pacific National)
- Railway Disaster Plan and Environmental Management (QR National Coal and Pacific National)
- Internal Communications (QR National Coal and Pacific National)
- External Communication (QR National Coal and Pacific National)

c) Network Manager sector – Coal Dust Mitigation Activities

- Coal Dust Removal from track (Ballast Cleaning)
- Complaints Management
- Community Liaison
- Infrastructure Liaison
- Internal/External Education and Awareness
- Weighbridge (Overload detectors)
- Monitoring Systems
- Corridor Barriers & Vegetation
- Commercial Agreements
- Corridor Coal and Spoil Removal
- Ballast Spoil Management
- Liaison with Local Government

d) Capricorn Domestic Terminal sector Coal Dust Mitigation Activities

1. Existing Capricorn Domestic Coal Terminal Unloading Facilities

   The majority of the domestic coal unloading facilities consist of aging infrastructure making modifications costly and technically difficult. Outlined below are some of the opportunities the domestic facilities may be able to pursue in reducing dust generation. New unloading facilities should be aiming to include current best practice in dust minimisation.

2. Short-term activities
   - Modify existing unloading procedures
   - Operator Procedural Training
   - Monitor Empty Wagons
   - Community liaison and communication
   - Increase Environmental Awareness Internally

3. Medium-term activities
   - Washing of train wheels after unloading
   - Wagon vibrators
   - Moisture levels in transit
   - Wagon Sill Brushes

4. Long-term activities
   - Install a Wagon cleaning station
   - Improved unloading pit design

e) Goonyella Export Terminal sector Coal Dust Mitigation Opportunities

- Wagon unloading practices
- Operator Procedural Training
- Hopper level/Train speed indicators
- Wagon cleaning facility
- Washing of train wheels after unloading (DBCT only)
- Wagon vibrators
- Unloading facility infrastructure
- Increase Environmental Awareness Internally
- Residual Coal Monitoring

f) Capricorn Export Terminal sector Coal Dust Mitigation Activities

- Training / Communication – Internal Training / Environmental Awareness
- Training / Communication – Community liaison and External communication
- Procedural / Infrastructure – Wagon unloading practices
- Procedural / Infrastructure – Hopper level/Train speed indicators
- Procedural / Infrastructure – Remnant Coal Monitoring
- Procedural / Infrastructure – Remnant Coal Elimination / Removal (Wagon Interior)
- Procedural / Infrastructure – Remnant Coal Elimination / Removal (Wagon Exterior)
- Procedural / Infrastructure – New Unloading facility infrastructure

Appendix E

Many of the technical aspects presented in this paper have been sourced from a paper written by Mr Simon Shelley, Technical Director Asset Strategy at Aurizon Network. A copy of his paper is available on request.

South Africa

The most relevant comparison in relation to the critical fouling point can be made with the coal lines of the South African Railways (Transnet). The track gauge, axle load, operating parameters and product are most similar to the CQCN. The Mpumalanga coal producing area (Mpumalanga-Richards Bay Coal line) averages around 1,000 mm rainfall a year which although not as intense as many areas of the CQCN (McKay 1600mm) is a much closer comparison than the Power River Basin in the USA, a semi-arid environment with annual rainfall of the order of 250-350mm.

Transnet [2] set the critical fouling point for intervention on their coal line in accordance with the depth of the competent ballast below the sleeper. At a depth of clean ballast of 70 mm below sleeper the ballast is deemed “fully fouled” (100% fouled) and no longer performing competently in support of the track. The critical fouling point is set to different levels for different Transnet line operations. The intervention limit for the heavy haul coal lines is set at 75% which equates to approximately 120-130 mm of competent ballast below the sleeper. This is very similar to the Central Queensland Coal Network intervention mentioned above based on 30% PVC or approximately 100mm of competent well drained ballast below the base of the sleeper. Aurizon Network is if anything less conservative, however, this is potentially reflective of other local conditions within each railway, for example the design ballasts depth.

