AURIZON

NETWORK

Annex AC

[redacted] Aurizon Network – Ballast Fouling, 4 March 2013

Overview of the problem

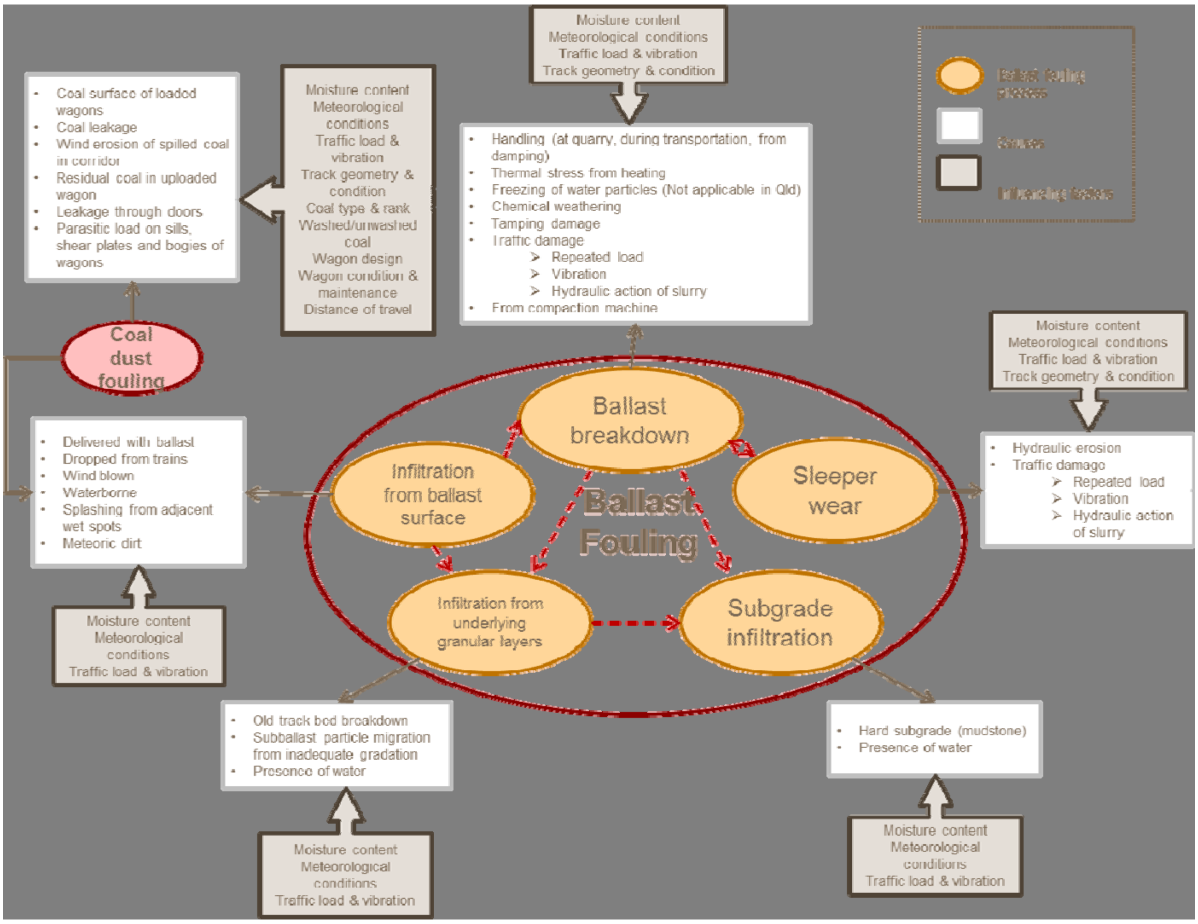
Ballast is the material that is laid on the rail bed under the sleepers, providing stability and drainage to the track structure. It is an essential structural component of the track as it transfers the loads of the train through the sub-ballast and formation. The interlocking properties of the shape of the ballast rock also provide track stability by reducing the lateral, horizontal and vertical movement of the rail track.

Ballast is graded stone material where the voids between stones also allow for the drainage of water from the track. It can deteriorate in a number of ways, including crushing by the loads borne by the track infrastructure.

