TRAFNIDIAETH CYMRU
TRANSPORT FOR WALES

NetworkRail

Autumn Investigation: Progress Report

V 2.4
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Executive Summary

Autumn 2018 saw an exceptionally high number of wheel flats across the Transport for Wales Rail Services (TfW) fleet. For several weeks in November, service delivery was severely impacted with up to 25 of the total 127 units stopped awaiting tyre turning for wheel flat damage. In addition, 4–5 units' wheelsets were approaching the end of their operational lifespan which put further strain on maintenance facilities.

Wheel flats are formed when a wheel slides along the rail instead of rolling, a situation caused by lower than usual friction in the contact patch ('slippery rail'). This is a well-known problem on railways worldwide and is typically associated with leaves and moisture on the rails. However, it has become apparent that a wider range of factors can also have an influence, which include:

- Localised foreign substances contaminating the railhead;
- The interaction of wheel, rail and brake block profiles;
- Modern on-board technologies to manage low adhesion;
- Driver training, policy and experience of low adhesion conditions;
- Railhead treatment approaches;
- Processes for reacting and learning from low adhesion reports/ wheel flats;

Considering the wheel-rail system as a whole, an action group has been set up to look more deeply into the above issues. This is jointly funded by TfW and Network Rail (NR), with independent consultants advising where needed. The Railway Safety and Standards Board (RSSB) will also be involved to support with a broad base of knowledge and ensure that outputs can be shared with the wider industry.

The recommendations of this report aim to direct mitigating efforts where the biggest gains will be seen for autumn 2019. The current agreed actions and timescales are as follows:

- Consider areas where autumn preparation worked well and where a different approach could bring improvements;
- Continue to localise and investigate foreign substances on the railhead which could have contributed to poor adhesion in 2018;
- Understand any wider wheel-rail interaction issues affecting the TfW fleet;
- Carry out a package of modifications to improve the fleet's autumn resilience and gain quantitative data on adhesion;
- Implement a process to review and respond to adhesion information in a timely manner.

This report describes the work undertaken since the investigation launch in November 2018, findings so far and steps to mitigate the impacts for Autumn 2019. The recommendation tracker will be updated following each monthly meeting between TfW Operations, Engineering and NR.

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TfW/ NR Actions Timeline (Summary to date)

Task	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Monthly Taskforce meetings												
Review videos and investigate problem sites												
Fit WSP to Class 150 units												
Re-write Drivers' braking policy												
Arrange supply of replacement wheels												
Agree process for autumn control/ data management												

Introduction

Wheel flats, examples of which are shown in Figure 1, are a form of wheel damage resulting from wheel slip or slide against the railhead. This occurs where the coefficient of friction between wheel and rail is insufficient to maintain the adhesion required for the desired traction/ braking force. As the wheelset ceases to roll freely, either rolling more slowly than the rest or locking completely, a flat develops on the wheel tread and control of the train is momentarily lost. Once present, a wheel flat is noticeable by the banging sound as the wheel rotates. This is accompanied by an increase in vertical wheel-rail forces which can damage the vehicle and track if not addressed.

Figure 1: Examples of severe wheel flats from November 2018.

There are two main standards that govern wheel flats in terms of size and impact forces they generate including the Railway Group Standard GM/RT 2466 [1] that requires the units with wheel flats of 40- 60 mm in length to be withdrawn from service and Network rail Standard NR/SP/TRK0133 [2] that sets limits in terms of impact forces above which the units should be taken out of service.

Wheel flats are rectified by re-profiling the wheel on a lathe, which results in loss of wheel material and shortening of the wheelset's lifespan, as well as impacting train availability for service - therefore measures must be implemented to reduce risk of wheel flats. Wheel flats are caused by a number of mechanisms across the railway system including:

Infrastructure – poor railhead conditions caused by leaves (and the lineside vegetation management strategy) or other external contaminants such as grease, oil, Diesel, industrial and farming deposits, track geometry (gradients and curvature);

Vehicles – brake configuration and adjustment, wheel slide protection (WSP) systems, sanding system and wheel/rail profile compatibility;

Operations – Timetabling, drivers' acceleration/ braking behaviour, training and experience in low adhesion conditions;

Environment – effects of temperature and humidity combined with the above, or climate trends changing the timing and volume of leaf fall.

