



C300/410

Western Tunnels & Caverns Project

Final Monitoring Report

TBM DRIVES ~ Tottenham Court Road Station to Fisher Street

CRL Document No. **C300-BFK-C4-RGN-CRT00_ST005-51129**

Contract MDL reference: C14.022

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		[REDACTED]	[REDACTED]	[REDACTED]	

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Stakeholder submission required: LU RfL Purpose of submission: For no objection
 NR LO For information
 DLR Other: _____

This document has been reviewed by the following individual for coordination, compliance, integration and acceptance and is acceptable for transmission to the above stakeholder for the above stated purpose.

Sign: _____ Name: _____ Role: _____ Date: _____
 Sign: _____ Name: _____ Role: _____ Date: _____

2b. Review by Stakeholder (if required):

Stakeholder Organisation	Job Title	Name	Signature	Date	Acceptance
					<input type="checkbox"/>
					<input type="checkbox"/>

3. Acceptance by Crossrail:

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Reviewed/Accepted by: (signature)	[REDACTED]	Print Name: [REDACTED]	Position: [REDACTED] Date: 18/12/15
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1. Purpose and Scope

The purpose of the present document is to provide a summary of the observed movements relative to the TBMs works between Tottenham Court Road Station and Fisher Street Shaft in accordance with the requirements of the Instrumentation and Monitoring Specification KX10, Clauses KX10.2113 and KX10.2114.

KX10.2114 Close-Out Reports

Prior to the de-commissioning of any instrumentation, the *Contractor* shall produce a "close-out" report which summarises the data from the instrumentation the *Contractor* wishes to remove and relates it to the construction activities which produced any observed changes. The report shall demonstrate that the rate of change in the data has reached an acceptably small rate either in accordance with specified rates or, where no rate is specified, in relation to trigger values and an evaluation of any potential residual risks.

This report is one of a series of 5 which cover the TBM drives between Royal Oak Portal and Farringdon Station as listed in Table 1.

Report title: <i>Final and Close Out Monitoring</i>	Report Number: C300-BFK C4-RGN- CRT00 T005-	Eastbound Tunnel		Westbound Tunnel	
		Start Chainage	End Chainage	Start Chainage	End Chainage
Royal Oak Portal to Paddington Station (ROP to PAD)	51232	510	1312	510	1300
Paddington Station to Bond Street Station (PAD to BOS)	51015	1670	3561	1660	3568
Bond Street Station to Tottenham Court Road Station (BOS to TCR)	51016	4187	4672	4159	4679
Tottenham Court Road Station to Fisher Street Shaft & Crossover (TCR to FIS)	51129	5147	5792	5108	5856
Fisher Street Shaft & Crossover to Farringdon Station (FIS to FAR)	51130	6097	6860	6162	6945

Table 1 List of Final / Close Out Reports for TBM drives Royal Oak Portal to Farringdon.

1.1. Executive Summary

This document includes settlement data from instruments on assets (BRE) and from general ground transects (PLP) for the TBM drives between Tottenham Court Road Station and Fisher Street Shaft.

A summary of the monitoring data is provided, with the influence of the two TBM drives identified. The rate of post-construction settlement is compared to the specified limit of 2mm/year and the absolute magnitude of settlement is compared to the trigger values given in the C122 I&M plan. Points where trigger levels have been exceeded are listed.

Information about Thames Water assets is provided, both within the report and in Appendix 3 (summary table). In general, no deflection amber trigger (average of 3 values) has been breached on Thames Water assets.

The transects from which data is presented are listed in Table 2. The locations of the instruments are plotted in Appendix 7 and those from which data is presented are identified. A summary of the final settlements recorded on all BRE and PLP is also given in Appendix 7. The maximum recorded settlement between Tottenham Court Road Station and Fisher Street Shaft. is -19mm.

The transects marked with “*” in Table 2 were de-scoped less than 1 year after the passage of the TBMs. This was agreed during dedicated meetings with CRL and C122 based on analysis of the monitoring data (trends and settlement values).

TBM progress information, supporting documents references, and a summary of claims for building damage (provided by CRL) are provided in Appendices 1, 2 and 4 respectively.

The data from LU assets is presented in Appendix 6. The slides reported in Appendix 6 have been presented to LU, CRL and C122 representatives during dedicated meetings at which further monitoring was de-scoped.

It should be noted that the data from all instruments is available on the UCIMS platform.

Table 2: Transects presented

Sections
Stacey Street PLPs
New Compton Street PLPs
Shaftesbury Avenue PLPs
Monmouth Street PLPs
Neal Street PLPs
Endell Street PLPs
Drury Lane PLPs
Stukeley Street / Macklin Street PLPs
Newton Street PLPs
Earnshaw Street PLPs*
St. Giles High Street West PLPs*
St. Giles High Street East PLPs*
Smart's Place*
High Holborn*
Southampton Place*
Southampton Row*



LU assets
LU13 – Central line West of Holborn

It should be noted that some transects include a large number of measuring points. In these cases, for the sake of clarity, only the points within the zone of influence of the TBMs were included in the charts.

Learning Lega y Document

2. Summary of the observed settlements

2.1. Stacey Street PLPs

2.1.1. Data

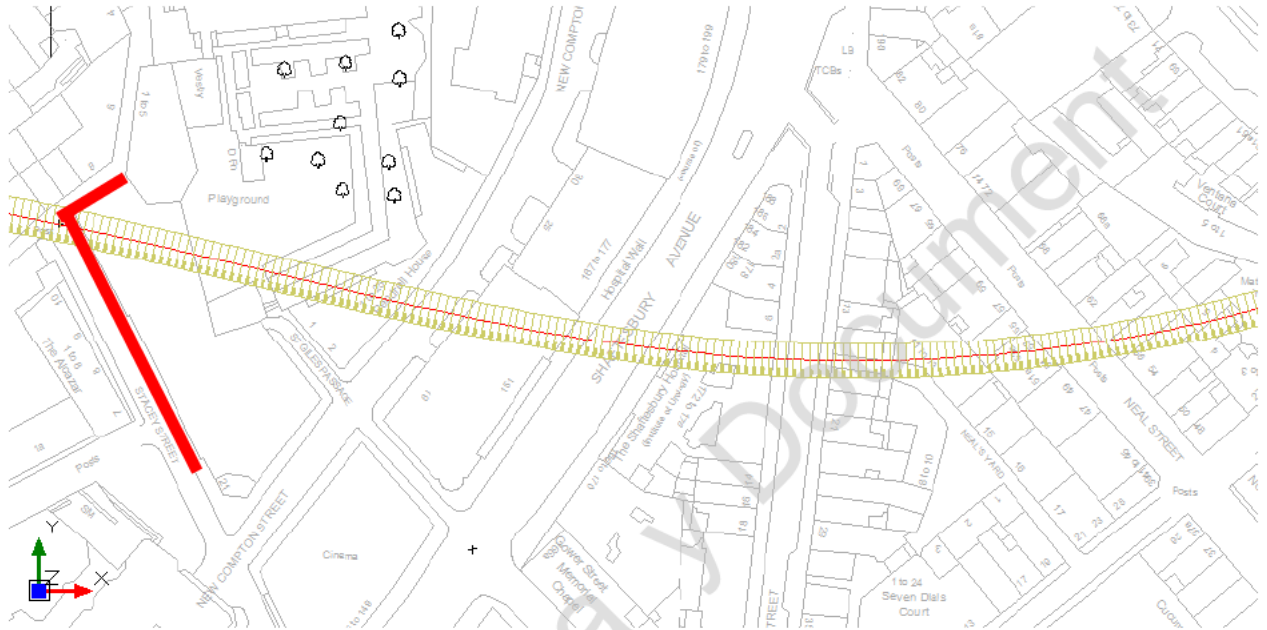


Figure 1: Location

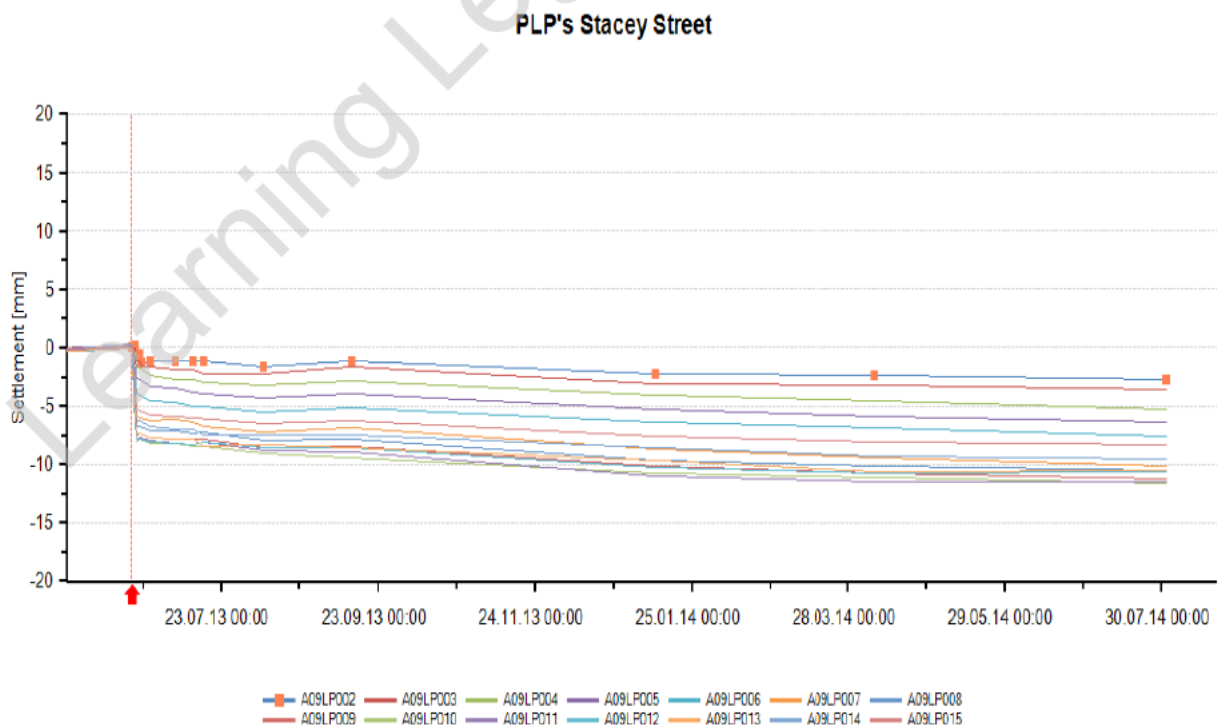


Figure 2: data time-plots: comparison against settlement triggers

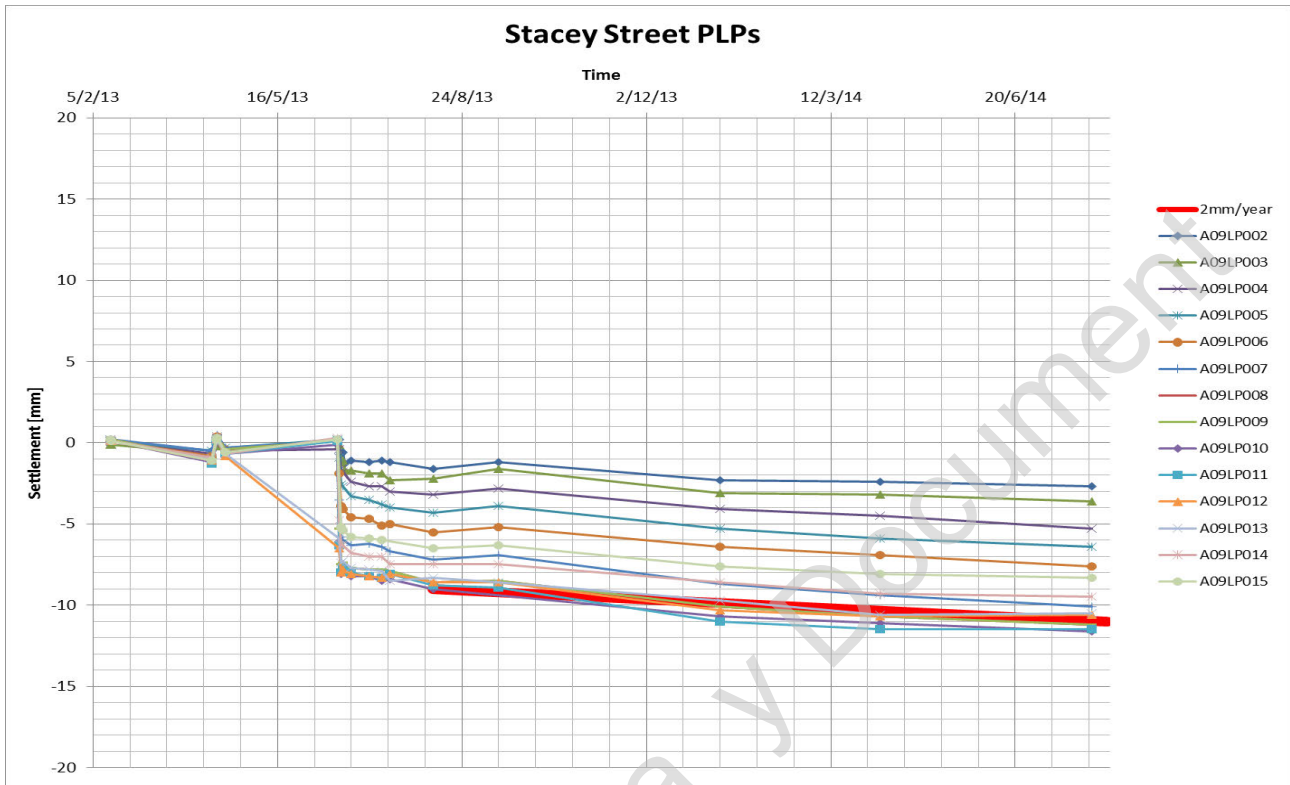


Figure 3: data time-plots - comparison against 2mm/year settlement rate (long-term)

