Civil Engineering Report

Percentage Void Contamination (PVC) Testing After Ballast Cleaning

Rev 3, 16 September 2021

Executive Summary

To assess annual ballast replacement requirements, the effectiveness of ballast cleaning by on-track screening is needed. In 2021, a project to estimate this was completed. It quantified actual ballast fouling levels after screening by the RM900 and RM902 ballast cleaning machines. Ballast fouling levels were measured with percentage void contamination (PVC) tests. These were performed in a laboratory on ballast samples obtained from track immediately after the final tamping that followed cleaning by screening.

PVC is a volume-based test which measures the extent of void fouling for the depth of a ballast profile. It takes into account the different densities of the contaminants and provides a quantitative measurement of ballast fouling. PVC is calculated by measuring the volume of contaminants (material passing a 9.5mm sieve) and dividing by the volume of voids within the ballast (material retained on a 9.5mm sieve).

Ballast samples for PVC testing are taken from between the rails and from the base of the sleeper to the top of the formation, nominally 300mm deep for CQCN main line track. However, PVC values are calculated from the top of the sleepers which are typically 230mm deep at the centre and ends. Therefore, for this sleeper type, the PVC values returned from the laboratory are factored by *ballast sample depth / (ballast sample depth + sleeper depth)*, as shown in Figure 1.

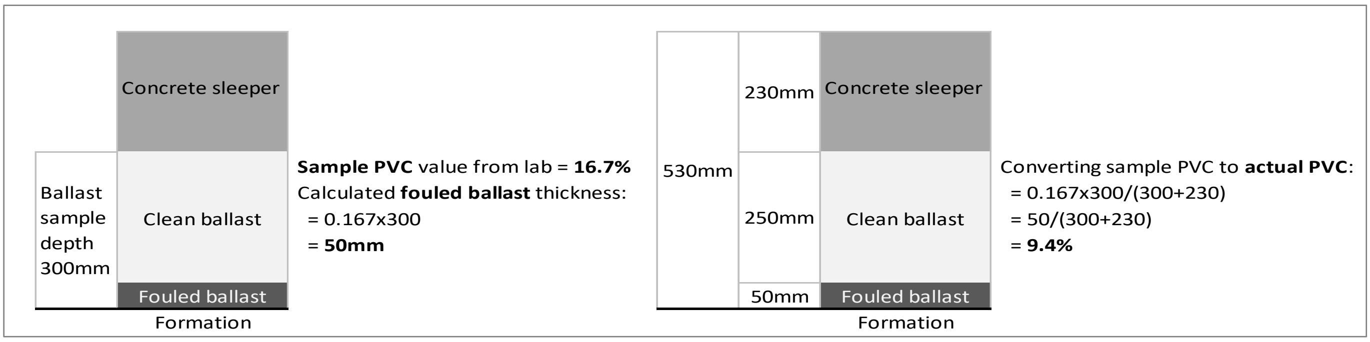

Figure 1 – Example of conversion from sample PVC value to actual PVC value

32 PVC samples were obtained from RM900 during September and October 2020 from the Goonyella and Blackwater Systems. 11 PVC samples were obtained from RM902 during July and August 2021 from the Goonyella System. The range and average of the converted PVC test results are included in Table 1.

Table 1 – Summary of PVC test results

Ballast cleaning method and comment	Number of samples	PVC Range (%)	PVC Average (%)	Sampled ballast type
Full ballast replacement	2	0.2 - 0.4	0.3	New ballast
Screened (classified as unscreenable)	3	10.4 - 11.8	11.1	Screened ballast
Screened as planned	**38**	**0.1 - 13.2**	**4.2**	**Screened ballast**

The average screened as planned ballast PVC test result of 4.2% (38 samples) is expected to be typical across the CQCN, although continued sampling would increase confidence in this and establish any differences between the systems. The range of PVC values is likely to be from factors such as moisture content rather than screening methodology.

The average PVC test result of 0.3% for ballast cleaned by full replacement with new ballast came from only two samples. While this is a small sample, it is expected to reflect the average across all quarries supplying ballast to the CQCN.

It is therefore recommended that the following average residual PVC values be used when estimating average ballast replacement cycles:

- 4.2% for ballast cleaned by screening.
- 0.3% for ballast cleaned by full replacement with new ballast.

Document Version Table

Version	Description of changes from previous version	Issue Date
Initial issue		19 November 2020
Revision 1	Amendment to title of Table 1, and other minor amendments	02 December 2020
Revision 2	• removal of references to ballast screenability return rate, • removal of references to use of GPR ballast screenability values to assess the screenability of ballast, • transfer of background information from the scope document in an appendix to the background section, then removal of this scope document, • inclusion of text of “unplanned circumstance” to Executive Summary, • inclusion of an example of a PVC test report in a new appendix, • other minor changes to align with the above changes for Revision 2, • other minor amendments.	17 December 2020
Revision 3	• Correction that PVC samples are taken from the base of sleeper to top of formation. • Correction that BCMs no longer leave bottom 50mm ballast layer uncleaned. • Removal of off-track ballast cleaning section. • Inclusion of RM902 sample results. • Minor amendments throughout.	16 September 2021

Approval of latest version

Function	Name / Position / Section	Signature	Date
Authors:	Damien Foun, Engineer Level 2 (Rev 3: Mark Boyce, Principal Engineer)		17/12/20
Checked:	Mark Boyce Principal Engineer	M. Boyce	16/09/2021
Approved:	Simon Larsen Engineering Leader Civil		20/09/21

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Percentage Void Contamination (PVC) Testing After Ballast Cleaning

1. Background

1.1 Ballast cleaning

Ballast cleaning by a ballast cleaning machine (BCM) is performed on approximately 140km of track throughout the CQCN each year. This cleaning was performed with a Plasser RM900 BCM until mid-2021, after which it was replaced by a higher production RM902. At the time of writing, RM900 may be recommissioned, so results from both machines are included.