One key source of deterioration is the fouling of the ballast. Fouling occurs from a number of sources including natural attrition of the ballast itself, external contaminants such as dust, sand and dirt either blown or falling into ballast, the infiltration of underlying layers into the ballast and through foreign contaminants such as coal. The retention of fine particles in the ballast can trap water and lubricate it, which can eventually compromise the track stability. This also reduces the service life of the ballast and increases the frequency of maintenance interventions.

Figure 1 shows a diagram of the interactions that cause ballast contamination and illustrates the dynamic and interrelated nature of the various elements.

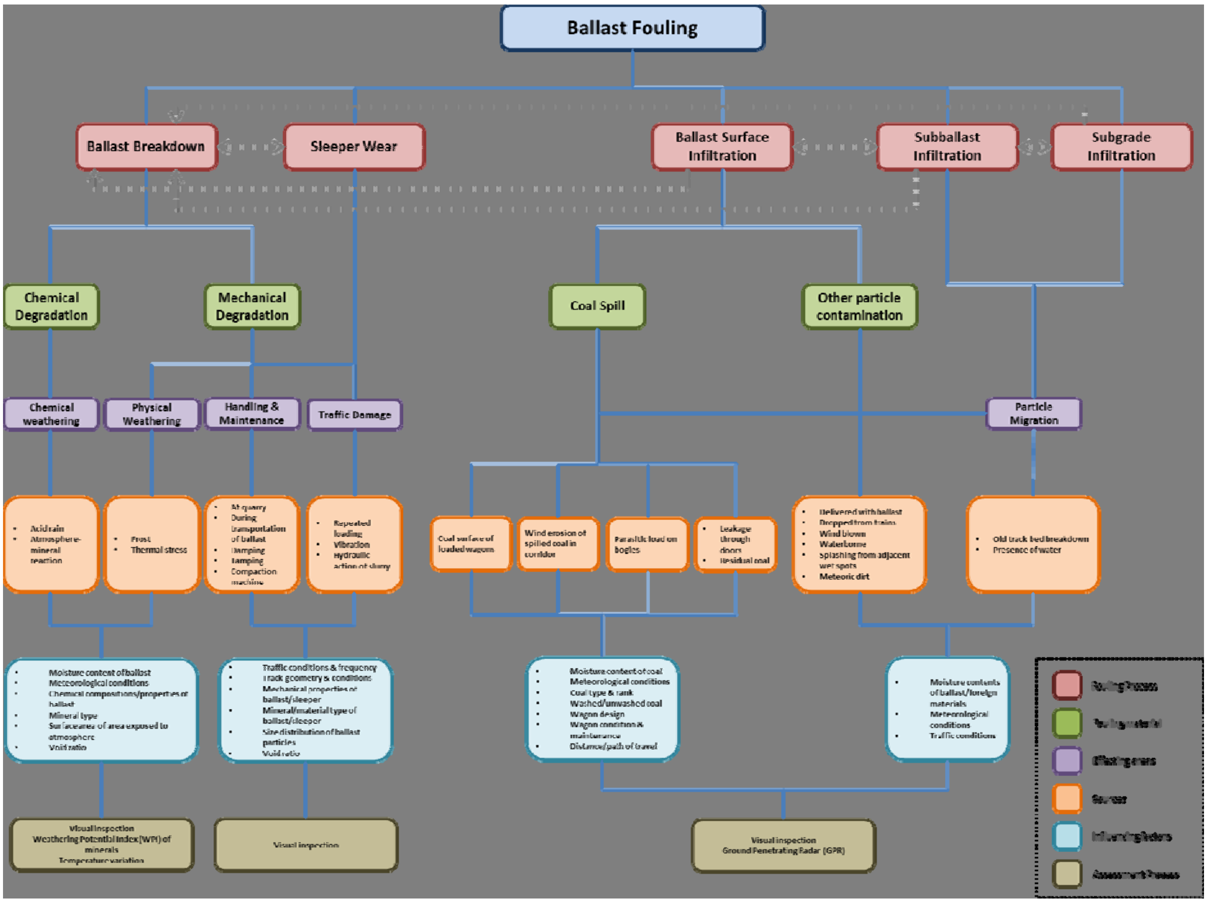
Figure 1: Ballast fouling interrelationships



The ballast therefore needs to be cleaned to remove these particles in order to restore the elasticity and draining properties of the ballast. Ballast cleaning machines remove the accumulated dirt, coal and broken ballast, before the rail bed is topped up with new ballast.

Figure 2 shows in an alternative cause and event layout the causes for Ballast contamination.