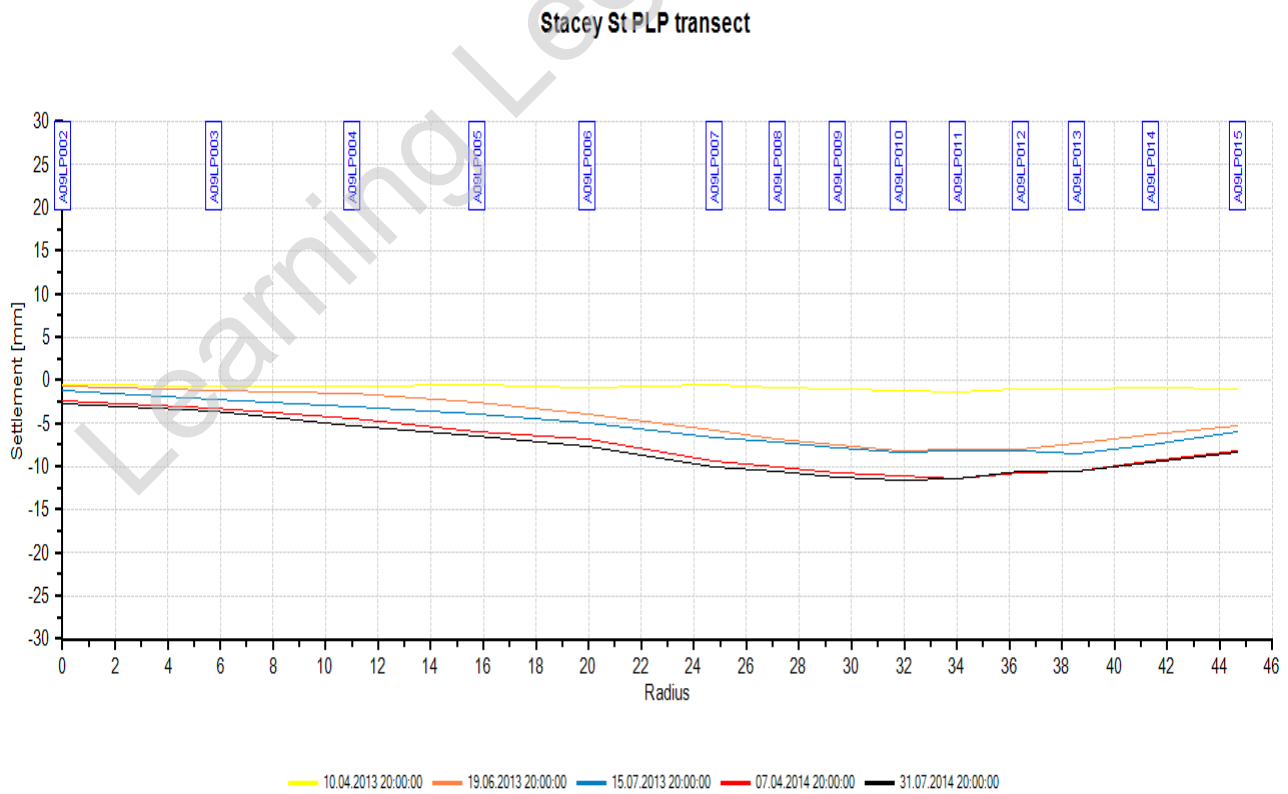


Figure 4: cut

Table 3: Achieved Triggers – settlement and deflection ratio

Point Code	Point type	Achieved Trigger
A09LP009	PLP	Green
A09LP010	PLP	Green
A09LP011	PLP	Green

Worst case deflection ratio (average of 3 values) [1/-]	Trigger
38,700	no

2.1.2. Comments

The points in Stacey Street settled up to approx. 11mm due to the C300 running tunnels excavation. The effect of the WB TBM is visible from the settlement time-plots. Green settlement triggers have been breached on three points, as per Table 3.

The overall long term behaviour appears to be slightly over the 2mm/year, however, the time-plots show a stabilising settlement trend.

The residual risk associated with long term settlements is considered to be negligible.

2.2. New Compton Street PLPs

2.2.1. Data

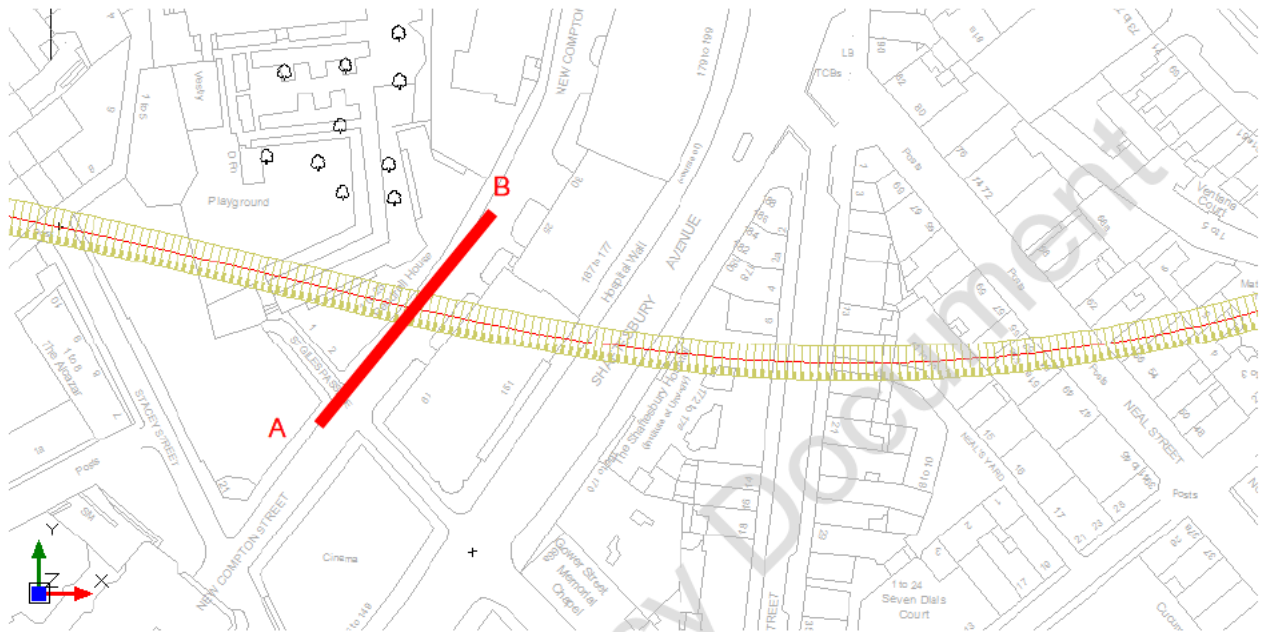


Figure 5: Location

PLP's New Compton Street

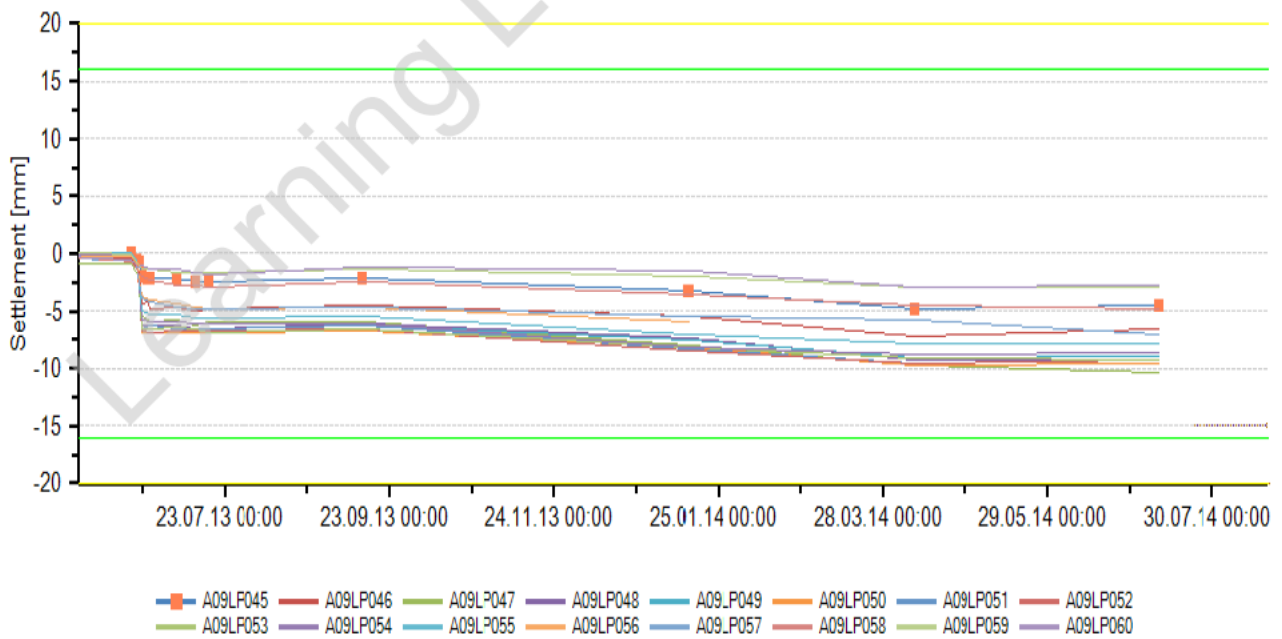


Figure 6: data time-plots: comparison against settlement triggers

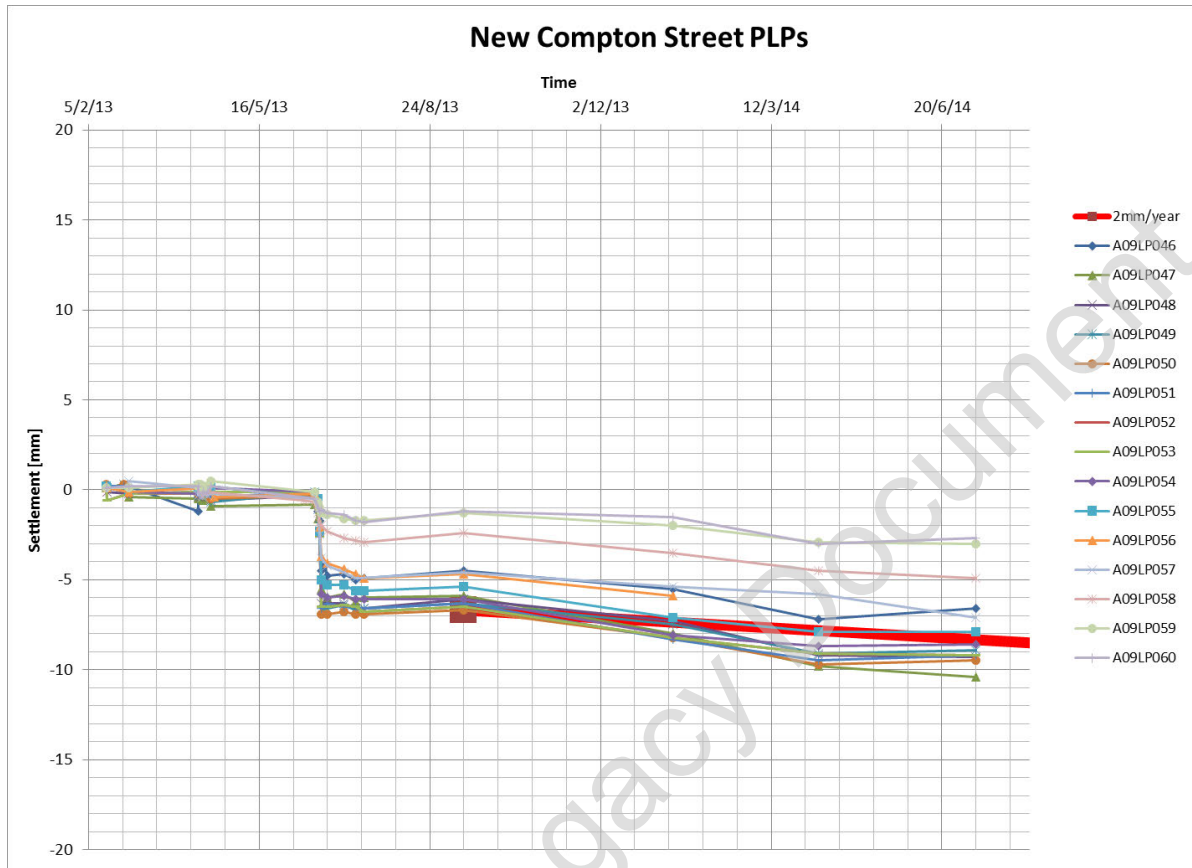


Figure 7: data time-plots - comparison against 2mm/yea settlement rate (long-term)

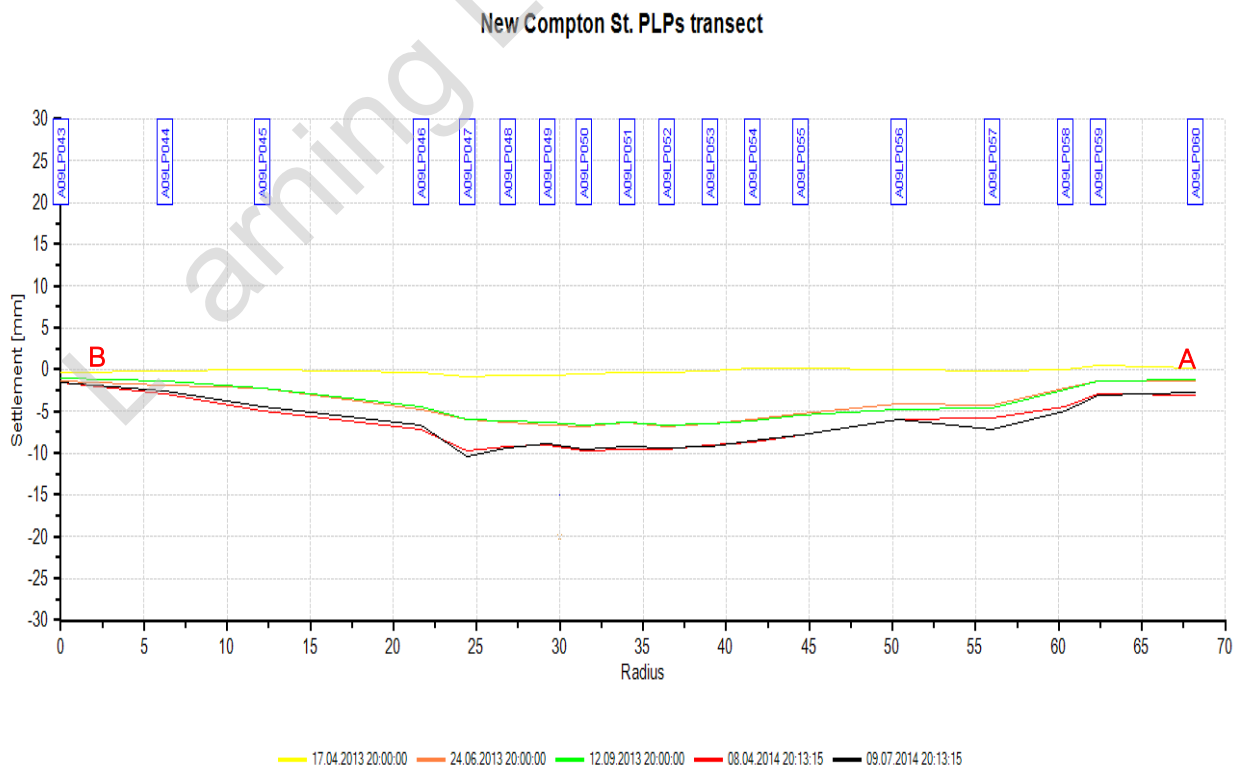


Figure 8: cut

Table 4: Achieved Triggers – deflection ratio

Worst case deflection ratio (average of 3 values) [1/-]	Trigger
9,000	no

2.2.2. Comments

The points in New Compton Street settled up to approx. 11mm due to the C300 running tunnels excavation. The effect of the WB TBM is visible from the settlement time plots. Settlement triggers have not been breached.