Cleaning is required to remove ballast fouling which degrades performance of the ballast. Fouling is the accumulation of fine materials, such as coals fines and broken-down ballast, within the voids of the ballast structure.

Key aspects of ballast cleaning operations are:

- Fouled ballast is removed from under the track structure (rail and sleepers) for the full depth to the formation level. The ballast cleaning Superintendent advised that an earlier practice of leaving the bottom 50mm of fouled ballast to avoid formation damage is no longer followed.
- This fouled ballast is either:
    - passed over screens on the BCM to remove fouling material (if ballast is screenable), then deposited back onto the track structure. Screening of ballast by the BCM is referred to as “on-track” screening.
    - transferred to spoil wagons coupled to the BCM or placed next to the track for later disposal (if ballast is unscreenable). Removal of ballast from track that is classified as unscreenable is referred to as “total excavation”.
- New ballast is deposited onto the track structure if required to achieve standard ballast profile. Sources are:
    - spoil wagons coupled to the BCM, and
    - ballast trains.

Some of these operations are shown in Figure 2 and Figure 3.

Figure 2 – RM900 cutter bar area

Figure 3 – RM900 discharging material (unscreenable ballast and/or screened fouling material)

Ballast types in track after ballast cleaning operations with the BCM are:

- Ballast that has been screened by the BCM, with addition of a small quantity of new “top-up” ballast to reinstate the ballast profile, if required.
- Ballast that has been screened by off-track screening plant, then placed in track:
  - by the BCM.
  - behind the BCM, after being dropped from a ballast train.
- New ballast dropped from a ballast train.
- Mixture of above three ballast types.

1.2 Assessment of ballast screenability

The extent of ballast to be screened within planned ballast cleaning works is currently determined from visual assessment of ballast in “pre-dig” test pits, excavated approximately 4 weeks before the planned ballast cleaning. These test pits are excavated approximately 500m apart, and ballast screenability could vary considerably between these test pits located on the same continuous track sections.

1.3 Percentage Void Contamination Testing

The standard test method used by Aurizon to measure ballast fouling levels is the Percentage Void Contamination (PVC) test. The PVC test method is included in Appendix A.

The PVC test method is a volume-based method, which differs from the mass-based Fouling Index method. Ballast fouling material can consist of materials with different densities, such as coal fines and degraded ballast fines. The PVC method determines a measure of fouling that is independent of the density of different fouling materials. PVC is calculated by measuring the volume of contaminants (material passing a 9.5mm sieve) and dividing by the volume of voids within the ballast (material retained on a 9.5mm sieve).

PVC samples include ballast between the bottom of sleepers and the formation level.

2. PVC sampling project

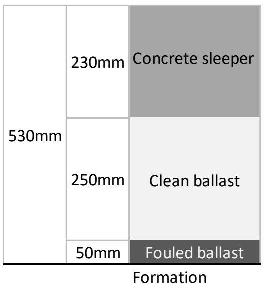
During a meeting attended by Tim Griffin, Sandra Xia and Damien Foun on 21 July 2020, a proposed project to measure actual ballast fouling levels after screening by the RM900 ballast cleaning machine was discussed. The objective of this project was to determine the effectiveness of screening by the RM900. Ballast fouling levels would be measured with percentage void contamination (PVC) test results performed in a laboratory on ballast samples obtained from track immediately after RM900 ballast cleaning using on-track screening.

This project was later approved and works proceeded based on a scope consisting of 32 PVC samples. Sampling from RM902 was added to the project following its introduction in 2021, and a further 11 PVC samples were obtained for a total of 43.

The PVC sampling works were completed in August 2021, with samples obtained from the following track sections:

- Goonyella System:
  - North Goonyella Line: Down and Up tracks (25),
  - Norwich Park Line: Red Mtn Loop track (2).
- Blackwater System:
  - NCL: Up track (4),
  - Central Line: Down and Up tracks (12).

PVC values can be correlated directly with ballast depth with the assumption that void volume does not vary with depth. For example, for a ballast depth of 300mm below the base of mainline concrete sleepers with a thickness at the track centreline of 230mm, a PVC value of 9.4% represents a fouled ballast layer 50mm deep as shown below:



$$PVC\ (\%) = \frac{depth\ of\ fouled\ ballast\ (50mm)}{total\ ballast\ depth\ from\ top\ of\ sleepers\ to\ formation\ level\ (530mm)} = 9.4\%$$

Ballast samples for PVC testing are taken from between the rails and from the base of the sleeper to the top of the formation, nominally 300mm deep for CQCN main line track. However, PVC limits are calculated from the top of the sleepers which are typically 230mm deep. Therefore, for this sleeper type, the PVC values returned from the laboratory are factored by *ballast sample depth / (ballast sample depth + 230)*.

Actual ballast depths below the base of sleepers in the field can differ from the design value for various reasons such as the presence of ballast pockets (isolated areas of increased ballast depth due to formation failures).

3. Methodology

The methodology for this project was as follows:

1. PVC sample location selection:
   a. a copy of the ballast cleaning program was obtained, as shown in Appendix B,
   b. ballast cleaning works planned on the required track sections as early as possible after project commencement were selected, and are shown as works displayed in bold in Appendix B,
   c. planned ballast screening extents within these planned ballast cleaning works were requested from Works Planning, and are included in Table 2,
   d. ground penetrating radar (GPR) PVC values recorded in 2018 were assessed, to identify locations with the highest GPR PVC values at the track centreline within planned ballast screening extents. An example of GPR 2018 PVC values at a planned PVC sample location on the WebMap is included in Appendix C. Highest GPR PVC values were selected as sample locations as these should provide the best measure of the effectiveness of screening by the RM900.
   e. Due to the requirement for results by August 2021, there was no choice for RM902 sample locations.
2. PVC samples were obtained immediately after ballast cleaning works, during the same closures in which these ballast cleaning works were performed at each selected work site. These samples were therefore obtained when

the level of ballast was at or close to the level of the top of sleepers (including placement of any required top-up ballast). These samples were obtained from the track centreline, and from the level of the bottom of sleepers to the formation level.