It is therefore necessary to consider all of the contributory factors when deciding on an approach to prevent wheel flats in future.

As shown in Figure 2, the number of wheel flats encountered by the TfW fleets has grown in the last 2-3 years. Autumn 2017 saw an unprecedented increase against 2016, which was exceeded again by over 50% during 2018. At the worst point in mid-November 2018, over a quarter of the TfW fleet was stopped awaiting the wheel lathe or wheelset changes.

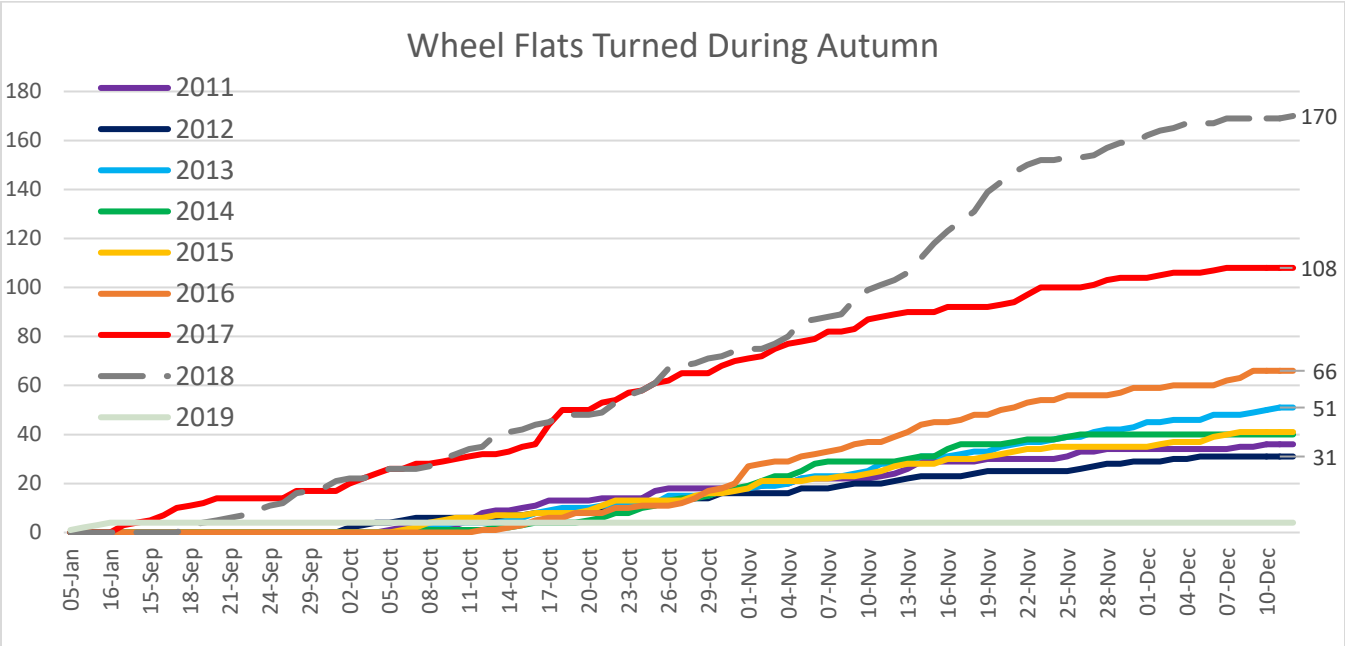

Figure 2: Units stopped for tyre turning each autumn – running total by date.

It can be seen that the rate of wheel flats decreased after the end of November, with only occasional flats found during December and into January 2019.

During 2018, flats were distributed evenly across class 142, 143 and 150 units. Class 150 trains cover a wider variety of routes, have more seats and take longer to turn - which is why their impact on passenger service was perceived to be more severe.