The overall long term behaviour appears to be slightly over the 2mm/year, however, the time-plots show a stabilising settlement trend.

The residual risk associated with long-term settlements is considered to be negligible.

2.3. Shaftesbury Avenue PLPs

2.3.1. Data

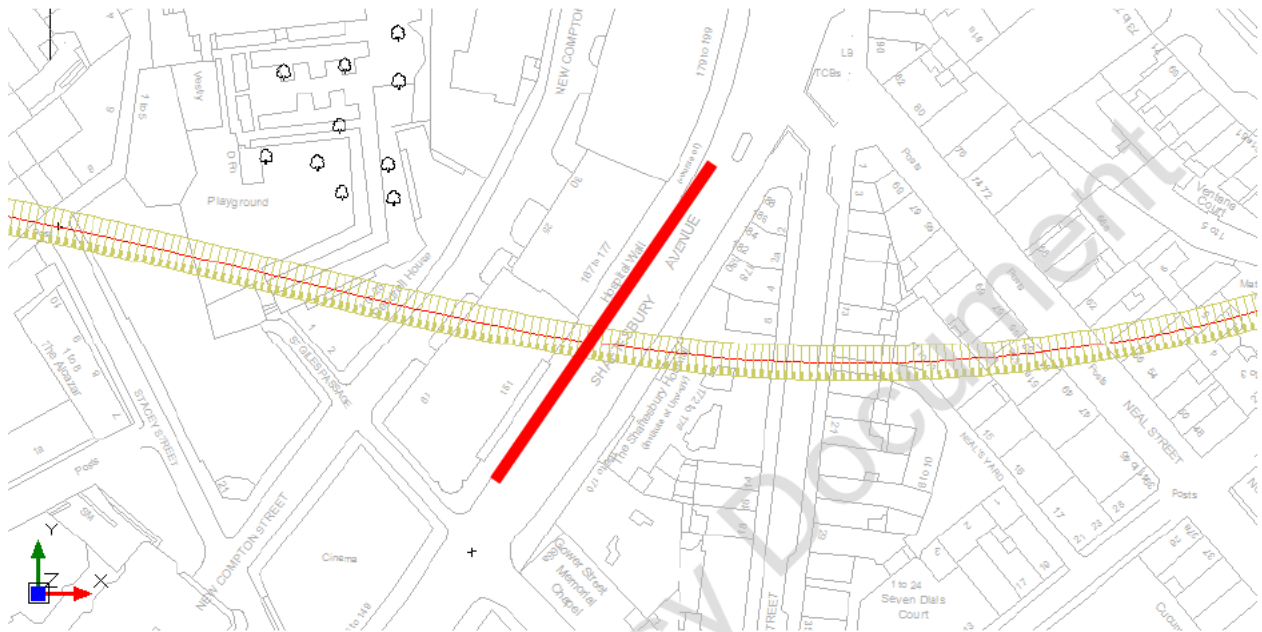


Figure 9: Location

Shaftesbury Avenue (Pipe Subway)

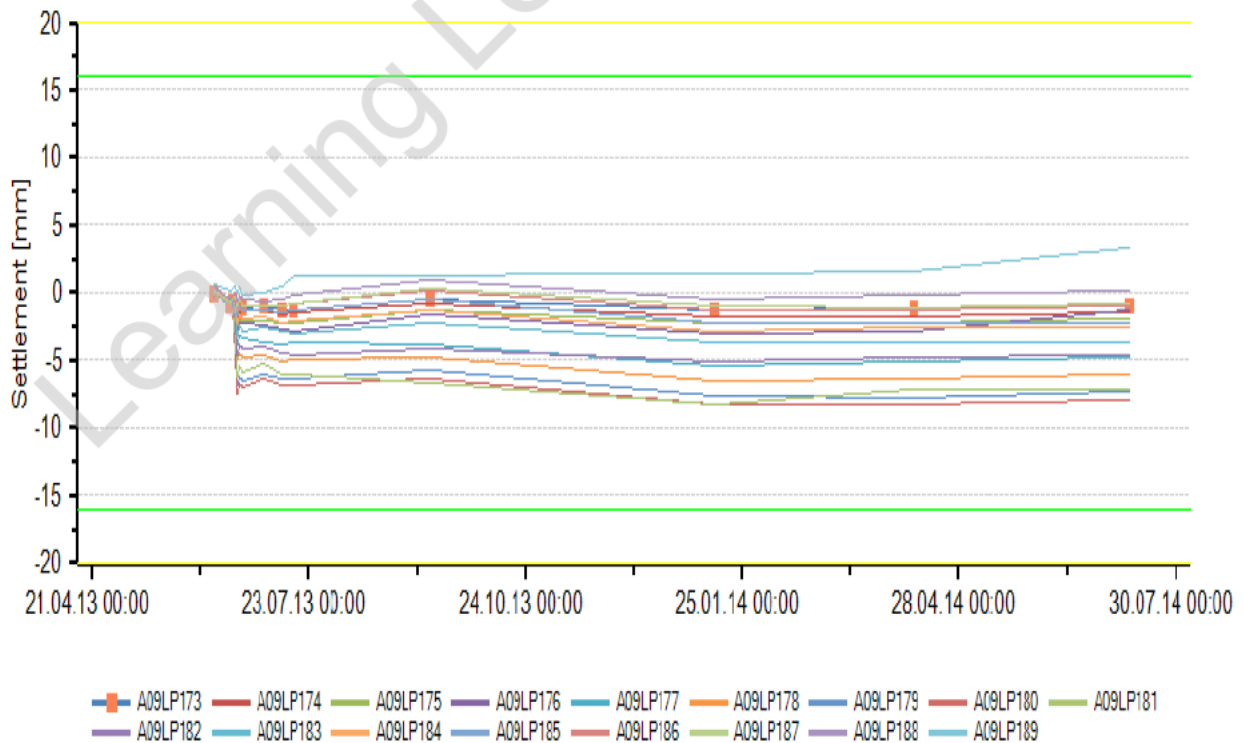


Figure 10: data time-plots - comparison against settlement triggers

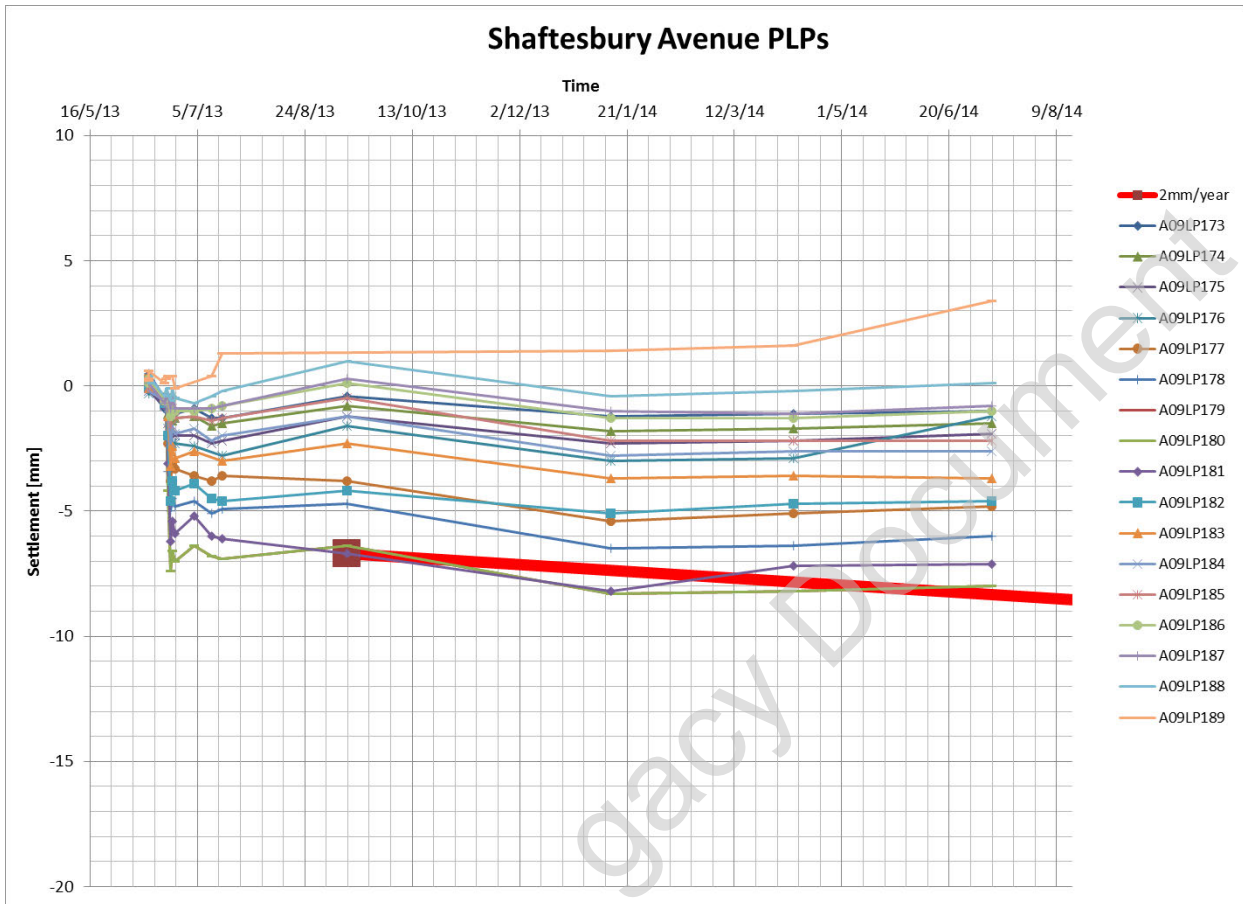


Figure 8: data time-plots - comparison against 2mm/year settlement rate (long-term)

2.3.2. Comments

The points in Shaftesbury Avenue settled up to approx. 8mm due to the C300 running tunnels excavation. The effect of the WB TBM is visible from the settlement time-plots. Settlement triggers have not been breached.

The time-plots are generally showing stabilising settlement trend, and the long term behaviour appears to be less than 2mm/year.