3. PVC samples were delivered to Construction Sciences laboratories at Mackay and Rockhampton for testing.
4. PVC test results were converted to a value representing the full ballast profile from top-of-sleeper to formation.

Table 2 – PVC sample sites

Site number	Line	Track	Planned ballast cleaning extent		Planned ballast screening extent	
			Start (km)	End (km)	Start (km)	End (km)
1	North Goonyella	Up	151.394	152.968	151.394	151.694
					151.898	152.098
					152.614	152.968
2		Down	24.296	25.614	24.296	24.996
					25.291	25.614
3	NCL	Up	555.190	555.645	555.190	555.519
4	Central	Down	63.570	63.735	63.615	65.238
			63.870	64.460		
			64.609	65.880	65.513	65.753
			66.000	66.295		
5		Up	88.120	90.651	88.120	89.542
					89.777	90.651
6	North Goonyella	Down	39.0	33.0	39.0	33.0
7			160.6	161.4	160.6	161.4
8	Norwich Pk	Loop	21.9	24.0	21.9	24.0

4. Sampling and PVC test results

An example of a PVC test report is included in Appendix D. PVC sample locations, PVC sampling dates, laboratory PVC test results, GPR 2018 PVC test results and information regarding ballast cleaning works are included in Appendix E. Appendix E also includes GPR 2020 PVC values, which became available after this project commenced.

A total of 43 PVC samples were obtained from required track sections in the Goonyella and Blackwater Systems.

Though samples obtained during this project were intended to only consist of ballast screened by the BCMs that was classified as screenable from inspection of ballast at the pre-dig test pits, some changes to planned ballast cleaning methods occurred by the time actual ballast cleaning works were performed. A comparison of relevant ballast conditions before and after ballast cleaning is outlined in Table 3 below.

Table 3 – Ballast conditions before and after ballast cleaning

Ballast condition number	Ballast condition at time of ballast cleaning	Actual ballast cleaning works performed	Condition after ballast cleaning (sampled ballast)
1	Screenable	Screening, as planned	Screened ballast (with low expected percentage of residual fouling material)
2	Unscreenable	Screening, due to a mechanical issue with RM900 preventing dumping of fouled ballast	Screened ballast (with potentially high expected percentage of residual fouling material)
3		Total excavation	Replacement ballast

Examples of cleaned ballast with Condition Number 1 (screened as planned) are included in Figure 4 (from RM900) and Figure 5 (from RM902).

Figure 4 – Photo of ballast in sample test pit at sample site 2F, at 24.774km on the Down track on the North Goonyella Line, 14 September 2020. Lab PVC 8.6%

Figure 5 - Photo of ballast in sample test pit for sample 1, at 38.5km on the Down track on the North Goonyella Line, 28 July 2021. Lab PVC 3.9%

An example of ballast with Condition Number 2 (screening attempted, though ballast was classified as unscreenable after screenability assessment of pre-dig test pits, sample location 3C), is included in Figure 6.

Figure 6 – Photo of ballast in sample test pit at sample site 3C, at 555.465km on the Up track on the North Coast Line, 24 September 2020. Lab PVC 18.5%

An example of ballast with Condition Number 3 (replacement ballast following total excavation, sample location 4E) is included in Figure 7.

Figure 7 – Photo of ballast in sample test pit at sample site 4E, at 65.534km on the Down track on the Central Line, 26 September 2020. Lab PVC 0.7%

The average ballast depth below the base of sleepers at all sample locations except 1A-1H (these values were not recorded) was 333mm, with a range of 240mm to 470mm.

5. Analysis

PVC test results and corresponding GPR 2018 and 2020 PVC values for the 32 sample locations are shown in charts in Appendices F and G. The range and average of the PVC test results for each of the 3 ballast cleaning methods are included in Table 4.

Table 4 – Average PVC test results

Ballast condition number	Number of samples	PVC Range (%)	PVC Average (%)	Comment regarding sampled ballast
1	38	0.1 - 13.2	4.2	Ballast screened as planned
2	3	10.4 - 11.8	11.1	Ballast classified as unscreenable attempted to be screened, due to unplanned circumstance
3	2	0.2 - 0.4	0.3	Full ballast replacement, which had been supplied from a quarry or screened off-site

Comments following analysis of these PVC test results are:

1. The average PVC test result for Ballast Condition 1 (ballast screened as planned, 38 samples) of 4.2% indicates the expected result for screening being performed effectively.
2. The average PVC test result for Ballast Condition 2 (screening of ballast classified as unscreenable, due to unplanned circumstance, 3 samples) of 11.1% was significantly higher than the average PVC test result for Ballast Condition 1, which was expected. Until further work is done to increase the sample size, this value of 11.1% may be used for reference purposes as a typical value representing efficient screening of unscreenable ballast.
3. Because of the small sample size for Ballast Condition 3 (full replacement with new ballast, 2 samples), a comparison was done of the supplying quarry's production sample test results with all other quarries supplying the CQNC. The average percent passing the 9.5mm sieve of 0.333% is consistent with the average of all quarries of 0.328%. On this basis, the result of 0.3% can be considered typical for ballast cleaned by full replacement with new ballast.

6. Conclusion

The average PVC test result of 4.2% for ballast screened as planned (38 samples) is expected to be typical across the CQCN. Similarly, the average PVC test result of 0.3% for ballast cleaned by full replacement with new ballast (2 samples) is expected to be typical across the CQCN.

Current ballast screening practices appear to be effective. The range of PVC values is likely to be from screenability factors such as moisture content rather than screening methodology.