Of the TfW fleet, only classes 158 and 175 are fitted with WSP. The class 14X and 15X units, operating predominantly on the Valley lines, are not protected and therefore suffered more heavily. Sanding equipment is present on these units to improve adhesion where needed. However, the system is

activated manually, which means it may not be deployed until wheel slide becomes noticeable to the driver.

Furthermore, there is no warning system in the cab to inform the driver that train is entering a low adhesion sites. Lineside signage is installed during autumn to inform drivers [3], in known poor adhesion areas (as listed in NR's Sectional Appendix), which provide a limited degree of warning.
It is vitally important that units are fitted with WSP and the sanding system is automatic and linked to WSP so that sand is deposited as soon as wheel slide is detected.

Work Carried Out, Autumn 2018

TfW have set up the present investigation to assess the factors contributing to 2018's wheel flats. To date, the following areas have been looked into:

ATW/ TfW Autumn Preparation

During the mobilisation period, KeolisAmey worked closely with Arriva Trains Wales (ATW) to minimise the fleet risks posed by autumn:

- Completing wheelset changes to ensure that wheel life at the start of autumn was at least 6 months in accordance with ATW's process QP002. For the 14X and 15X fleets, this was achieved for 83% of axles, when using average wear rates for 2016-17 calculated by KeolisAmey. However, at this point the number of wheels damaged far exceeded the prediction.
- Commissioning a condition assessment and maintenance contract for the wheel lathe at Canton, as well as agreeing access to other wheel lathes to reinforce tyre turning capability.
- Ensuring an available supply of replacement trailer/ powered wheelsets and the capability of local suppliers to re-pan/ overhaul axles when required.

Network Rail Autumn Preparation

Prior to the start of leaf fall, a number of agreed actions took place to mitigate the effect of leaf fall on wheel-rail adhesion, including:

- The Sectional Appendix list of low adhesion sites was updated. Based on past reports of incidents, this forms part of the drivers' briefing given in September.
- Priority de-vegetation was given to a number of areas, which were identified by a weighted assessment of SPAD risk. This was permitted despite a wider DfT review of lineside tree management.
- Railhead treatment train (RHTT) diagrams were planned, which for 2018 included 2 daily treatments of the Rhymney valley line. RHTTs began running on 1st October which was after the start of the low adhesion period as seen in Figure 1.
- Traction gel applicators (TGAs) were deployed at a number of locations and some upgraded for 2018. These lineside devices dispense a gel containing sandite onto the railhead at intervals determined by the passing of trains. Despite annual review, their positioning around the network has remained largely unchanged for several years.

Figure 3: (a) Railhead treatment train (b) Traction gel applicator.

TfW Preliminary Investigation

In order to ensure all parties are involved with actions going forward, a meeting was held on 3rd January 2019 between TFW, NR and MRCL. The following discussion points were identified:

- Review of NR's post-autumn report [4] showed that vegetation only accounted for a part of the adhesion problem and not all. The review gives a breakdown of records of low adhesion (ROLAs) by location and contamination level.
- NR's sample analysis following ROLAs shows that leaf contamination was present in 29 of 61 cases. The distribution of ROLAs also reflects this pattern, as mapped in Appendix A. The sites with the highest number of ROLAs, Llantwit Major and Trehafod, were both in areas with concentrated de-vegetation efforts.
- Use of ROLAs as a source of data must, however, be approached with caution. The numbers of these reports are low (at worst 4 in the entire season) and whether drivers decide to report conditions is very subjective. This is partly due to a terminology change for 2018, which classifies railhead conditions as 'good', 'expected' or 'reportable' The form is used for both passenger services stopping at stations and freight trains which may suffer from wheel slip on inclines. Therefore, further work is needed to refine the map in Appendix A.
- Prior to autumn 2017, Network Rail applied adhesion modifier to the railhead, as a supplementary treatment alongside water-jetting and lineside applicators, at 47 sites across the Wales and Borders network, excluding the valley lines. Adhesion modifier is a mixture of sand and metal particles in a gel suspension. It is designed to improve the coefficient of friction at the wheel-rail interface with the aim of reducing wheel slip and slide. Following a challenging autumn in 2016, it was jointly agreed by Network Rail and ATW to remove adhesion modifier application from the treatment specifications. Subsequently, data captured during autumn 2017 and 2018 has been analysed and shows that only 2 of the 47 sites previously treated with adhesion modifier, had an increase in the number of adhesion incidents reported over consecutive years since its use was stopped.
- The wheel-rail camera journeys as outlined in the following section have revealed a number of other substances present which could potentially be affecting adhesion especially if accompanied by condensation in certain weather conditions.
- TGA tests have previously been carried out using two different gel brands and their consumption rate shown to vary. The actual effectiveness of lineside applicators is a potential area to review