2.4. Monmouth Street PLPs

2.4.1. Data

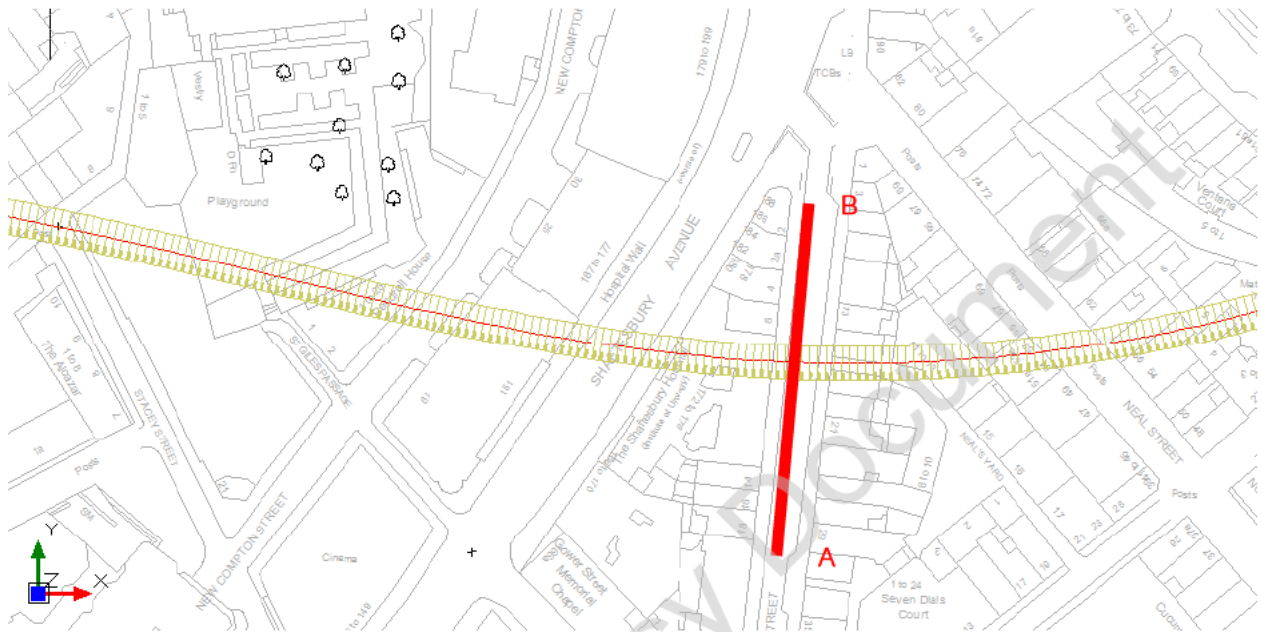


Figure 9: Location

PLP's Monmouth Street

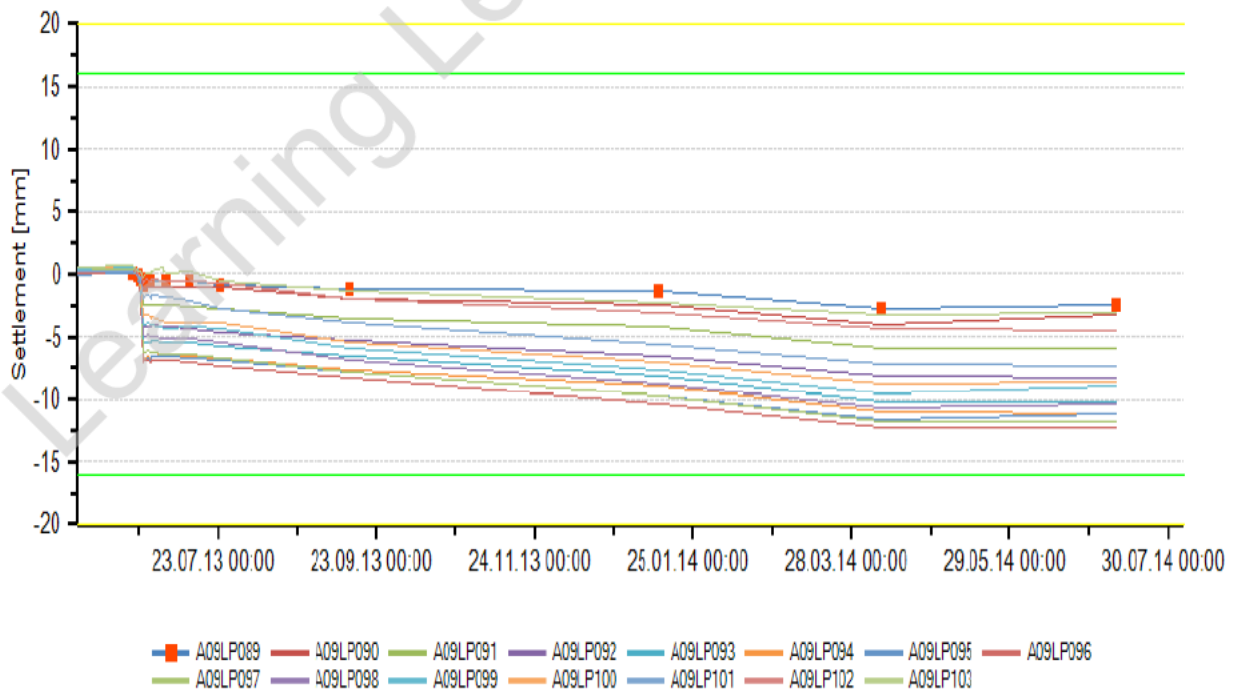


Figure 10: data time-plots - comparison against settlement triggers

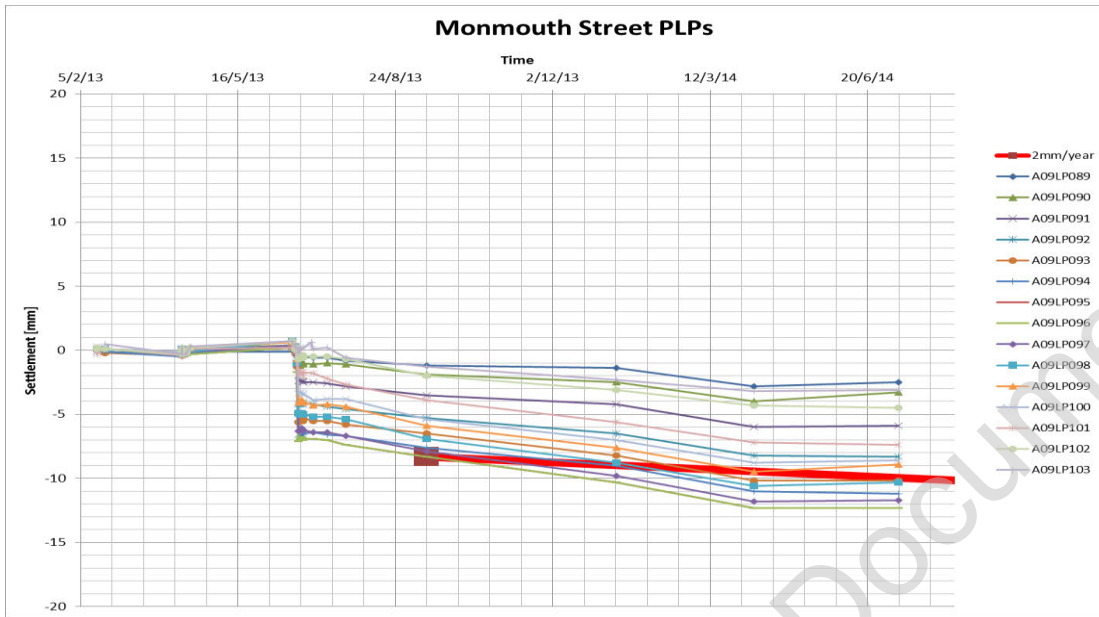


Figure 11: data time-plots - comparison against 2mm/year settlement rate (long-term)

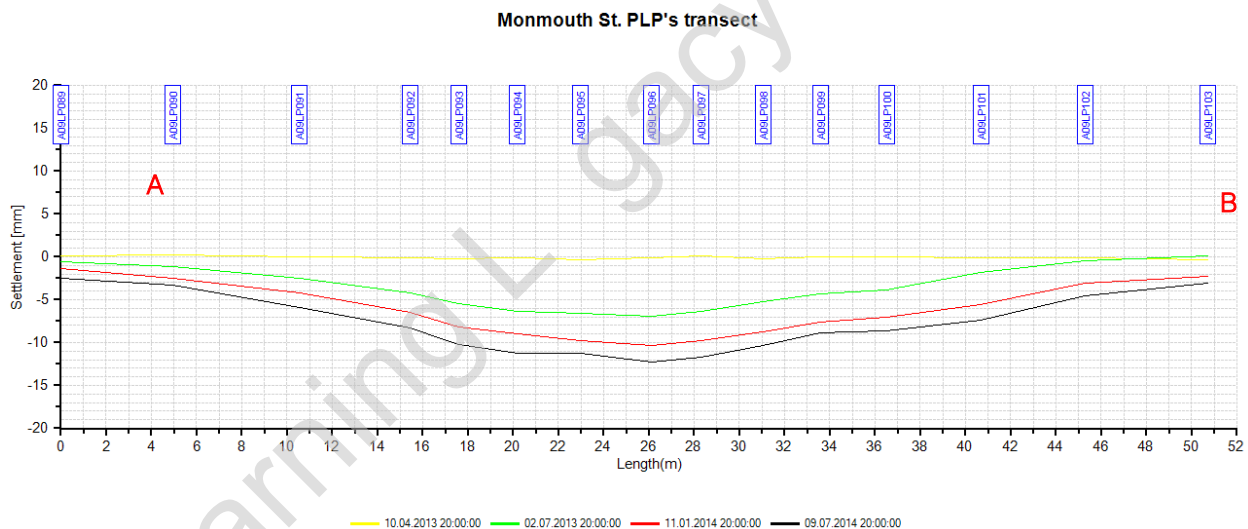


Figure 12: cut

Table 5: Achieved Triggers –deflection ratio

Worst case deflection ratio (average of 3 values) [1/-]	Trigger
5,700	no

2.4.2. Comments

The points in Monmouth Street settled up to approx. 13mm due to the C300 running tunnels excavation. The effect of the WB TBM is visible from the settlement time-plots. Settlement triggers have not been breached.

The overall long term behaviour appears to be slightly over the 2mm/year, however, the time-plots show a stabilising settlement trend.

The residual risk associated with long-term settlements is considered to be negligible.

2.5. Neal Street PLPs

2.5.1. Data



Figure 13: Location

PLP's Neal Street

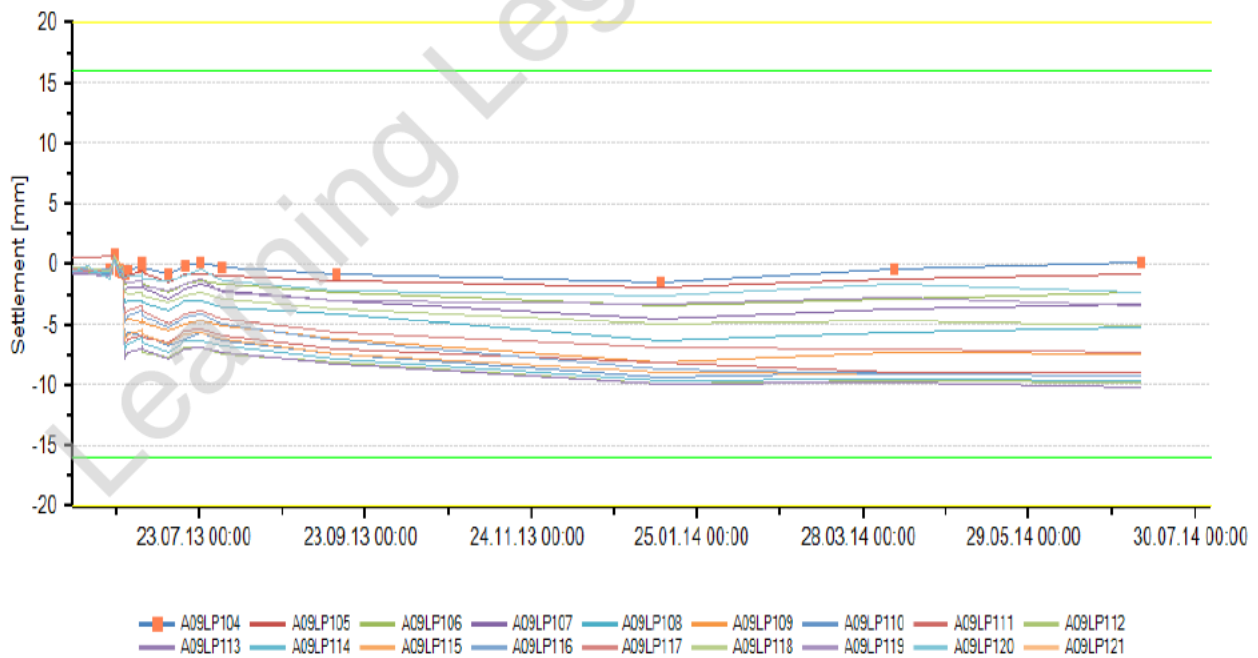


Figure 14: data time-plots - comparison against settlement triggers

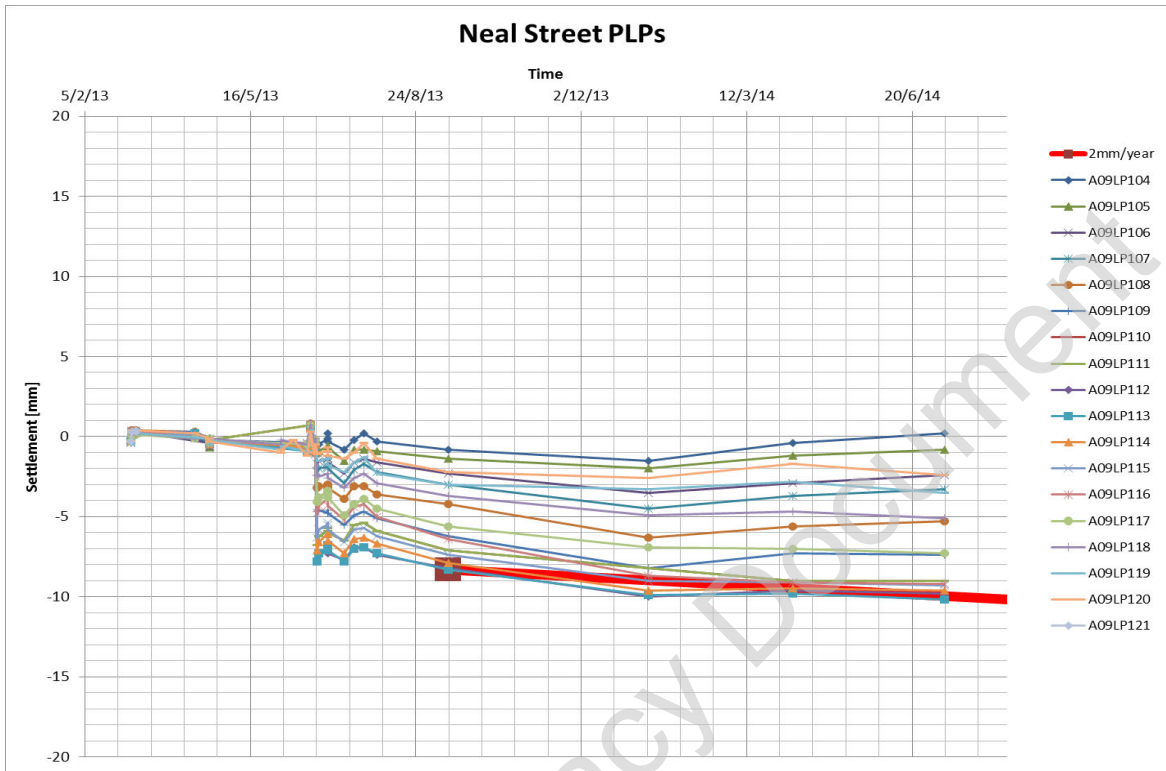


Figure 15: data time-plots - comparison against 2mm/year settlement rate (long-term)

2.5.2. Comments

The points in Neal Street settled up to approx. 10mm due to the C300 running tunnels excavation. The effect of the WB TBM is visible from the settlement time-plots. Settlement triggers have not been breached.

The time-plots are generally showing stabilising settlement trend, and the long term behaviour appears to be less than 2mm/year.

The residual risk associated with long-term settlements is considered to be negligible.