Transnet have found the measure of competent ballast depth below the sleeper to be practical with respect to application. Ref [2] states that although “the ballast grading envelope is a more scientific measurement of ballast fouling………this grading envelope in practice is, however, very difficult due to irregular results that will be obtained in trying to take a representative sample.” This approach is also very expensive. If the most effective use of ballast undercutting and renewal activities is to be achieved it is important to understand the network wide ballast condition and fouling rates. Sampling ballast grading does not provide this requirement. This requirement is being met by Aurizon Network by pursuing and implementing the use of world leading Ground Penetrating Radar technology to understand the overall Network condition.

Aurizon Network’s critical fouling point is consistent with South African practice

Further, the article, *Ballast Cleaning*, *Railways Africa* [2], (17 September 2012), states:

- 120% fouling that exceeds their definition of fully fouled (i.e. 100% fouled equivalent to 70mm of competent ballast below sleeper) "…. will clearly have no resilience and no drainage ability".
- "Very often, fouled ballast goes hand-in-hand with other deviations from the required design criteria of ballast, such as too little ballast depth, rounded and smooth stones etc. The result is that damage will be caused and geometry retention lost long before the ballast has reached 100% fouling" (i.e. 70mm competent ballast below sleeper).
- It is recommended "when ballast fouling has reached these measures…ballast screening must be a high priority to guarantee the integrity of the ballast bed and the whole track structure."

Europe

The European intervention limit is applicable in a particular context which is where the fouling material is of similar specific gravity to the source ballast. It is set at the limit at which surface water is prevented from draining away and corresponds to a critical rainfall rate of 1mm / hr.

Lichtberger indicates "Dirty ballast results in reduced carrying capacity so that the ballast is unable to fulfill its function. The fouling impedes the drainage of surface water, also a cause of reduced carrying capacity. Where there are timber sleepers, the presence of dampness reduces their service life."

Further "An indicator of fouled ballast is rapid loss of track geometrical quality after maintenance work, as the ballast bed is overloaded. As shown in Fig. 1, the critical level of fouling is reached when 30 % of the total consists of fine material – at this level surface water is prevented from draining away properly."

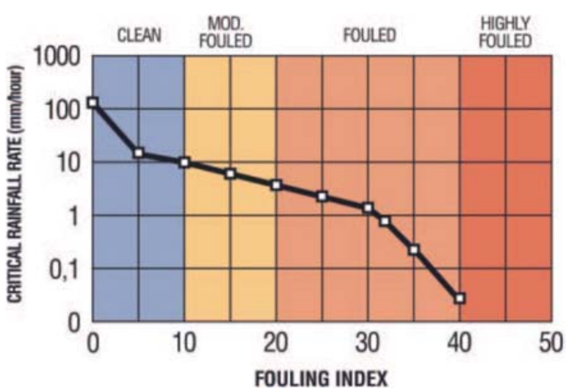

Figure 18. Fouling Index

Large-scale tri-axial tests [4] were carried out at the Institute for Geotechnology in Zurich, Switzerland, on behalf of European Rail Research Institute (ERRI), in order to explain how the ballast ageing process affects the most important mechanical properties of ballast. These studies confirmed earlier published work that the criterion for track bed fouling of 30% passing through a 22.4 mm sieve was a valid measure of when ballast performance breaks down.

The European fouling index of 30% shows significant reduction in drainage capability. In practice this means the ballast/formation structure remains wet, encourages high moisture content, reduces the strength of the ballast/formation, encourages development of ballast pockets and accelerates formation failures.

As mentioned above when the fouling material is of a similar Specific Gravity to the ballast material, The Aurizon Network PVC index of 30% is similar to a fouling index of 30% by weight using the ERRI Criteria, in that the height of competent free draining material below the sleeper is of a similar size using both measures. This is equivalent to a height of approximately 75-100mm of competent ballast below the sleeper. This indicates that Aurizon Network practice is consistent with European practice, albeit the need to take account of the Specific Gravity of coal versus the most common fouling materials on which the European experience is based.

Aurizon Network's critical fouling point is consistent with European practice

North America

The North American experiences draws on the European experience with some additional key findings relating to the specific case of coal fouling.

With respect to the required trigger for ballast cleaning for similar heavy haul operations to Aurizon Network, the North American experience [6] is similar to the ERRI Criteria described above in Section 4.2. In "Guidelines to the Best Practice for Heavy Haul Railway Operations" published by the International Heavy Haul Association [6] it is stated that "If the ballast contains more than 30% of fines sized less than 22mm sieve then ballast cleaning becomes appropriate, if there is more than 40 percent, then ballast cleaning is inevitable." This is again a by weight measure of fouling.