Figure 2: Ballast fouling interrelationships (Cause and Event layout)



While the causes of coal fouling are primarily driven by factors that are not within the direct control of the below rail network provider (i.e. through spillage from wagons), it bears most of the costs (i.e. as the entity required to maintain the ballast). The management of this externality is a feature of all coal networks around the world, including by the Class 1 railroads in the United States.

Aurizon Network has been working collaboratively with supply chain participants to invest in technologies and modify operating practices to substantially reduce coal spillage within the rail corridor under its Coal duct Management Plan.

In Australia (and in most other jurisdictions), coal is hauled in open top wagons. One of the key sources of coal loss is when coal falls out of the wagon. This could occur due to wind erosion or and/or load settling and displacement in transit.

Coal spillage from wagons can be from:

- Parasitic coal on external parts of the wagon due to poor loading practice
- Coal blown from the top of the wagon
- Coal falling through the doors
- Coal ploughed from loading or unloading facilities.

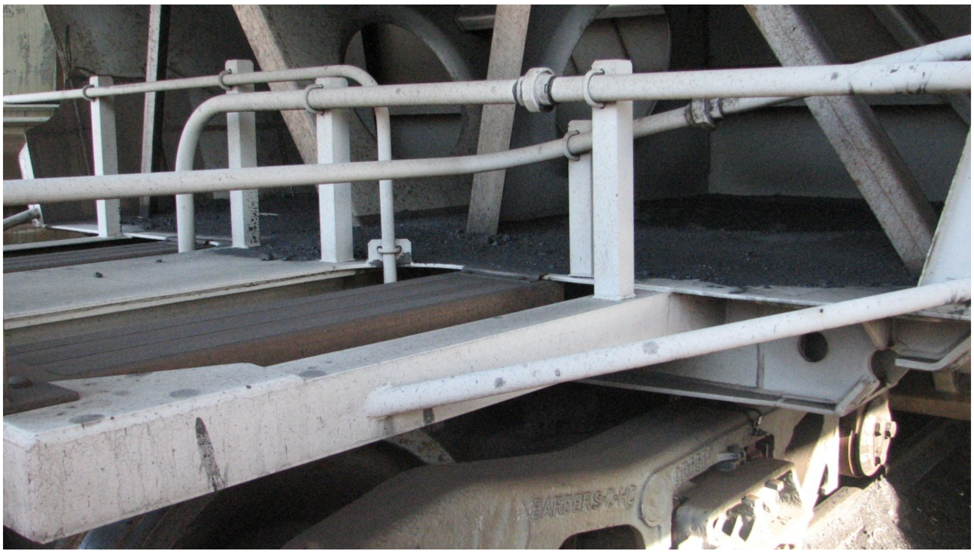
Figure 3 shows an example of the network where ballast has been contaminated with coal spillage.

Figures 4 and 5 shows evidence of the build up of parasitic coal on a wheel bogie and on a wagon.

Figure 3: Ballast contaminated with coal spillage

Figure 4: Example of parasitic coal on a wheel bogie

Figure 5: Example of parasitic coal on a wagon



To better manage this issue of ballast fouling, Aurizon Network have analysed 1170 km of Ground Penetrating Radar data on the Central Queensland Coal Network which represents the most highly trafficked tracks on the four systems including the North Coast Line, Central Line, Rocklands to Burngrove, Hay Point to Goonyella and the Oaky Creek Branch. This represents about 80% of the ballast cleaning requirements of the network.

The Science Behind Fouling Levels for Intervention

Aurizon Network intervention level for ballast cleaning is 30% PVC (Percentage Void Contamination). This has been derived empirically based on original research and with consideration of the limitations of other fouling measurements and intervention limits adopted by other railways. The 30% PVC represents that the voids (comprising [redacted] of the clean ballast profile) are 30 % filled with contaminant. Empirically this equates to 100mm depth of competent ballast below the sleeper.

Traditionally the fouling index has been based on the mass of fines in the ballast profile as a proportion of the total mass. Consequently it is sensitive to the specific gravity (s.g.) of the contaminants and this can vary wildly along a track length let alone between different railways with various operating parameters and product mix.

This is the main reason Aurizon Network has developed a fouling index based on PVC which is not reliant on the s.g. of the contaminant but is dependent on other physical properties of the contaminant such as hydraulic conductivity, moisture content and load bearing competence.