7. Recommendations

It is recommended that the following average residual PVC values be used when estimating average ballast replacement cycles:

- 4.2% for ballast cleaned by screening.
- 0.3% for ballast cleaned by full replacement with new ballast.

Methods for sampling and testing fouled ballast
PERCENTAGE VOID CONTAMINATION
Passing 9.5mm Sieve

1. SCOPE

The aim of this test method is to determine the percentage of void contamination of a ballast sample taken from the track. The percentage of fouled voids indicates the lack of drainage capabilities of the ballast. This information can then be used to formulate ballast-cleaning strategies. The Percentage Void Contamination is determined in a compacted state to assimilate actual track conditions.

2. REFERENCED DOCUMENTS

AS		
1141	Methods for sampling and testing aggregates	
1141.1	Method 1:	Definitions
1141.2	Method 2:	Basic testing equipment
1141.3.1	Method 3.1:	Sampling Aggregates

3. APPARATUS

- Two cylindrical water-tight measures made of steel and conforming to these dimensions - 25l capacity, 350mm diameter and 250mm depth & 5l capacity, 200mm diameter and 150mm depth
- Metal tamping rod, 16mm diameter, 600mm long with at least one tapered end for a distance of 25mm to a spherical shape having a radius of 5mm
- Balance or scale - + or – 5g
- Sample divider – AS 1141.2
- Scope or shovel

4. TEST PORTIONS

A sample of ballast shall be obtained in accordance with AS 1141.3.1. The location of the selected sample is between the top of sleeper and formation level. Divide the sample by sieving through a 9.5mm sieve.

5. PROCEDURE

5.1 Sample retained on 9.5mm sieve (ballast)

- Test portion sufficient to overfill measure by 10%
- Determine mass M1 of ballast retained on 9.5mm sieve
- Fill one third of 25l measure and compact 25 blows with tamping rod
- Repeat the above step until measure is full then level the surface
- Determine mass M1/1 of ballast in the measure
- Fill with water and determine mass of ballast and water M2
- Calculate volume of voids $V1 = \dfrac{M2 - M1/1}{\text{density of water}}$

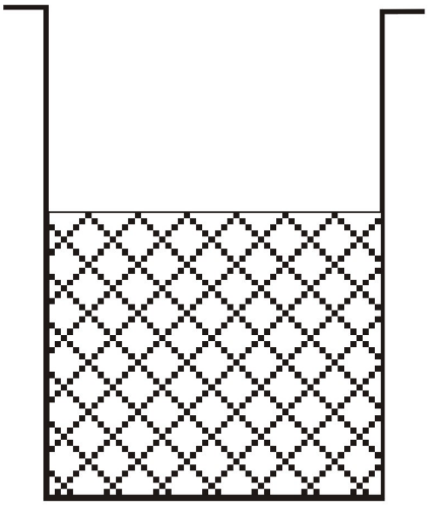
1

5.2 Sample passing a 9.5mm sieve (contaminates)

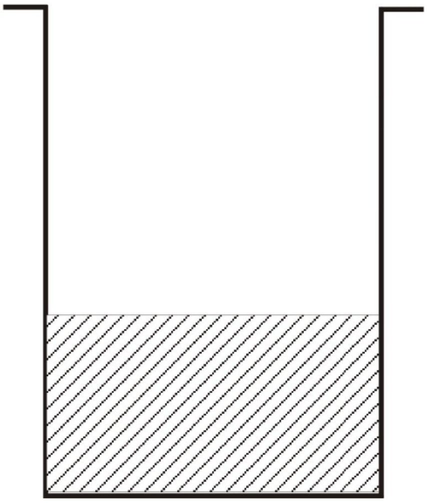
- Determine mass M3 of contaminates passing a 9.5mm sieve
- Calculate revised mass of contaminates M3/1 = $\dfrac{M1/1 \times M3}{M1}$
- Compact as above in 5l measure and determine volume of contaminates (M3/1), V2

5.3 Calculate Percentage Void Contamination

$$PVC\,\% = \frac{V2}{V1} \times 100$$



Volume of sample (Ballast) retained on 9.5mm sieve plus volume of voids



Volume of sample (Contaminates) passing a 9.5mm sieve

PERCENTAGE VOID CONTAMINATION

CLIENT:____________________________ JOB NO:_______________________

PROJECT:__________________________ DATE SAMPLED:______________

Laboratory Number			
Kilometrage			
Volume of containers			
Total Mass of Subsample	**M**		
Mass of Fines	**M3**		
Mass retained on 9.5mm	**M1 = M - M3**		
Mass +9.5mm remaining after filling container	**MR**		
Mass of Ballast in Container	**M1/1 = M1 - MR**		
Wt. of water in Bucket	**MB**		
Wt. remaining in Bucket	**MBR**		
Volume of Voids	$\mathbf{V1 = \dfrac{(MB-MBR)}{\mathit{Pw}}}$		
Mass of Ballast & Water	**M2**		
Vol. Of Voids in Ballast	$\mathbf{V1 = \dfrac{(M2 - M1/1)}{\mathit{Pw}}}$		
Recal. Mass of Fines	$\mathbf{M3/1 = \dfrac{(M1/1 \times M3)}{M1}}$		
Ht. of Mould			
Ht. above Fines			
Ht. of Fines	**H**		
Vol. Of Fines	$\mathbf{V2 = \pi r^2 H}$		
PVC	$\mathbf{= \dfrac{V2}{V1} \times 100}$ **%**		