2.6. Endell Street PLPs

2.6.1. Data

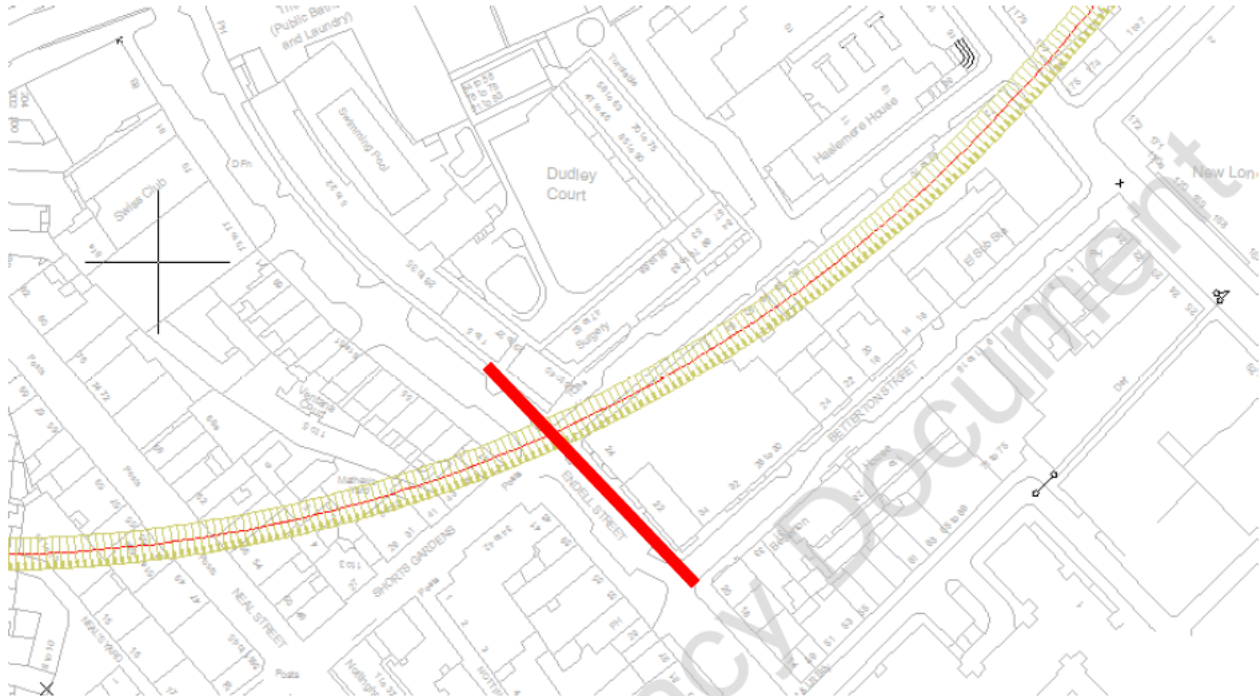


Figure 16: Location

PLP's Endell Street

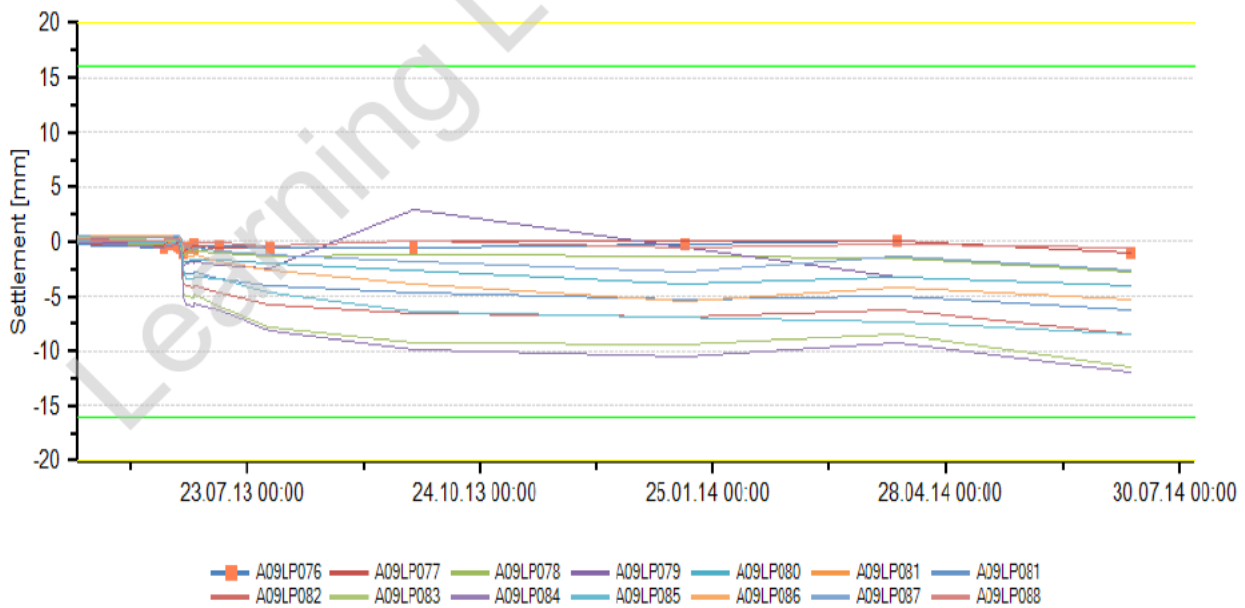


Figure 17: data time-plots - comparison against settlement triggers

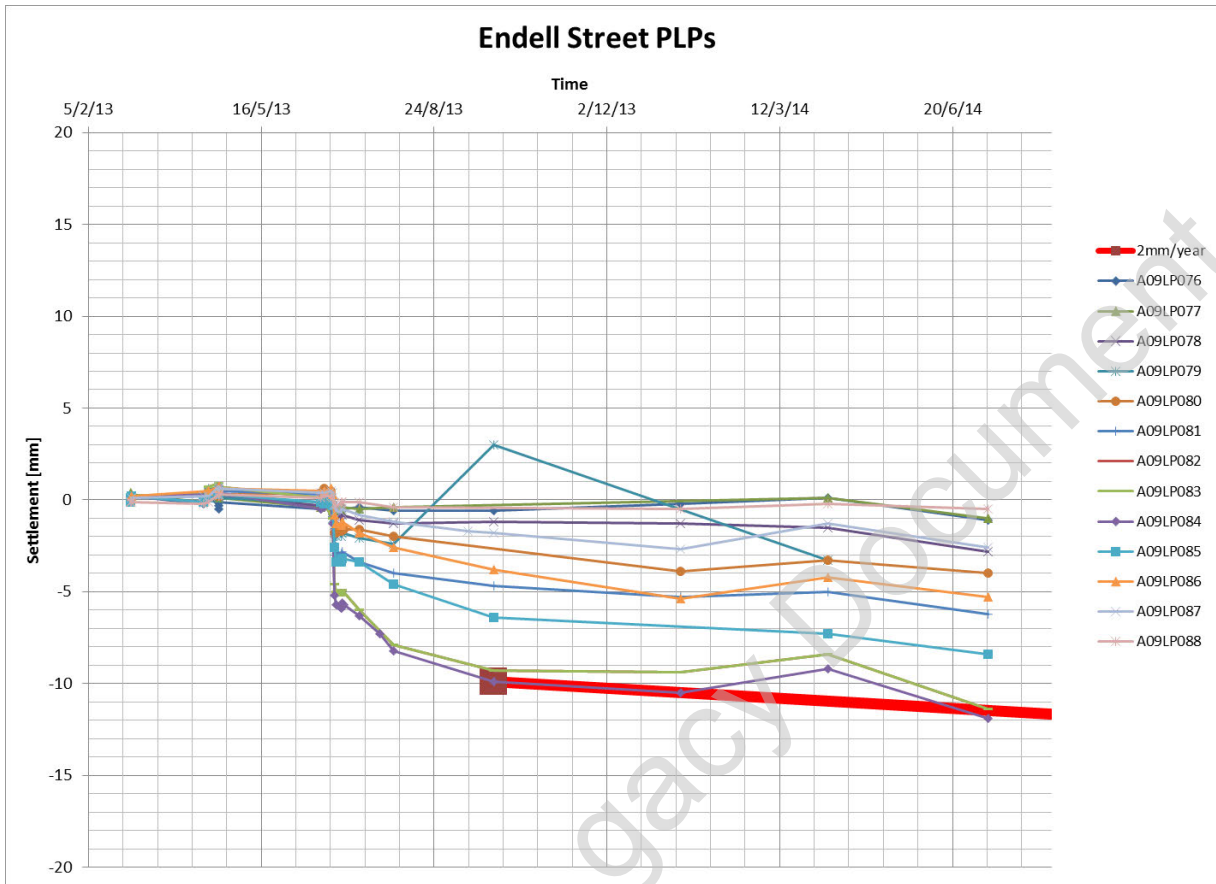


Figure 18: data time-plots - comparison against 2mm/year settlement rate (long-term)

Table 6: Achieved Triggers – deflection ratio

Worst case deflection ratio (average of 3 values) [1/-]	Trigger
13,000	no

2.6.2 Comments

The points in Endell Street settled up to approx. 12mm due to the C300 running tunnels excavation. The effect of the WB TBM is visible from the settlement time-plots. Settlement triggers have not been breached.

The overall long term behaviour appears to be slightly over the 2mm/year, however, the time-plots show a stabilising settlement trend.

The residual risk associated with long-term settlements is considered to be negligible.

2.7. Drury Lane PLPs

2.7.1. Data

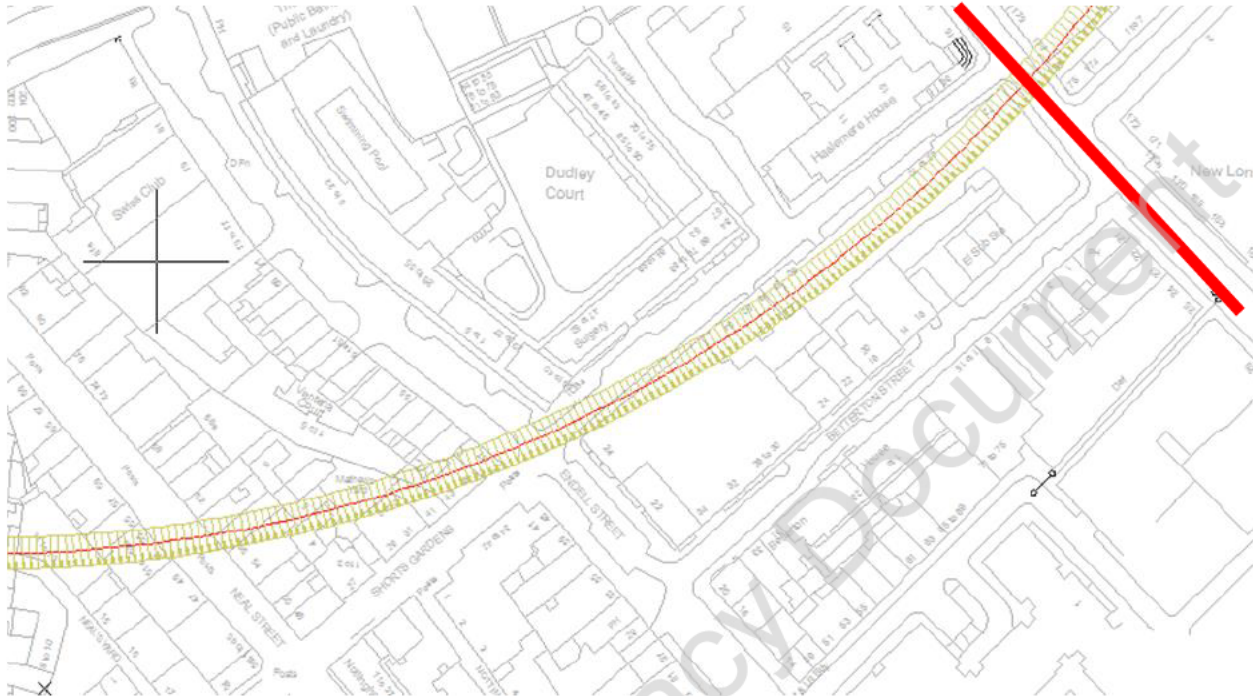


Figure 19: Location

PLP's Drury Lane

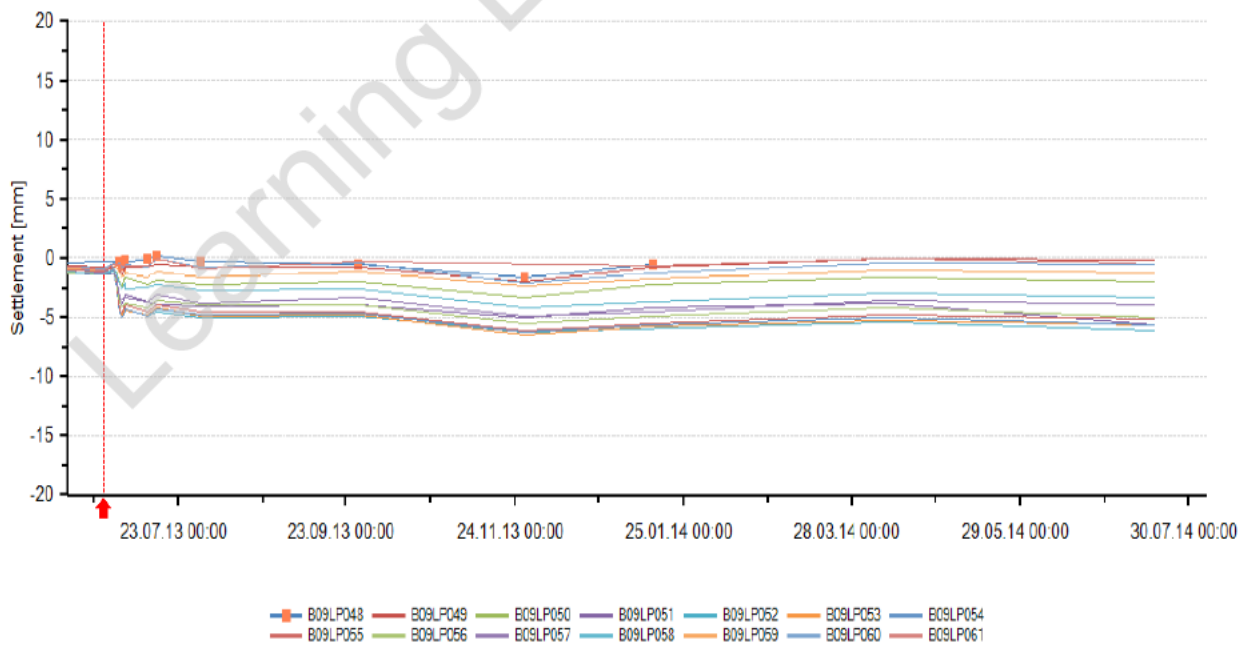


Figure 20: data time-plots - comparison against settlement triggers

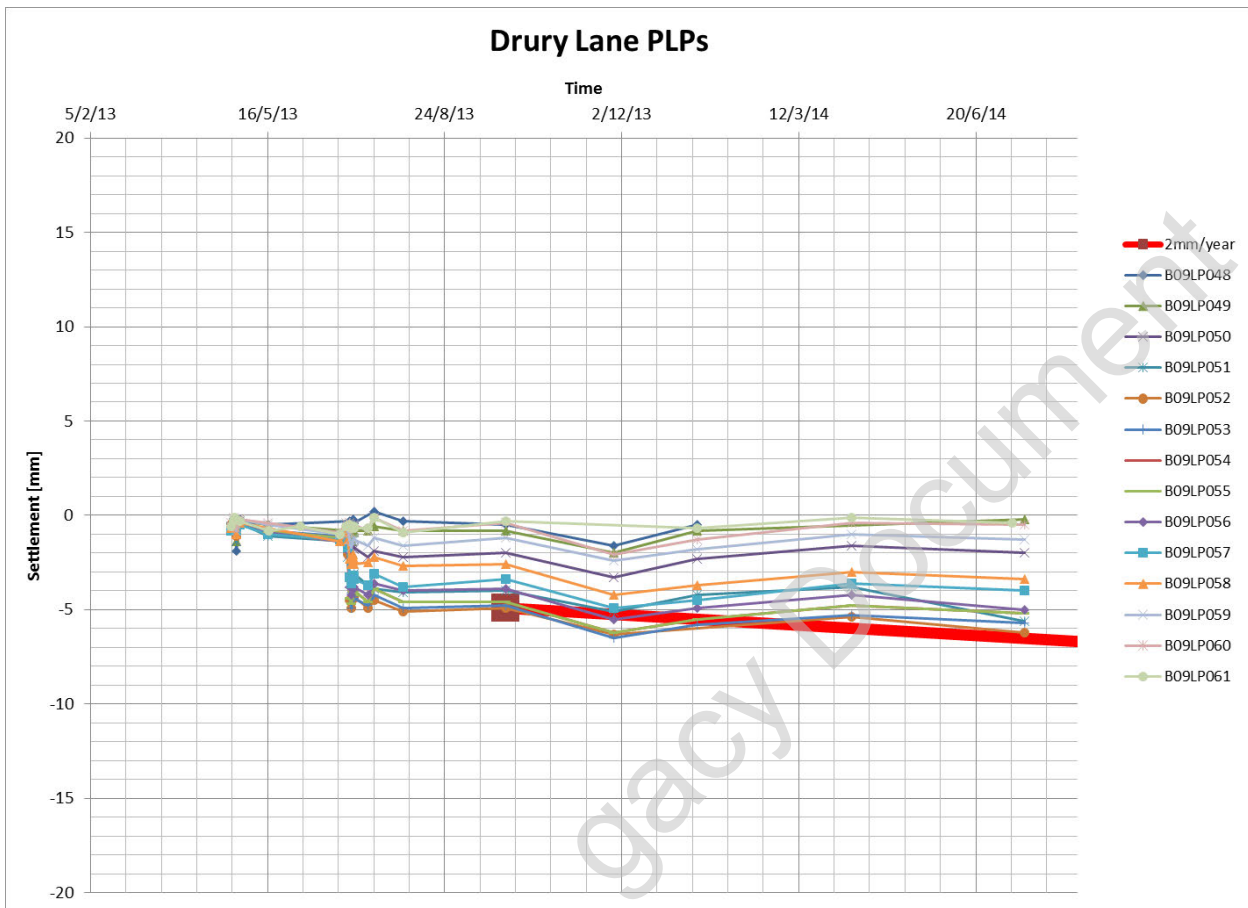


Figure 21: data time-plots - comparison against 2mm/year settlement rate (long-term)

2.7.2. Comments

The points in Drury Lane settled up to approx. 7mm due to the C300 running tunnels excavation. The effect of the WB TBM is visible from the settlement time-plots. Settlement triggers have not been breached.