The closest comparisons on intervention limits can be made with the Coal Lines of the South African Railways (Transnet). The axle load, operating parameters and product is most similar to the Central Queensland Coal Network. Transnet intervention limit for their coal line is defined as the “Critical Fouling Point” and set in accordance with the depth of the competent ballast below the sleeper so that perfectly clean ballast corresponds to the full depth of clean ballast and is 0%. At depth of clean ballast of 70 mm below sleeper the ballast is deemed “fully fouled” at 100%. By fully fouled it is meant the ballast is no longer performing competently so that the intervention limit is set at 70 to 75%.

In the context of our Central Queensland Coal Network ballast depth of 300mm the “critical fouling point” would equate to 120 mm competent ballast below the sleeper. This is very similar to the empirically defined Central Queensland Coal Network intervention mentioned above and based on 30% PVC.

The University of Illinois has carried out strength tests of coal fouled ballast collected from the BNSF Powder River Basin lines. They report that the lowest shear strength of foul ballast occurs at fouling index of 25% by weight of ballast at 35% moisture content. This condition occurs when the ballast voids are completely full. That is to say the performance of the fouled ballast at this level is no better than wet coal dust at 35% moisture content. At moisture saturation the situation is worse. The coal lacks any strength by way of soil suction and has lower shear strength so that track is quite unstable.

In 2005 BNSF reported track instability due to ballast fouling as a cause of two derailments on Powder River Basin coal lines.

This fouling index for coal fines of 25% by weight should be compared with the European intervention limit of 30 % which if applied to a coal fouling situation would be totally intolerable due to the low specific gravity of coal.

The European intervention limit is applicable in a particular context which appears to be 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 1 mm per hour.

Given that the rainfall rates commonly experienced in the Central Queensland Coal Network are far in excess of 10mm/ hr this intervention limit would appear to have no relevance to the Central Queensland Coal Network circumstance.

The University of Wollongong have carried our hydraulic conductivity tests on coal fouled ballast from Australian Railways and shows 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 byweight 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.

Moisture in the track structure has a deleterious effect and shortens life of ballast and formation. Foul ballast retains moisture at high levels and impedes the flow of water away from the track and formation.

Formation repair is costly and typically exceeds $1,500,000 per kilometre compared with ballast cleaning costs. Formation repairs of one kilometre require suspension of traffic for up to five days which is not a sustainable approach without significant additional infrastructure.

Forecasts for a total of 2200 track km of the Network and have been computed by applying an average fouling rate [redacted] Mnt of coal carried on a further 1030 km medium to low trafficked lines based on forecast tonnages. There are a further [redacted] he Network that are single mine spurs and balloon loops carrying low tonnage which have little impact on the forecasts in the period to 2019. The exception is some of the older mine balloon loops that have been considered in the forecasts of undercutting other than by Ballast Undercutting Machine works.

The Maintenance Effort

Ballast Fouling rates have been determined in terms of % PVC per 100Mnt of coal carried. [redacted] if coal fouling was not an issue, that is the natural degradation of the aggregate.

The methodology for determining the long term forecast for Ballast Undercutting Machine work relies on ballast fouling rates for each km of the track and applying these to the forecast coal tonnages for Draft Access Undertaking. Beyond this period a 5% pa tonnage increase is applied. Where rates of fouling are not able to be determined because of insufficient historical information or other reason a default average of 5% PVC per 100 Mnt is applied.

Other Undercutting Works

The areas inaccessible to the Ballast Undercutting Machine will continue to be fouled and an accumulated deficit will mount unless a method of foul ballast removal can be deployed for turnouts and adjacent track at production levels that match available possession windows. Included in this work are mine balloon loops

Forecasts are that the equivalent of [redacted] per annum of this type of undercutting work will be required [redacted]. expected in some of the older balloon loops. The Network Maintenance Renewal Plan 2012/13 this year, to some extent, includes funding for these types of work along with some specific capital funding. This work will need to be combined with the ability to attend to approximately [redacted]

On the Blackwater System in particular, there is a high incident of isolated short lengths of undercutting that will require undercutting not suited to the Ballast Undercutting Machine works.

Some more detailed analysis of this is required to quantify but may be assumed that:-

- The Network has around [redacted] y fouled mainline turnouts requiring attention immediately.
- Half of these are on the heavily trafficked Goonyella System.
- The Ground Penetrating Radar record covers around [redacted]
- [redacted] p.a.
- If yard turnouts were to be considered then it is estimated around [redacted]