The North American learning's with respect to the applying these weight based fouling indices to a coal fouled track were improved through unfortunate operational experiences in the Powder River Basin and follow up research by the University of Illinois and BNSF.

Coal fouling levels of up to 25% by weight (note: less than ERRI Criteria of 30%) were tested and found to contribute to two BSNF derailments which threatened coal supply to power stations. 25% coal dust fouling by weight completely filled the voids in the clean ballast structure and represented an intolerable "fully fouled" stage which impacted the track structural integrity.

Following the identification of coal fouled ballast as a contributor to the 2 derailments [7, 8], direct shear tests were conducted at the University of Illinois for BNSF on both clean and coal dust fouled ballast samples of granite aggregate.

Mechanical properties of representative coal dust samples obtained from the Powder River Basin joint line in Wyoming were determined for the first time through laboratory testing. Key findings were:

- Coal dust can absorb and hold a lot of water when compared to clays and silts
- Tri-axial Shear Strength of coal dust at Optimum Moisture Content (OMC) = 3 psi – which is <u>very low</u>
- Coal dust friction angle at Optimum Moisture Content (OMC) indicated a <u>large reduction</u> with increasing moisture content

Large-sized direct shear (shear box) laboratory tests were also conducted on granite ballast samples obtained from the Powder River Basin joint line in Wyoming to investigate the strength and deformation characteristics of both clean (new) and coal fouled ballast at various stages. Key findings were:

- The highest shear strength values were obtained from the clean ballast at all applied normal stress levels
- When ballast samples were fouled, the shear strength always decreased.
- Wet coal dust fouling (at 35% optimum moisture content) always resulted in lower ballast shear strengths than dry coal dust fouling.
- For the fully fouled case with 25% wet coal dust by weight of ballast, the internal friction angle and cohesion obtained were equivalent to those properties of the wet coal dust itself and were approximately 50% of the clean ballast strength.
- Even more drastic strength reductions can occur when dry coal dust is subjected to inundation and 100% saturation.
- When dry coal dust is wetted, this results in a drastic loss of strength.

For the case of 25% wet coal dust fouling (by weight) of ballast these results indicate the shearing action in the direct shear apparatus was mainly resisted by the wet coal dust itself and this governed the behavior. It should be noted that 35% OMC condition does not represent fully saturated coal dust state. After soaking or highly saturated conditions, soil suction would break down thus resulting in significantly lower strengths and unstable ballast conditions.

The learning here are therefore that, poor drainage is a characteristic of wet coal fouled ballast which must be managed. The BNSF experience clearly demonstrates the undesired outcome should coal fouling not be managed to the critical fouling point and the ballast function breaks down.

It should be also borne in mind that the Powder River Basin experience relates to a semi-arid environment and the need to manage fouling is therefore much more critical under Central Queensland environmental conditions. Annual rainfall in the Power River Basin, a semi-arid environment, is of the order of 250-350mm in comparison to the intense rainfalls that can be experienced in the CQCN (McKay 1600mm). Fouled track in the Queensland environment is therefore going to experience much higher levels of inundation, higher level of track moisture and be in this state for much longer periods.

Aurizon Network's critical fouling point is consistent with North American practice and learning's from the Powder River Basin with respect to coal dust fouling

Supporting Australian Research

To identify and understand the risk associated with fouling, it is important to understand the effects of the amount of fouling on drainage conditions. The University of Wollongong [1] carried out studies to critically assess different types of mass based fouling indices. They also proposed a new parameter, the Void Contaminant Index (VCI), which considers variations in the specific gravity of ballast and fouling materials. A series of large scale constant head hydraulic conductivity tests were conducted to establish the relationship between the extent of fouling and the associated hydraulic conductivity. Subsequently, a seepage analysis was carried out using finite element software to simulate a more realistic two-dimensional flow under actual track geometry to capture the drainage capacity of ballast. The drainage condition of the track was classified into different categories using the average rainfall in Australia.