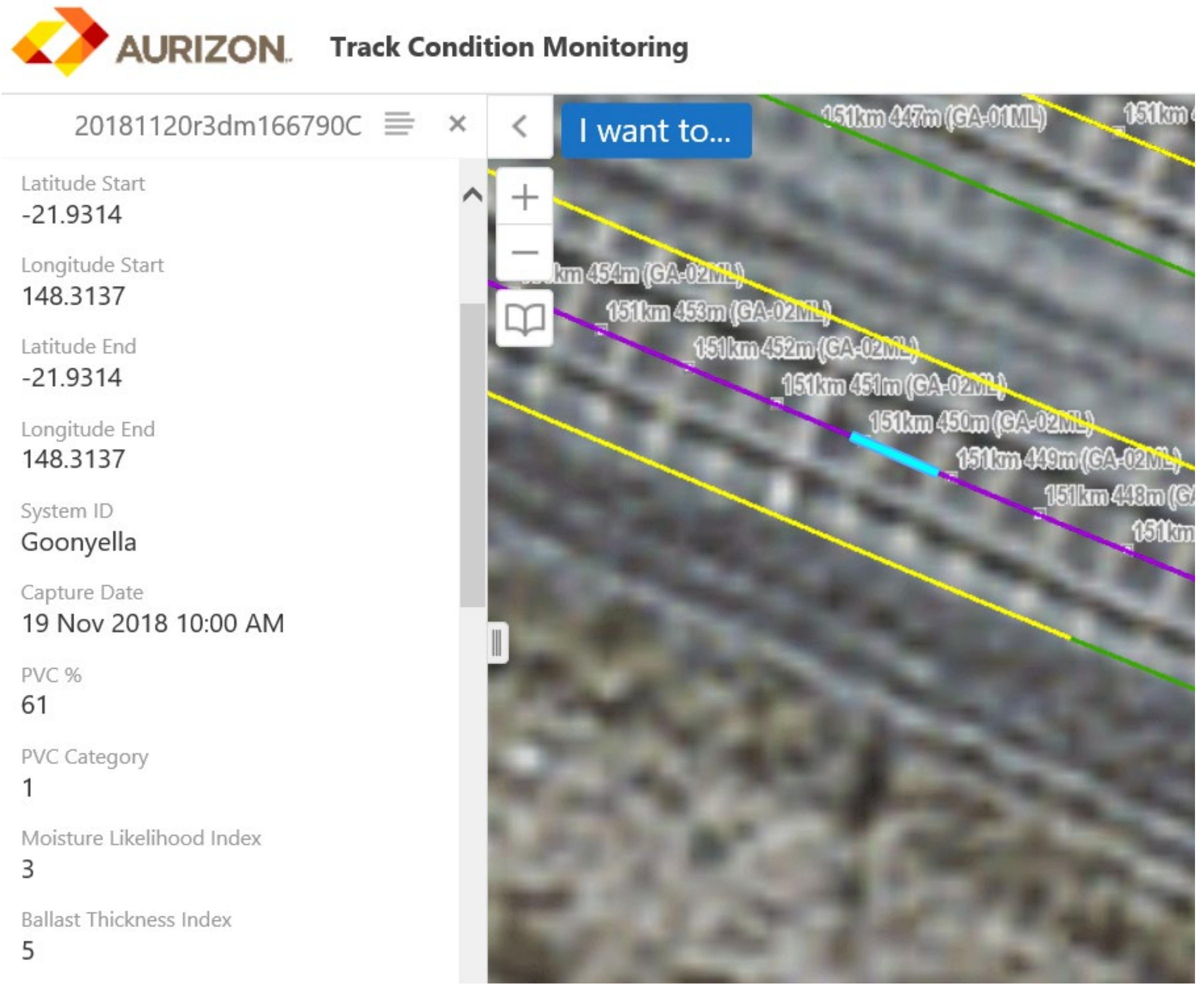
Tested by:_______________________ Checked by:_____________________

Date:____________________________ Date:____________________________

Appendix B – Ballast cleaning program, as at 25 August 2020, with projects during which samples obtained displayed as bold

Date	System	Activity	Notification	Project No.	Location	Daily planned scope start	Daily planned scope end	Daily planned scope
Wednesday, 26 August 2020	GA	Production	2000055881	1008	Harrow - Saraji Main	60.600	63.260	2.660
Thursday, 27 August 2020	GA	Production						
Saturday, 29 August 2020	GA	Production	2000055879	1010	Wandoo - Waitara Up	87.871	87.260	0.611
Sunday, 30 August 2020	GA	Production				87.180	86.880	0.300
Monday, 31 August 2020	GA	Production	2000055878	1011	Hatfield Yard - Bolingbroke Up	52.646	54.000	1.354
Tuesday, 1 September 2020	GA	Production				52.459	51.563	0.896
Monday, 7 September 2020	GA	Production	2000055878	1011	Hatfield Yard - Bolingbroke Up	51.563	49.270	2.293
Tuesday, 8 September 2020	GA	Production						
Thursday, 10 September 2020	**GA**	**Production**	**2000055880**	**1009**	**Coppabella - Broadlea Up**	**151.394**	**152.968**	**1.574**
Friday, 11 September 2020	**GA**	**Production**						
Sunday, 13 September 2020	**GA**	**Production**	**2000055877**	**1012**	**Jilalan Bypass Yard - Yukan Down**	**25.614**	**24.296**	**1.318**
Monday, 14 September 2020	**GA**	**Production**						
Wednesday, 23 September 2020	**BW**	**Production**	**2000055859**	**1013**	**Aldoga Yard - Mt Larcom Up**	**555.190**	**555.645**	**0.455**
Thursday, 24 September 2020	**BW**	**Production**						
Friday, 25 September 2020	**BW**	**Production**	**2000055858**	**1014**	**Windah - Grantleigh Down**	**63.570**	**63.735**	**0.165**
Friday, 25 September 2020	**BW**	**Production**				**63.870**	**64.460**	**0.590**
Friday, 25 September 2020	**BW**	**Production**				**64.609**	**65.880**	**1.271**
Saturday, 26 September 2020	**BW**	**Production**				**66.000**	**66.295**	**0.295**
Monday, 28 September 2020	BW	Production	2000053266	1042	Starlee - Rolleston	99.721	102.860	3.139
Tuesday, 29 September 2020	BW	Production				103.020	103.694	0.674
Wednesday, 30 September 2020	BW	Production						
Friday, 23 October 2020	**BW**	**Production**	**2000055857**	**1017**	**Edungalba - Aroona Up**	**88.120**	**90.651**	**2.531**
Saturday, 24 October 2020	**BW**	**Production**						
Monday, 26 October 2020	BW	Production	2000057562	1043	Bajool to Archer Down	606.625	613.080	6.455
Tuesday, 27 October 2020	BW	Production						
Tuesday, 3 November 2020	BW	Production	2000055855	1019	Duaringa - Wallaroo Down	108.744	111.170	2.426
Wednesday, 4 November 2020	BW	Production						
Friday, 6 November 2020	BW	Production	2000055854	1020	Walton - Bluff Down	167.826	165.626	2.200
Saturday, 7 November 2020	BW	Production						
Monday, 9 November 2020	BW	Production	2000055853	1020	Parnabal - Bluff Yard Down	163.202	164.402	1.200
Tuesday, 10 November 2020	BW	Production				169.226	167.826	1.400
Wednesday, 18 November 2020	BW	Production	2000055852	1021	Boonal - Blackwater Yard Down	184.567	187.567	3.000
Thursday, 19 November 2020	BW	Production						
Friday, 20 November 2020	BW	Production						
Saturday, 21 November 2020	BW	Production	2000055852	1021	Boonal - Blackwater Yard Down	181.916	184.567	2.651
Sunday, 22 November 2020	BW	Production						
Monday, 23 November 2020	BW	Production						
Wednesday, 2 December 2020	BW	Production	2000055851	1022	Windah - Grantleigh Up	58.589	61.589	3.000
Thursday, 3 December 2020	BW	Production						
Friday, 4 December 2020	BW	Production						
Saturday, 5 December 2020	BW	Production	2000055851	1022	Windah - Grantleigh Up	61.589	64.589	3.000
Sunday, 6 December 2020	BW	Production						
Monday, 7 December 2020	BW	Production						