– NR conducted a trial of the gel's carry-down distance in April 2017, finding that the gel is only in contact once per wheel revolution and extends around 50 metres beyond the applicator. It is also noted that gel may be consumed, or nozzles may become blocked, before the 2-week inspection/ replenishment cycle. Their limitations mean that their presence could be causing drivers to overestimate the adhesion conditions and brake harder as a result.

- Following the end of autumn, Network Rail carried out swab tests at four sites known to have low adhesion. The result of swab analysis did not show significant contaminant on rails except traces of black/brown debris, calcium (one site), silicon, phosphorus and hydrocarbons. These could be minerals or grease. Greases often contain calcium and phosphorus, so it is possible that excess grease contributed to the issue.
- Analysis of the on-train monitoring and recording (OTMR) downloads, taken from units stopped with wheel flats, revealed that in some cases running brake tests were carried out using brake step 2 from the start, rather than using a controlled increase through step 1, as shown in *Figure 4* below. This practice originated from ambiguity in the drivers' braking instructions, which included actions no longer required by the rulebook. As a result, the instructions are to be updated, to apply the brakes more gradually on tread-braked units without WSP.

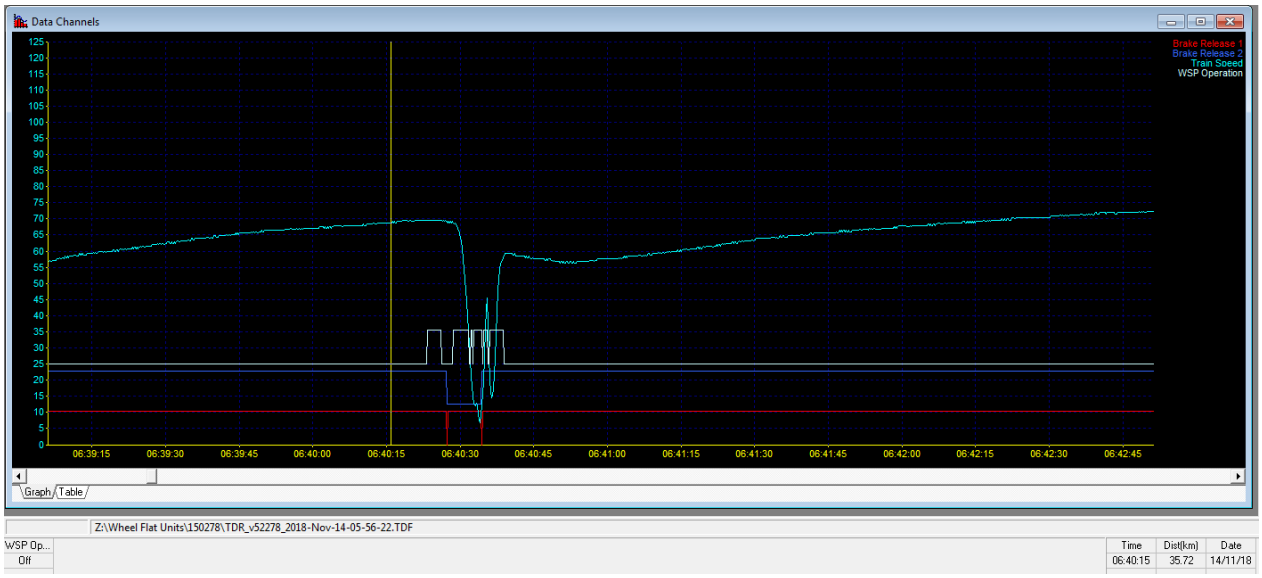

Figure 4: Example of a class 150 OTMR download showing a wheel slide at 70 mph. Speed (blue) drops rapidly towards zero following a brake application indicating that the wheelset is locked whilst the train continues moving.