The time plots are generally showing stability, and the long term behaviour appears to be less than 2mm/year.

The residual risk associated with long-term settlements is considered to be negligible.

2.8. Stukeley Street / Macklin Street PLPs

2.8.1. Data

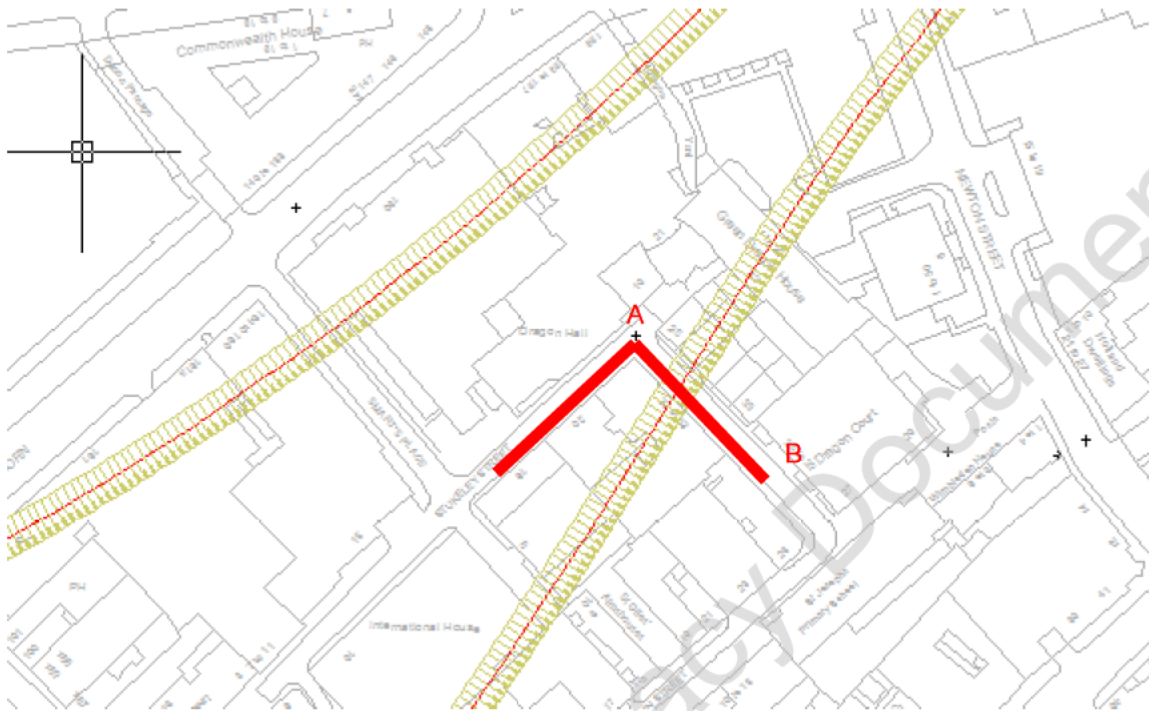


Figure 22: Location

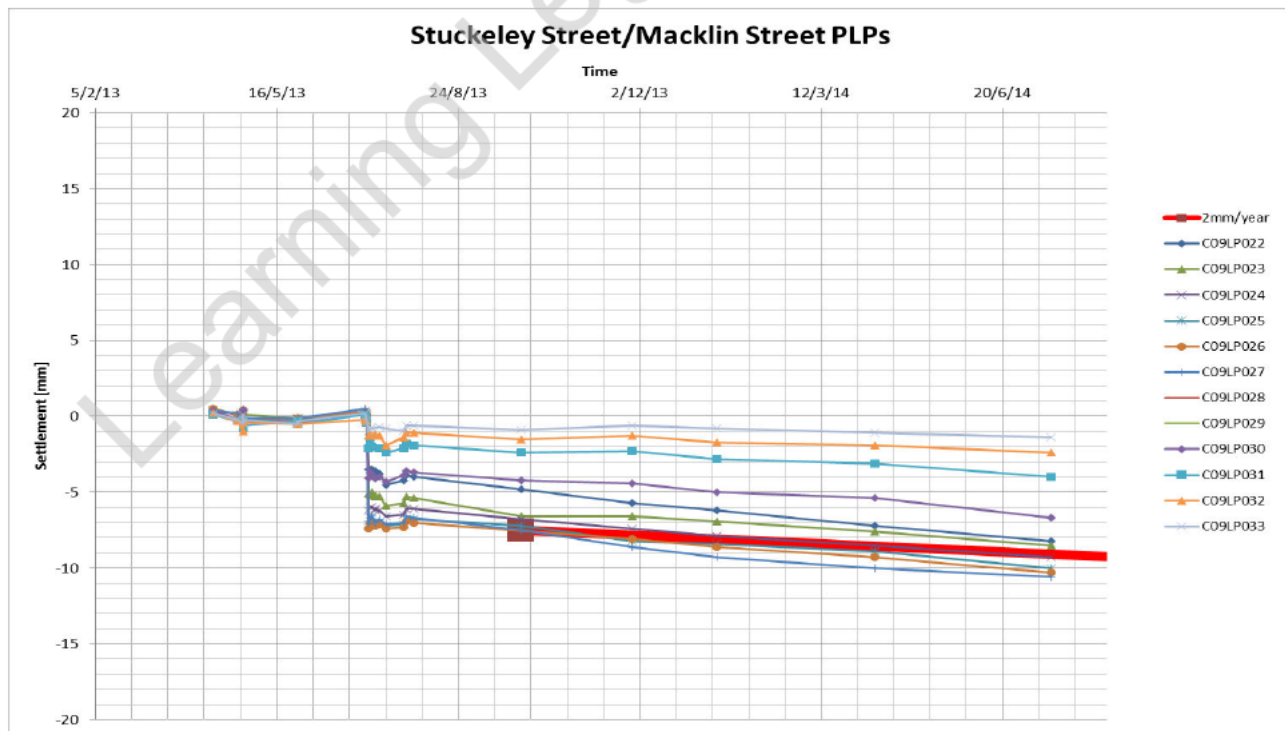


Figure 23: data time-plots - comparison against 2mm/year settlement rate (long-term)

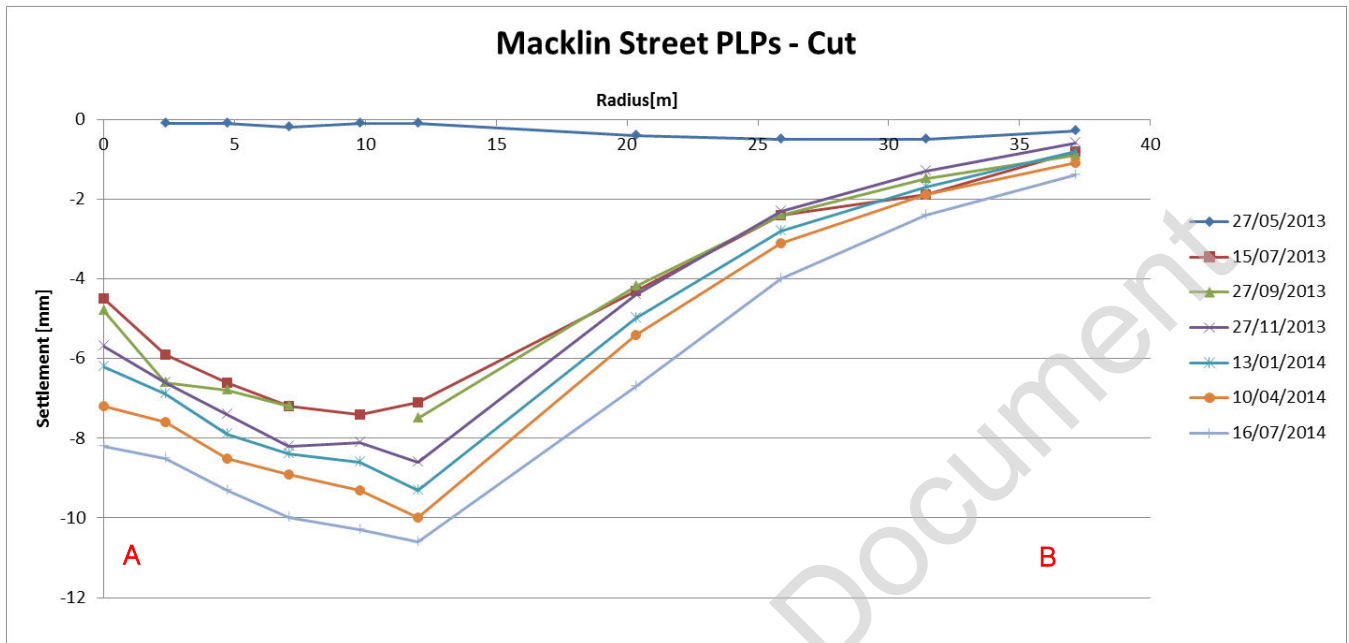


Figure 24: Macklin Street Cut

Table 7: Achieved Triggers –deflection ratio

Worst case deflection ratio (average of 3 values) [1/-]	Trigger
4.8 E+04	no

2.8.2. Comments

The points in Macklin Street settled up to approx. 11mm due to the C300 running tunnels excavation. The effect of the WB TBM is visible from the settlement time-plots. Settlement triggers have not been breached.

The time plots are generally showing stability, and the long term behaviour appears to be slightly over 2mm/year.

The residual risk associated with long-term settlements is considered to be negligible.