The study investigated coal fouled ballast and the analysis showed that as long as there is at least a 100mm thickness of clean competent ballast below the sleeper at any time, the overall track will have sufficient drainage. Test results indicated:

- that even a small increase in the VCI leads to a significant decrease in the hydraulic conductivity of the fouled ballast

- Beyond a certain limit of VCI (50% for ballast fouled with coal) the hydraulic conductivity of fouled ballast converged to that of the fouling materials itself.

The University of Wollongong hydraulic conductivity tests on coal fouled ballast from Australian Railways indicated that the hydraulic conductivity of 0.5 mm/s of coal fouled ballast at around 30 % PVC is equivalent to a fouling index of 7% fouling by weight of coal.

Putting this into the European context the hydraulic conductivity of 0.5 mm/s is similar to ballast fouled with sand at the intervention level of 30% by weight of ballast.

Aurizon Network’s critical fouling point is consistent with these findings

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Appendix F

Refer Pages 172 to 175 from the UT3 Maintenance Cost Submission

Category	Role	No.
Management/ Administration	Overall Management and Administration of the Ballast Cleaning Organisation	6
Supervisors/ Team Leaders	Direct Supervision of the Ballast Cleaning, Resurfacing Team & Machine Maintenance Teams, production planning, inventory control, ballast testing.	13
Operator Maintainers	Ballast Cleaner & Resurfacing teams, Multi-skilled teams who also carryout minor routine maintenance.	42
Safety Staff	Carryout the protection arrangements for the maintenance and operating teams	2
Apprentices	Apprentice Electrician, Mechanical & Diesel Fitters.	7
Total		70

Figure 19. Table 6.7: Roles in the Ballast Cleaning Team

	50 MFS Option			
	2009/10	2010/11	2011/12	2012/13
Accommodation	$0.7	$0.7	$0.8	$0.8
Ballast	$6.2	$7.7	$9.3	$9.3
Fuel	$0.5	$0.7	$0.8	$0.9
Hire charges	$2.5	$2.7	$2.5	$2.6
On track vehicles	$1.3	$1.4	$1.4	$1.5
Op consumables	$2.3	$3.7	$4.0	$4.1
Plant Maintenance	$2.3	$3.7	$4.0	$4.1
TOTAL	$15.8	$20.6	$22.8	$23.3

Figure 20. Table 6.8 Estimated Consumable costs – UT3 Period ($M)

	Management	Operations	Total
Base labour	$0.6	$3.0	$3.6
Overtime	$0.1	$1.0	$1.1
Allowances	$0.0	$0.9	$0.9
Total (excl oncost)	$0.7	$4.9	$5.6

Figure 21. Table 6.43: Estimated Base Labour Costs 2009/10 ($M)

	2009/10	2010/11	2011/12	2012/13
44 MFS wagons				
Opening Asset value	6.9	56.5	84.7	78.4
Depreciation	0.9	4.2	6.3	6.3
MV lease charges	$0.3	$0.3	$0.3	$0.3
Total asset charges	1.8	9.9	14.8	14.2

Figure 22.Table 6.45: Estimated Machine Asset Charges – UT3 Period ($M)

	50 MFS Option			
	2009/10	2010/11	2011/12	2012/13
Direct wages etc	$5.6	$5.8	$6.0	$6.2
On-costs	$0.9	$0.9	$1.0	$1.0
IT, HR etc	$0.1	$0.1	$0.1	$0.1
Plant maintenance	$5.0	$6.8	$8.2	$8.2
Consumables	$13.5	$15.7	$17.6	$18.0
Asset charges	$1.8	$9.9	$14.8	$14.2
Margin	$4.0	$5.9	$7.1	$7.1
Total	$30.9	$45.1	$54.7	$54.7

Figure 23. Table 6.22: Estimated Ballast Cleaning Costs UT3 Period ($M)

=Year	2009/10	2010/11	2011/12	2012/13
Number of MFS Wagons available	6	30	50(+2)	50(+2)
Minimum kms Ballast cleaned (0% return)	70	80	90	90
Maximum kms ballast cleaned (70% return)	95	130	160	160
Ballast cleaning proposed (km)	83	105	125	125
Shoulder Replacement (km)	25	25	25	25
Stoneblowing (km)	55	55	55	55
Total KM Treated	158	180	205	205
Surplus (Deficit)	(30)	(8)	17	17

Figure 24. Table 6.41: Ballast Cleaning – Summary of Scope