Wheel-rail interface cameras

Fitting cameras to the underframe of trains, along with GPS to monitor the trains' speed and location, gives the ability to capture the curving and braking behaviour of wheelsets. This approach aims to localise any issues involving wheel and rail profiles, as well as help identify areas with contaminants (either vegetation or external sources) which could be affecting adhesion.

Figure 5: Equipment fitted to the underframe and picture from camera.

Following the initial meeting, the engineering change process was completed to allow fitment of the cameras to trains running as empty coaching stock (ECS) in traffic during the night. A class 150 unit was used to cover as much of the network as reasonably practical and because '150s had seen an increase in wheel flats in-line with other fleets.

The sites suggested for testing included a mixture of those with good adhesion; known poor areas as listed in the Sectional Appendix (several of which were newly added in 2018); and some which potentially have further contaminants on the railhead. The test runs were carried out over two consecutive nights of 12th and 13th December. Full details of the headcodes, planned and actual times were recorded [5]. Running brake tests were carried out by drivers as normal and stops were planned at stations which were known low adhesion areas. A total of around 15 hours of footage were captured, which covered approximately 450 miles of running.

It should be noted that on the testing dates, the adhesion index as forecast by NR was classed as 'good', and leaf fall was nearing completion. Leaves on the ground were forecast at 1.1%, in contrast with >5% during the most severe peaks of leaf fall season.

The cameras captured several notable occurrences, as described in Appendix B, which formed discussion points for the initial meeting between NR and TfW.

Conclusions to date

Based on the work undertaken above, the following findings have emerged which set the direction for further actions:

- Leaf fall is not the sole cause of adhesion issues. Therefore, a broader approach is needed, whilst the trackside de-vegetation programme may require re-visiting to make it concentrated where it is most relevant.

- There was 64% increase in ROLAs in 2018 despite the terminology change, highlighting the significance of the trend. These remain a subjective way of reporting railhead conditions and more reliable data is needed to inform decisions.
- Running of the RHTT on some parts of the Wales route may have to be brought forward. In 2018 the RHTT operation started on 1st October (2 weeks earlier than previous years), but flats on the TfW fleet started emerging in September. By 1st October there were 60 flats already stopping trains.
- Detail study of OTMR outputs showed overly aggressive braking by some drivers when step 3 braking was used at high speed.
- Video recording showed several potential wheel-rail interface issues:
- Wheel slide occurring when braking on a sharp curve;
- Grease or water on the railhead;
- Vegetation growing near the line;
- Dust being expelled from the interface, particularly during flange contact.
- Swab tests have shown that sand is being used in some locations outside of autumn, reinforcing the idea that underlying adhesion issues may be found year-round.

Recommendations

The objective following this report is to hold a monthly working group, in order to minimise risk of wheel flats in autumn 2019. The investigation team will include TfW, Network Rail and an independent wheel/rail interface consultant to ensure that issues are addressed by all stakeholders. The RSSB will also be involved to mediate discussion if necessary and ensure that findings are representative of (or can help inform) industry best practice. The scope of the working group should be guided by this report's findings and updated iteratively as actions are completed.