2.9. Newton Street PLPs

2.9.1. Data

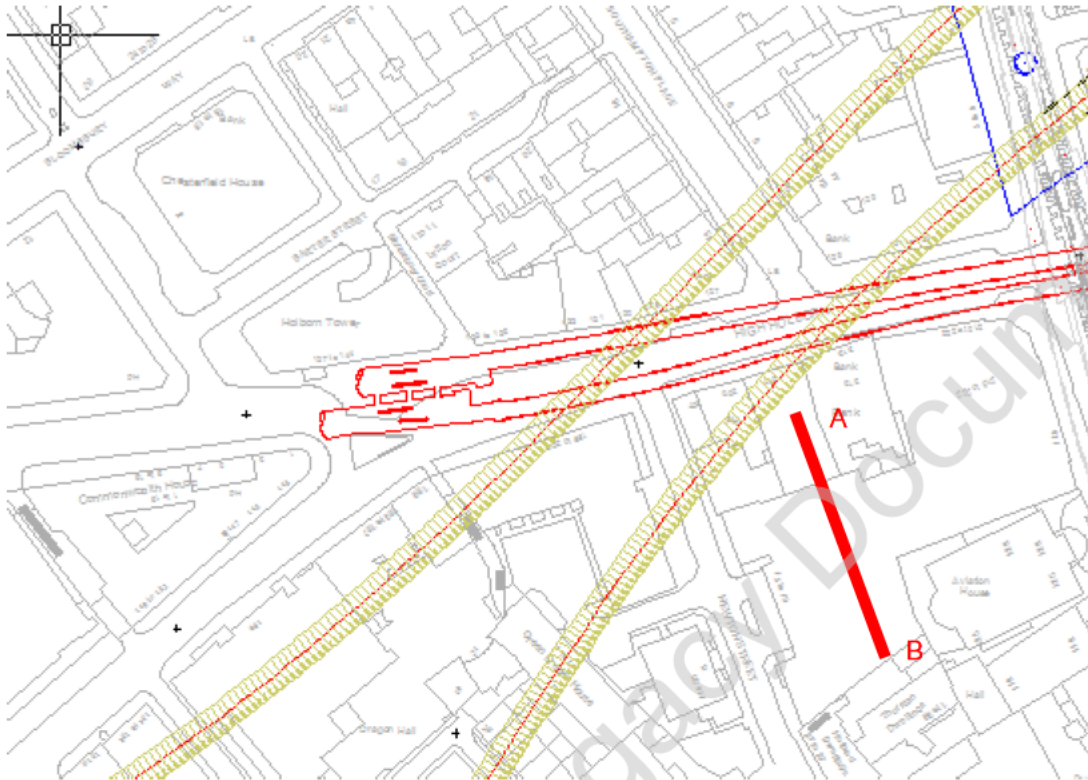


Figure 25: Location

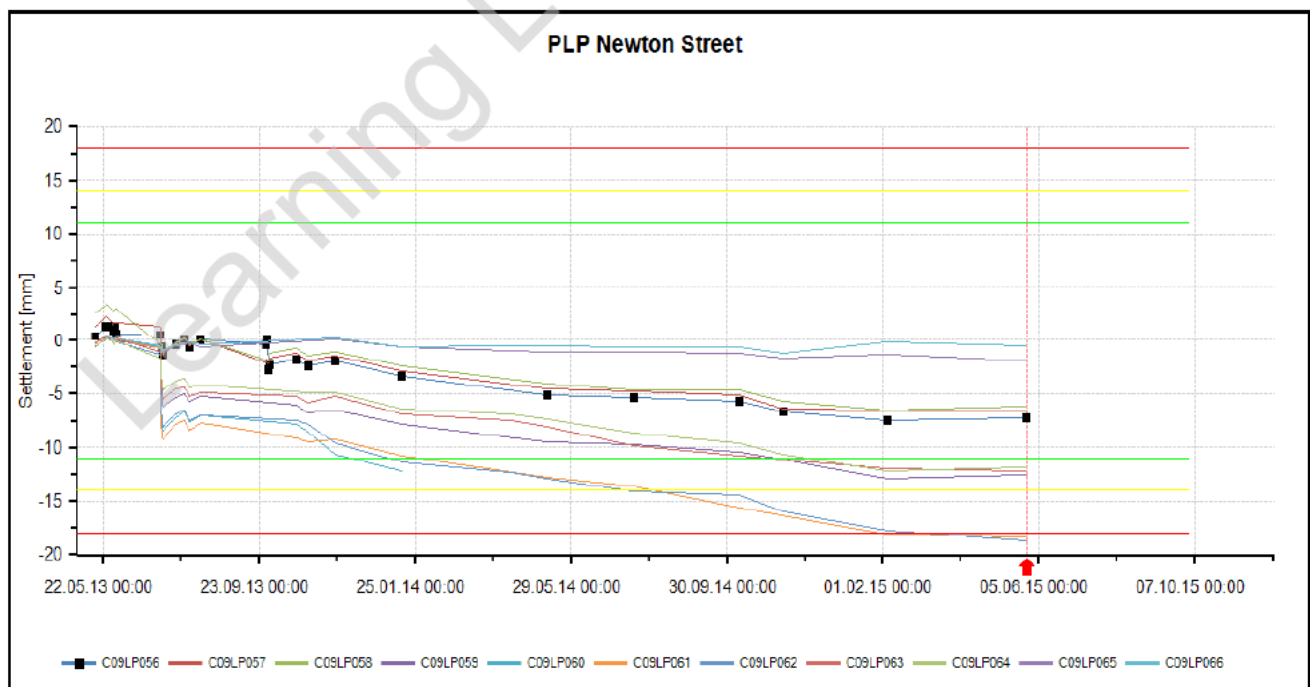


Figure 26: data time-plots - comparison against settlement triggers

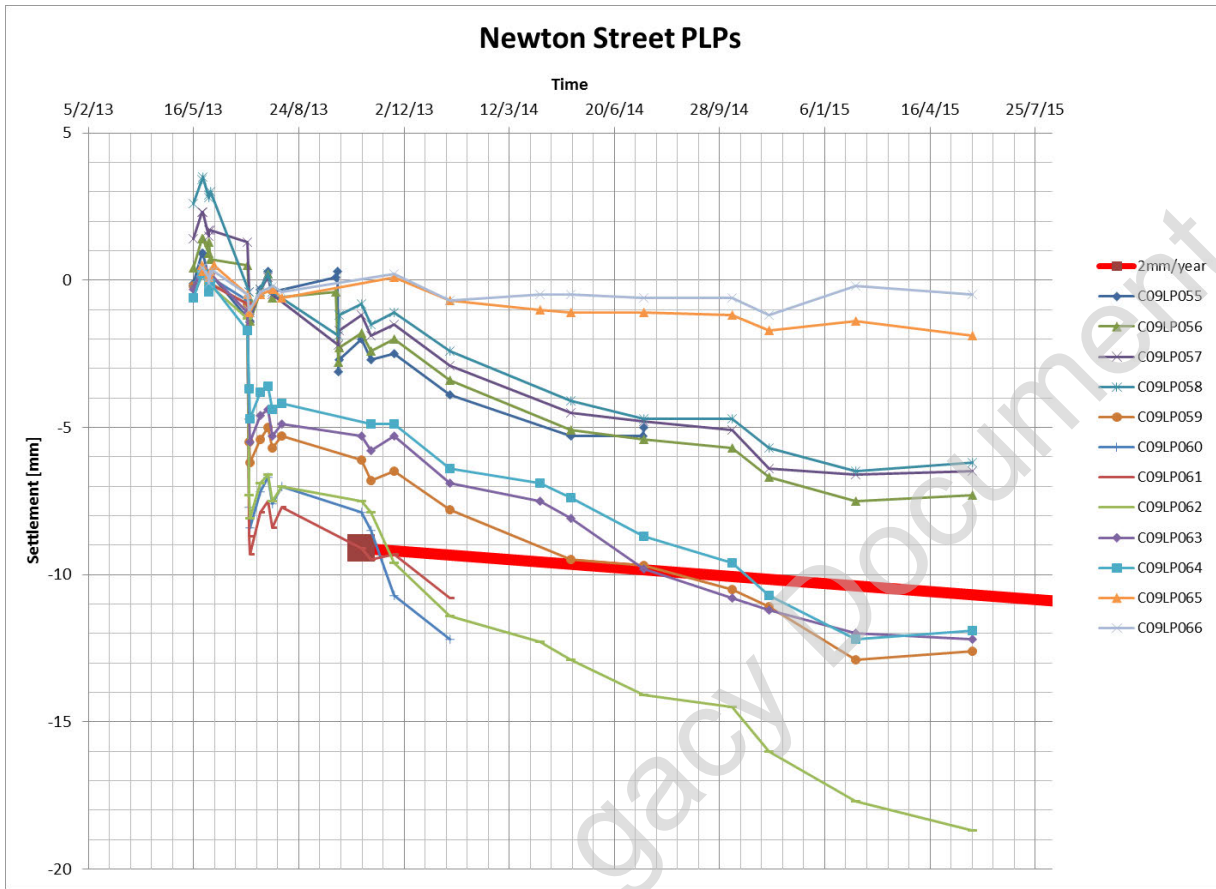


Figure 27: data time-plots - comparison against 2mm/year settlement rate (long-term)

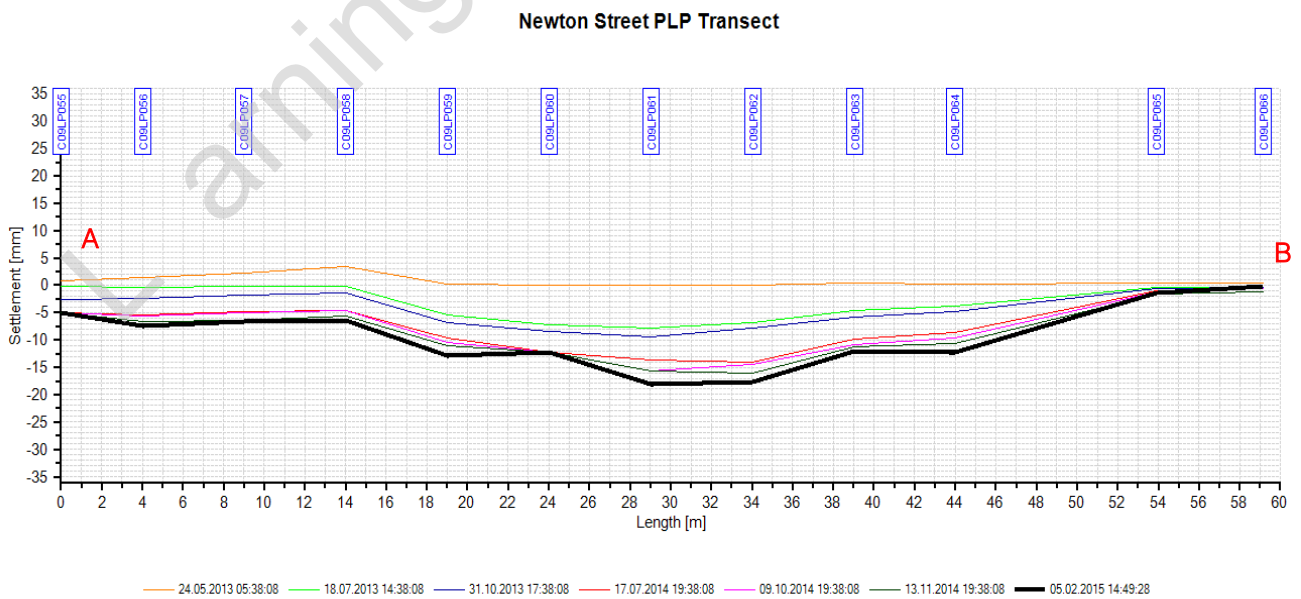


Figure 28: Newton St. PLPs cut

Table 8: Achieved Triggers – settlements and deflection ratio

Point Code	Point type	Achieved Trigger
C09LP059	PLP	Green
C09LP060	PLP	Green
C09LP061	PLP	Red
C09LP062	PLP	Red
C09LP063	PLP	Green
C09LP064	PLP	Green
C09LB015	BRE	Red
C09LB014	BRE	Amber
C09LB013	BRE	Amber
C09LB050	BRE	Green

Worst case deflection ratio (average of 3 values) [1/]	Trigger
3,600	no

2.9.2. Comments

The points in Newton Street settled up to approx. 1mm due to the C300 running tunnels excavation. The effect of the WB TBM is visible from the settlement time-plots. Settlement triggers have been breached in three points.

The time-plots are generally showing some settlement trend, and the long term behaviour appears to be still over 2mm/year.

The residual risk associated with long-term settlements is considered to be negligible. It should be noted some renovation works were on-going within the building on the east side of the road at the corner with High Holborn during the long-term monitoring period.

2.10. Earnshaw Street PLPs ONLY EASTBOUND

2.10.1. Data

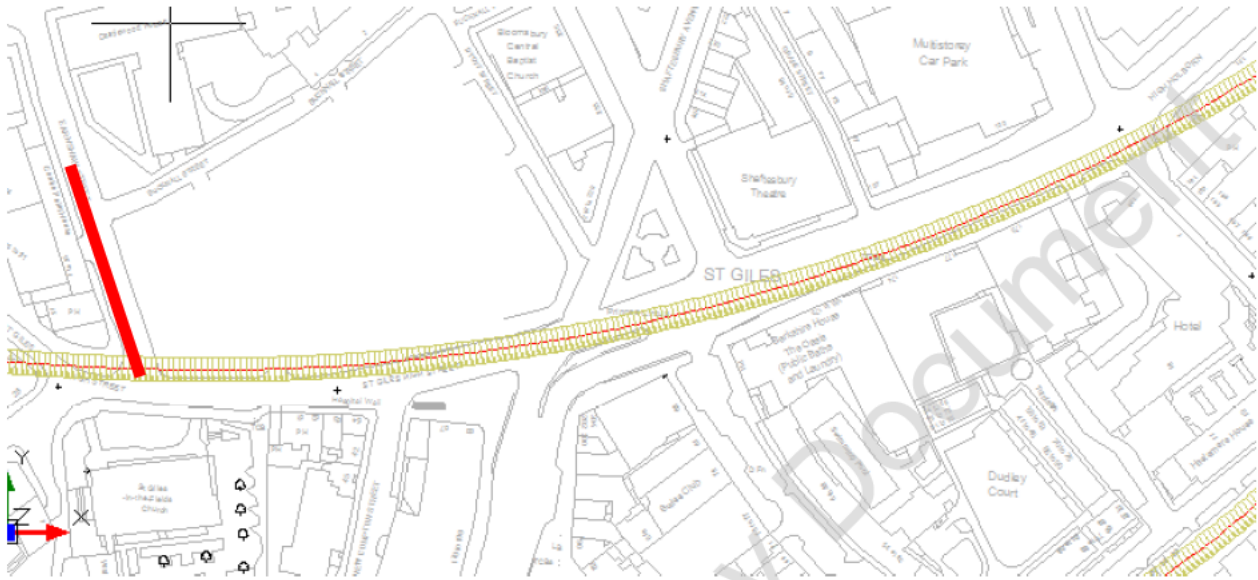


Figure 29: location

PLPs Earnshaw Street West

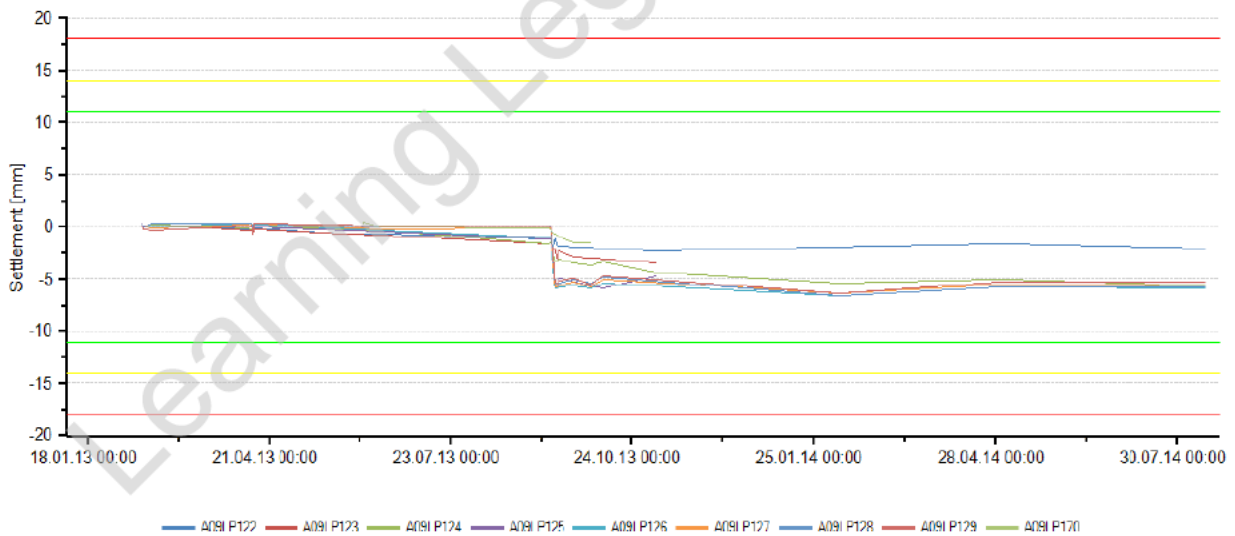


Figure 30: data time-plots - comparison against settlement triggers/residual

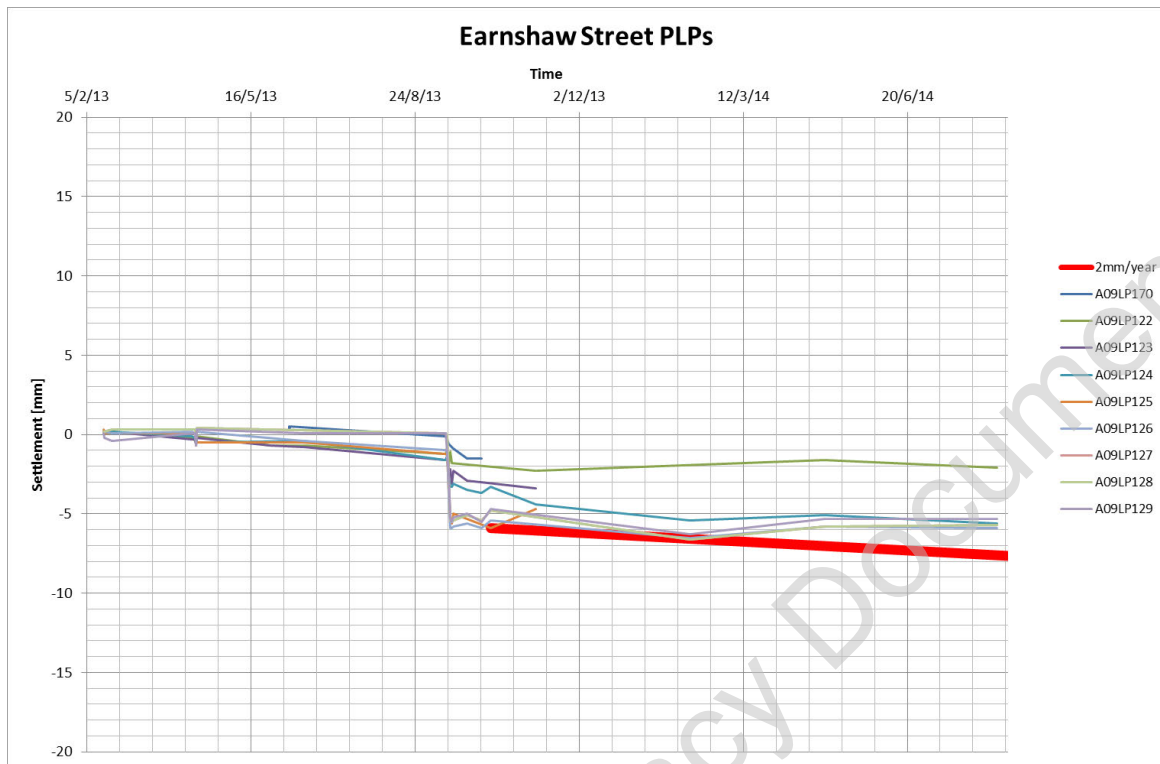


Figure 31: data time-plots - comparison against 2mm/year settlement rate (long-term)

2.10.2. Comments

The points in Earnshaw Street settled up to approx. 6mm due to the C300 running tunnels excavation. The effect of the EB TBM is visible from the settlement time-plots. Settlement triggers have not been breached

The time-plots are generally showing stability, and the long term behaviour appears therefore to be within 2mm/year

The residual risk associated with long-term settlements is considered to be negligible.