Appendix C – WebMap image with GPR PVC 2018 values at a PVC Sample 1A location



Appendix D – Example of a PVC test report

Construction Sciences

Mackay Laboratory
2 Progress Drive, Paget, QLD, 4740
Phone: 07 4952 4750
Email/Fax: Mackay@constructionsciences.net

Report for
Determination of Percent Void Contamination of Ballast

Client:	Aurizon Network Pty Ltd	Report No:	5676_R_159505
Address:	Level 8 900 Ann Street Fortitude Valley QLD 4006	Project No:	5676/P/3858
Project:	Percent Void Contamination of Submitted Samples	Request No:	5676/T/40672
		Sample No:	5676/S/159505
		Client Request Ref:	Coppabella - Broadlea

Client Reference:		Area Description:		
Component:		Location:	Location:	Bin 1E
Sample Source:	Existing			151.926 km
Sample Description:	Ballast			Up
Sampling Method:	Tested As Received			
Sampled By:	Client Sampled	Date Sampled:	11/09/20	
Tested By:	Dm	Date Tested:	17/09/20	

Test Method: STM 002

TEST RESULT

Percentage Void Contamination (%)	**7.0**
Percentage passing 26.5mm (%)	**7**
Percentage Passing 9.5mm (%)	**4**

Remarks: Results Apply to the Sample(s) as Received

NATA
WORLD RECOGNISED ACCREDITATION

Corporate Site Number: 5676
Accreditation Number: 1986

The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.
Accredited for Compliance with ISO/IEC 17025 - Testing.