	Owner	Action	Update	Status
1	All	Agree terms of engagement and organisation of project		Completed
2	TfW/ MRCL	Provide categorised list of locations for further investigation of contaminated areas based on evidence gained from the camera footage (with GPS location/ ELR & mileage).	Shortlisted sites provided in map form with video stills.	Completed
3	NR	Better understanding of low adhesion sites (factors besides leaves, moisture etc) and how to deal with them – cross reference with MOM visit/ possession records.	Swab samples showing traces of hydrocarbon waxes along with sand in March. Add review of TGA function.	In Progress
4	All	Investigate how to measure/quantify adhesion at ROLAs and other sites – using data gathered from units in service.	Process to be developed on how to act and action remote data such as: 1) WSP 2) ROLA – Driver Feedback 3) OTMR – Driving styles	In Progress
5	NR	Review timing/ location of failure reports for grease lubricators and traction gel units on Wales route.		To start
6	TfW	Check braking system on most affected units to ensure good pressure distribution and brake block setting.		To start

7	TfW	Review brake block replacement policy and how it fits in with wheel replacement/re-profiling policy.		In progress
8	TfW NR	Review sample wheel profiles for low, medium and high mileage. Obtain sample rail profiles particularly in ROLAs sites	MRX wheel monitoring system commissioned, need to assess the reliability of measurement data. TfW developing new software for wheel wear trends. New action: Establish when the 6 months wheel life entering autumn was mandated	In progress
9	TfW	Begin project to retrofit fleets to improve autumn resilience: • C150 Wheel slide protection, to automatically vary brake pressure in response to wheel slip. The system should include warning system in the cab. • OTMR live data harvesting, to monitor WSP activity and better. • Automatic sanding to deploy more effectively. • Wheel tread adhesion modifier trial to dispense sandite where needed, with better coverage and maintainability than lineside TGAs.	WSP installation planned to begin in June, with ~70% of units completed by October. Auto-sanding will work in all forward-facing cabs, giving double fixed rate sanding (shown by RSSB to improve braking performance).	In Progress
10	TfW	Install permanent w/r interface video system on a class 150 to carry out periodic recording of the interface.	Needs development of cable routing for use in passenger service. Note, this could be aligned with the requirements for UGMS for 3 of our new units (MV & Tri-Mode)	To start

11	NR / TfW	Appropriate visualization to be developed for NR/ drivers/ maintenance control.	Agreed that a shared, unified viz. approach will keep all informed with the same information.	In progress
12	TfW	Agree process for reporting wheel flat to TfW Engineering team by drivers as soon as noticed and reviewing ROLAs with drivers.	Internal process to be drafted in parallel with actions 4 & 11.	To start
13	TfW	Revise driving policy instructions for running brake tests (safety validation following workshop session).		In progress
14	TfW	Review driving policy to include specific instruction for autumn and winter months – update for WSP installation.		Planned June
15	NR	Organise Wales RHTT workshop session to jointly agree treatment specifications for autumn 2019.	Current plan to start 1/10/2019	To start
16	All	Discuss feasibility of methods to quantitively measure adhesion/ moisture	Link with Adhesion Research group.	To start
17	TfW	Progress case for including TOC resources in Autumn Control – experienced controllers to best manage maintenance and/or analysts to process new information.	Ops to draft a business case for additional manning during autumn.	In progress
18	All	Summary investigation of novel approaches to adhesion management: • Dry ice for railhead treatment (Uni. Sheffield trial) • Modifying trains for sandite (Picc. Line experience) • Magnetic track braking (metro and/or mainline) • Variable rate sanding (application to new fleets)	Many of these were captured in the RSSB's Adhere research programme. Feasibility of each to be assessed for TfW fleets.	In Progress
19	All	Implement process for monitoring adhesion issues outside of autumn periods.		To start

20	TfW	Carry out a benchmarking exercise against WMT's Cross-city Line (Birmingham)	This line has many similarities to the valleys and has taken innovative steps with the RSSB to improve their autumn performance.	In progress

Further conclusions will be added to this report once those involved are confident that root causes have been pinpointed and that actions agreed address these as fully as possible. The project risks below have been identified and the relevant mitigations agreed.