Signature

Name: David Gray
Function: Authorised Signatory
Date: 18-Sep-20

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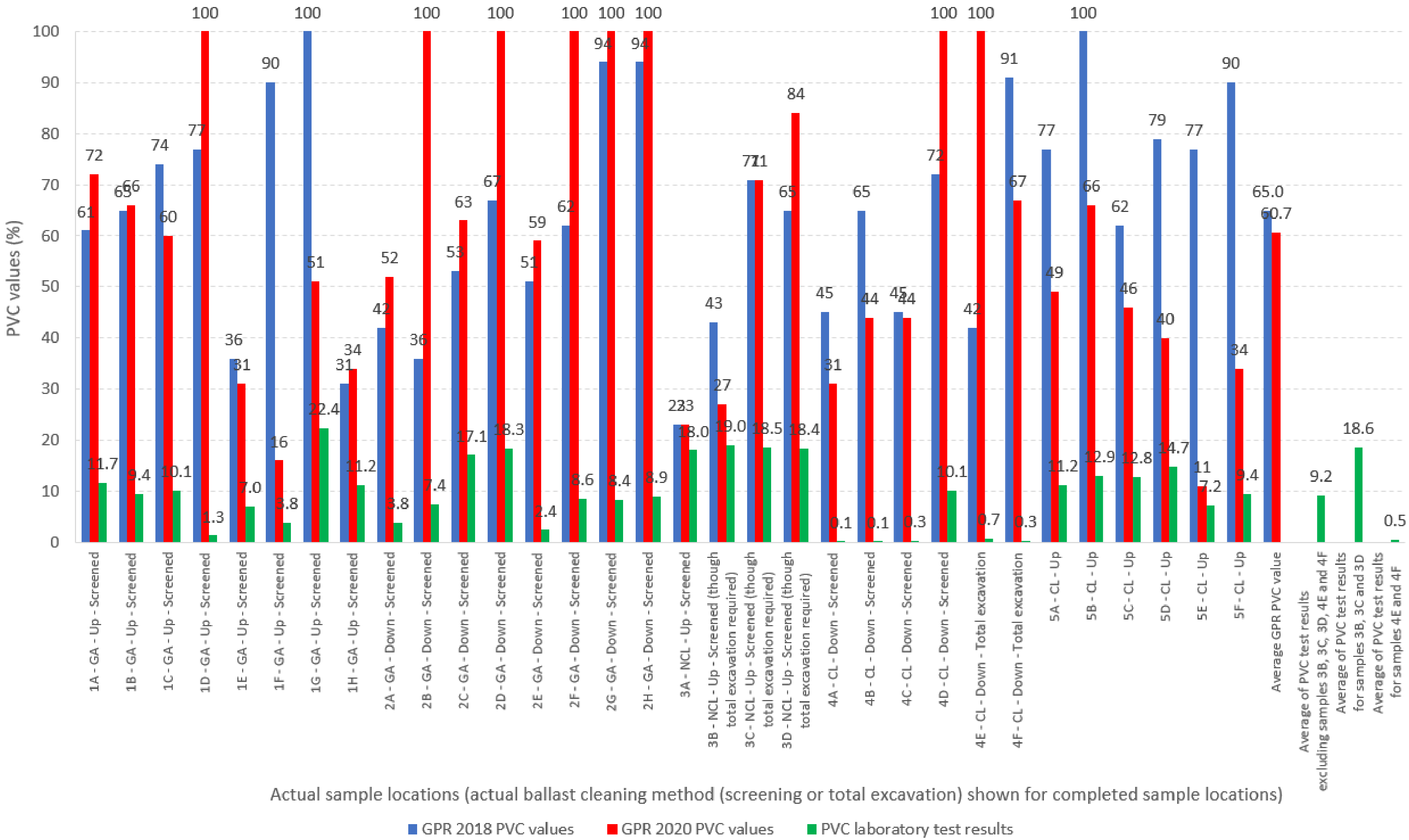
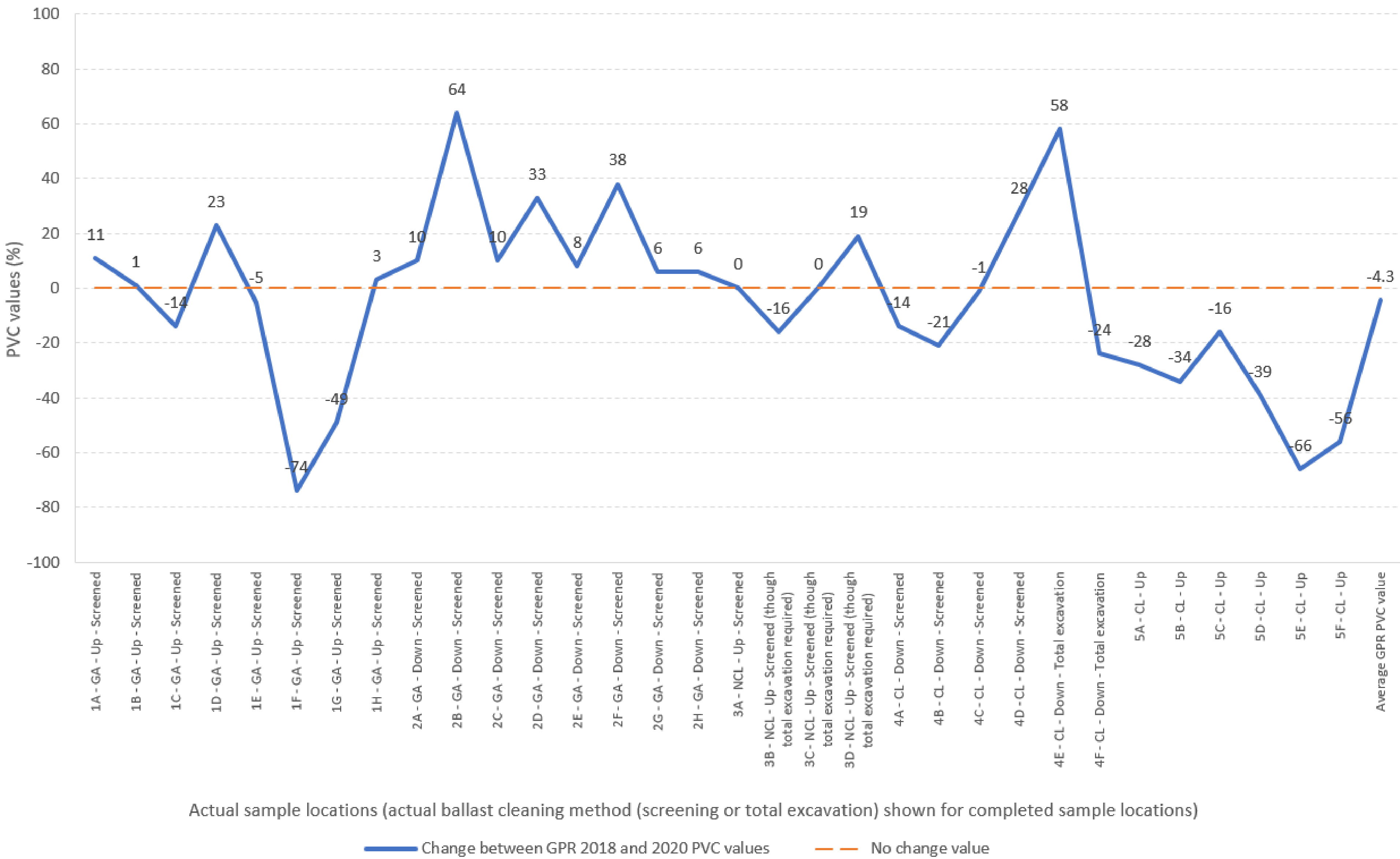
Appendix E – PVC test results for each sample location

Site No.	BCM	System	Line	Track	Sample date	Sample number	Sample location (km)	Sample depth below the base of sleepers (mm)	Screening status	PVC value in GPR 2018 data (%)	PVC value in GPR 2020 data (%)	PVC laboratory test result (%)	PVC adjusted for full ballast profile depth (%)
1	RM900	Goonyella	Goonyella	Up	Friday,	1A	151.450	Not recorded	Screened	61	72	11.7	6.9
1	RM900	Goonyella	Goonyella	Up	11-Sep-20	1B	151.504	Not recorded	Screened	65	66	9.4	5.5
1	RM900	Goonyella	Goonyella	Up		1C	151.558	Not recorded	Screened	74	60	10.1	6.0
1	RM900	Goonyella	Goonyella	Up		1D	151.665	Not recorded	Screened	77	100	1.3	0.8
1	RM900	Goonyella	Goonyella	Up		1E	151.926	Not recorded	Screened	36	31	7.0	4.1
1	RM900	Goonyella	Goonyella	Up		1F	151.970	Not recorded	Screened	90	16	3.8	2.2
1	RM900	Goonyella	Goonyella	Up		1G	151.994	Not recorded	Screened	100	51	22.4	13.2
1	RM900	Goonyella	Goonyella	Up		1H	152.028	Not recorded	Screened	31	34	11.2	6.6
2	RM900	Goonyella	Goonyella	Down	Monday,	2A	24.423	320	Screened	42	52	3.8	2.2
2	RM900	Goonyella	Goonyella	Down	14-Sep-20	2B	24.480	340	Screened	36	100	7.4	4.4
2	RM900	Goonyella	Goonyella	Down		2C	24.556	390	Screened	53	63	17.1	10.8
2	RM900	Goonyella	Goonyella	Down		2D	24.613	340	Screened	67	100	18.3	10.9
2	RM900	Goonyella	Goonyella	Down		2E	24.719	310	Screened	51	59	2.4	1.4
2	RM900	Goonyella	Goonyella	Down		2F	24.774	330	Screened	62	100	8.6	5.1
2	RM900	Goonyella	Goonyella	Down		2G	24.845	370	Screened	94	100	8.4	5.2
2	RM900	Goonyella	Goonyella	Down		2H	24.917	290	Screened	94	100	8.9	5.0
3	RM900	Blackwater	NCL	Up	Thursday,	3A	555.337	470	Screened	23	23	18.0	12.1
3	RM900	Blackwater	NCL	Up	24-Sep-20	3B	555.420	380	Screened (though total excavation required)	43	27	19.0	11.8
3	RM900	Blackwater	NCL	Up		3C	555.465	340	Screened (though total excavation required)	71	71	18.5	11.0
3	RM900	Blackwater	NCL	Up		3D	555.501	300	Screened (though total excavation required)	65	84	18.4	10.4
4	RM900	Blackwater	Central	Down	Saturday,	4A	64.442	300	Screened	45	31	0.1	0.1
4	RM900	Blackwater	Central	Down	26-Sep-20	4B	64.683	280	Screened	65	44	0.1	0.1
4	RM900	Blackwater	Central	Down		4C	65.076	310	Screened	45	44	0.3	0.2
4	RM900	Blackwater	Central	Down		4D	65.167	350	Screened	72	100	10.1	6.1
4	RM900	Blackwater	Central	Down		4E	65.534	320	Total excavation	42	100	0.7	0.4
4	RM900	Blackwater	Central	Down		4F	65.684	280	Total excavation	91	67	0.3	0.2
5	RM900	Blackwater	Central	Up	Saturday,	5A	88.221	240	Screened	77	49	11.2	5.7
5	RM900	Blackwater	Central	Up	24-Oct-20	5B	88.339	270	Screened	100	66	12.9	7.0
5	RM900	Blackwater	Central	Up		5C	89.266	290	Screened	62	46	12.8	7.1
5	RM900	Blackwater	Central	Up		5D	89.464	260	Screened	79	40	14.7	7.8
5	RM900	Blackwater	Central	Up		5E	89.916	390	Screened	77	11	7.2	4.5
5	RM900	Blackwater	Central	Up		5F	90.176	350	Screened	90	34	9.4	5.7
6	RM902	Goonyella	Yukan-Bk Mtn	Down	Wednesday,	1	38.500	360	Core excavated – only shoulders screened			3.9	2.4
6	RM902	Goonyella	Yukan-Bk Mtn	Down	28-Jul-21	2	38.000	425	Core excavated – only shoulders screened			1.0	0.6
6	RM902	Goonyella	Yukan-Bk Mtn	Down		3	37.500	300	Core excavated – only shoulders screened			0.5	0.3
6	RM902	Goonyella	Yukan-Bk Mtn	Down		4	37.000	330	Core excavated – only shoulders screened			1.3	0.8
6	RM902	Goonyella	Yukan-Bk Mtn	Down		5	36.500	300	Core excavated – only shoulders screened			2.2	1.2
6	RM902	Goonyella	Yukan-Bk Mtn	Down		6	36.005	330	Core excavated – only shoulders screened			2.2	1.3
6	RM902	Goonyella	Yukan-Bk Mtn	Down		7	35.500	320	Core excavated – only shoulders screened			1.8	1.0
7	RM902	Goonyella	B'lea-Mallawa	Down	Wednesday,	1	160.900	290	Screened			1.4	0.8
7	RM902	Goonyella	B'lea-Mallawa	Down	4-Aug-21	2	161.100	320	Screened			1.3	0.8
8	RM902	Goonyella	Red Mtn Yard	Loop	Wednesday,	3	23.300	470	Screened			1.8	1.2
8	RM902	Goonyella	Red Mtn Yard	Loop	4-Aug-21	4	23.600	400	Screened			1.7	1.1

Appendix F – Chart of laboratory PVC values, and GPR PVC 2018 and 2020 values at RM900 PVC sample locations



Appendix G – Chart of change in GPR PVC values between 2018 and 2020 at RM900 PVC sample locations



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Final Audit Report 2021-09-19

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