Risk	Mitigation
Making several changes to adhesion management (coupled with natural weather variability) could mask whether changes are truly addressing root causes.	*Where practicable*, novel changes should be made on a site-specific trial basis for an initial period to quantitatively assess their effectiveness before rolling out. RSSB involvement to bring in practice from other routes/ TOCs.
New drivers (50) starting on Valley Lines entering autumn for the first time.	Use of simulators for low adhesion training, considering benefits/drawbacks against skid-pan training days. Briefings provided by drivers with experience of variable conditions. Regular feedback on adhesion to encourage sustained reporting.
Class 150 WSP installation programme in progress, but not completed before October.	Driver pre-autumn briefing to reflect this.

Reference documents

[1] Railway Group Standard GM/RT 2466 Issue 03 February 2010
[2] Network rail standard NR/SP/TRK0133 Issue 3 June 2006
[3] Arriva Trains Wales, Drivers' Brief, September 2018
[4] Network Rail, Wales & Borders Autumn 2018 Review
[5] TFW Rail Services, Wheel-rail camera test run timing log, December 2018

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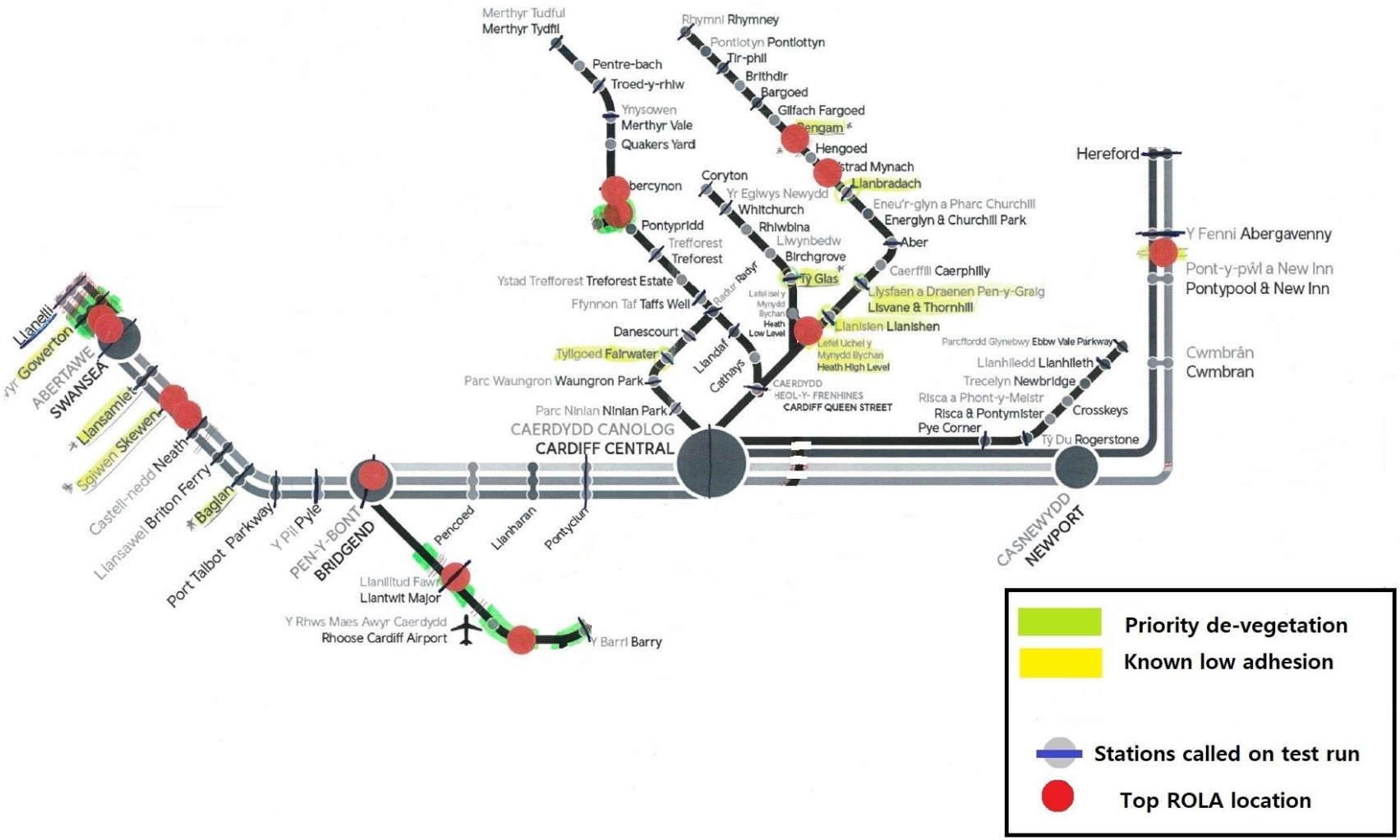
Appendix A: Low adhesion sites covered

Date & time 1	Date & time 2	Location	Line reference	Mileage	Gradient	Pass/stop/ running brake test	Priority de-veg?	SA listed poor adhesion?	SA Newly added 2018?	2018 ROLAs
12/12/2018 20:01	12/12/2018 21:43	Heath High Level	CAR	3m60ch	1/80	RBT	N	Y - Both	N	2
12/12/2018 20:03	12/12/2018 21:41	Llanishen	CAR	4m70ch	1/82	Stop	N	Y - Both	N	0
12/12/2018 20:05	12/12/2018 21:39	Lisvane & Thornhill	CAR	5m00ch	1/82	Stop	N	Y - Both	N	0
12/12/2018 20:16	12/12/2018 21:26	Llanbradach	CAR	10m70ch	1/560	Stop	N	Y - Both	N	0
12/12/2018 20:20	12/12/2018 21:21	Ystrad Mynach	CAR	13m60ch	1/189	Pass	N	N	N/A	2
12/12/2018 20:24	12/12/2018 21:16	Pengam	CAR	16m25ch	1/367	Pass	N	Y - DOWN	Y	2
12/12/2018 22:06	12/12/2018 22:21	Fairwater	RAD	2m60ch	1/284	Pass	N	Y - Both	N	0
12/12/2018 23:42	13/12/2018 00:42	Abergavenny	HNL	21m0ch	1/81	Stop	N	Y - DOWN	N	2
13/12/2018 02:00	13/12/2018 02:44	Llandow	VOG	12m0ch	1/140	Pass	Y (UP)	N	N/A	0
13/12/2018 02:08	13/12/2018 02:42	Llantwit Major	VOG	9m55ch	1/103	Stop	Y	N	N/A	4
13/12/2018 02:12	13/12/2018 02:39	St Athan	VOG	8m60ch	1/147	Pass	Y	N	N/A	0
13/12/2018 02:23	13/12/2018 02:31	Porthkerry	VOG	2m40ch	1/165	Pass	Y	N	N/A	3
13/12/2018 19:43	13/12/2018 19:52	Ty Glas	CRY	1m25ch	0	Stop	N	Y - DOWN	Y	0
14/12/2018 00:08	14/12/2018 02:01	Baglan	SWM2	204m50ch	1/635	Stop	N	Y - Both	Y	0
14/12/2018 00:22	14/12/2018 01:52	Skewen	SWM2	210m30ch	1/92	Stop	N	Y - UP	Y	2
14/12/2018 00:25	14/12/2018 01:49	Llansamlet	SWM2	212m0ch	1/74	Stop	N	Y - DOWN	Y	0
14/12/2018 01:00	14/12/2018 01:26	Gowerton	SWM2	219m40ch	0	Stop	Y	Y - Both	N	1

This table lists the sites of interest covered during the two camera journeys– as mapped.



Routes covered by the camera test runs, showing sites with known low adhesion, priority vegetation management and more than 2 records of low adhesion (ROLAs) submitted.

Appendix B: Camera findings

Reviews of the footage revealed some potential contributing factors – some examples are given here:

Foliage on the ballast at Skewen down platform.

Metal swarf visible when braking, down approach to Llanhilleth.

Wheel slide, up approach to Llanhilleth.

Water on railhead, Cockett tunnel down.

Dust expelled from wheel-rail interface, up direction beyond Pontypridd station.