2.11. St. Giles High Street West PLPs

2.11.1. Data

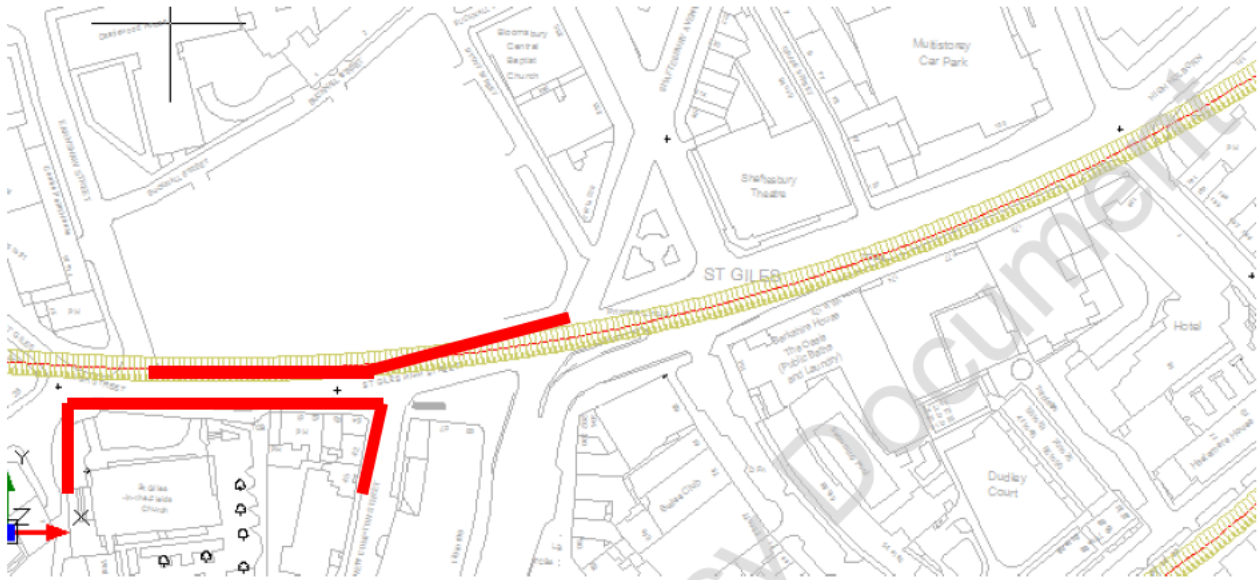


Figure 32: location

PLPs St. Giles High Street North

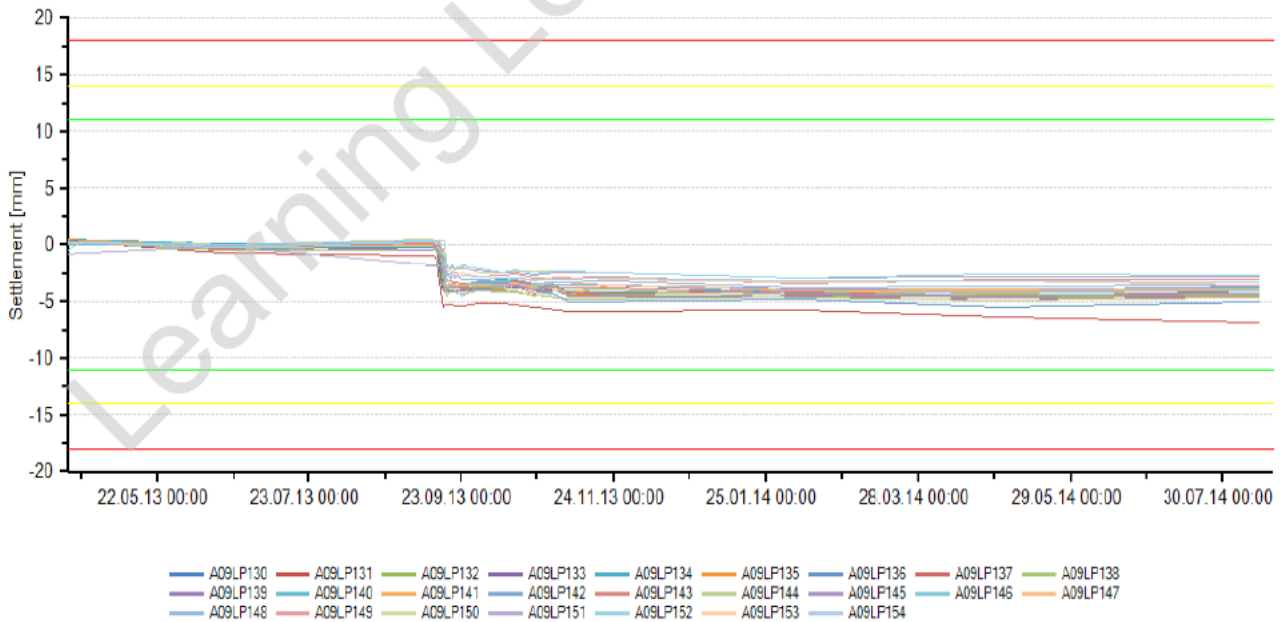


Figure 33: data time-plots - comparison against settlement triggers

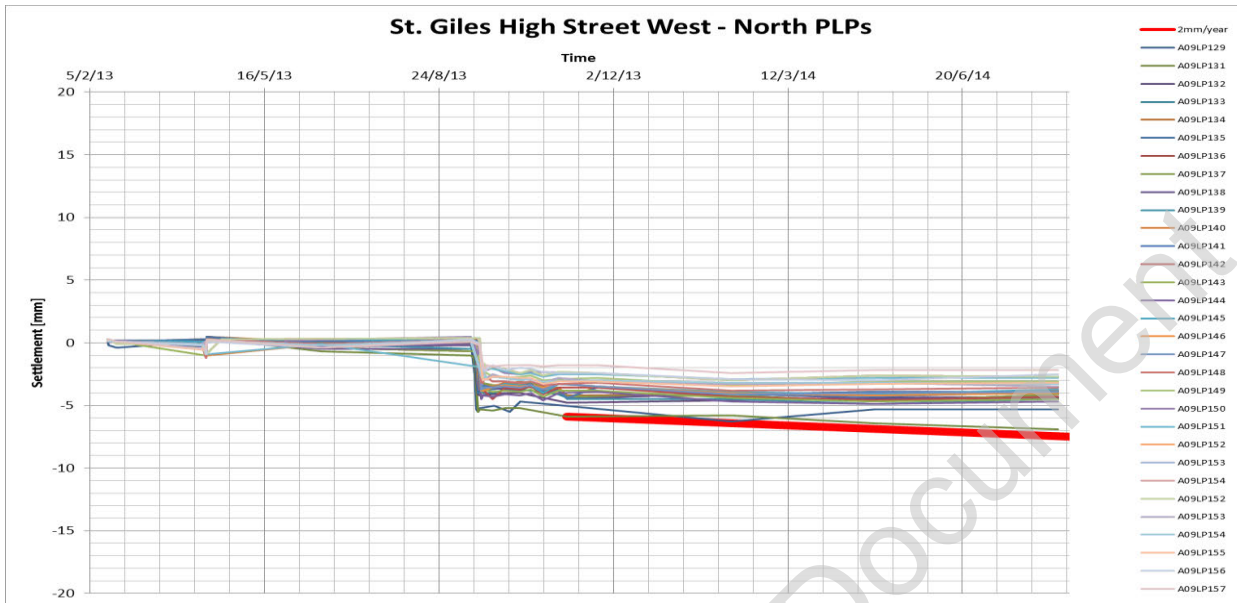


Figure 34: data time-plots - comparison against 2mm/year settlement rate (long-term)

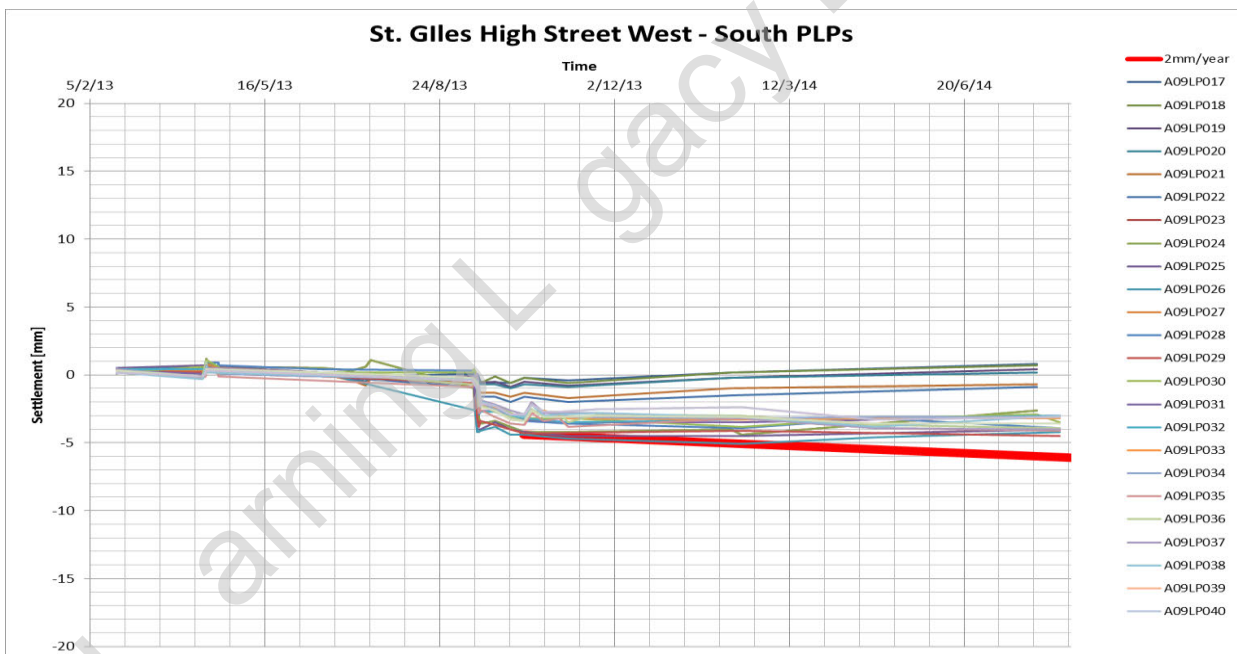


Figure 35: data time-plots - comparison against 2mm/year settlement rate (long-term)

2.11.2. Comments

The points in Saint Giles High Street West settled up to approx. 5mm due to the C300 running tunnels excavation. The effect of the EB TBM is visible from the settlement time-plots. Settlement triggers have not been breached

The time-plots are generally showing stability, and the long term behaviour appears therefore to be within 2mm/year.

The residual risk associated with long-term settlements is considered to be negligible.

2.12. St. Giles High Street East PLPs

2.12.1. Data

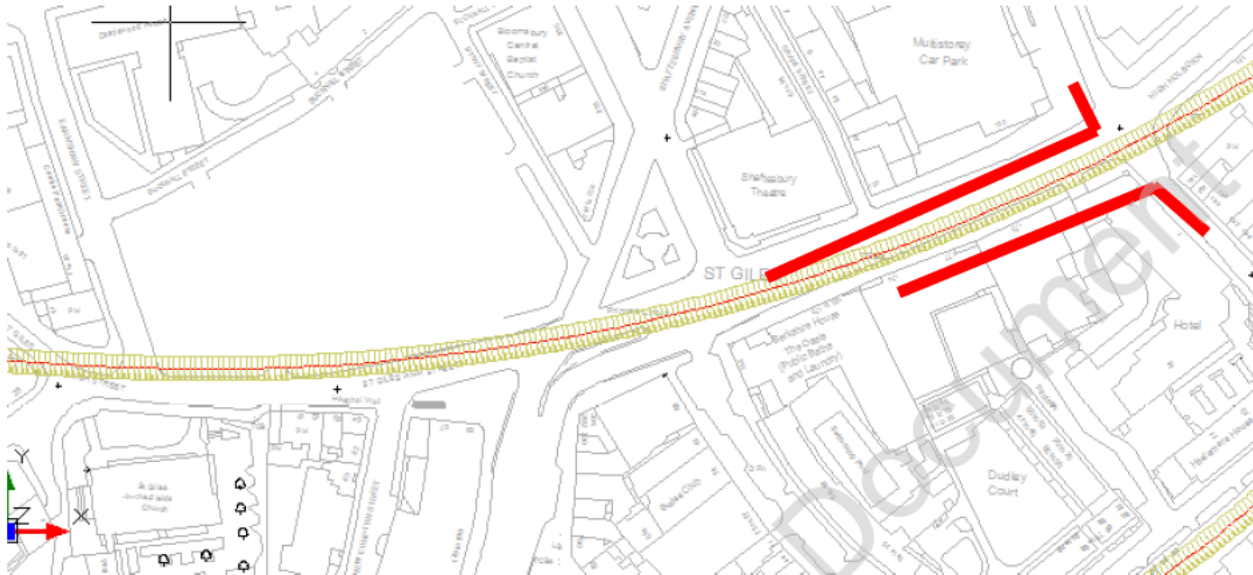


Figure 36: location

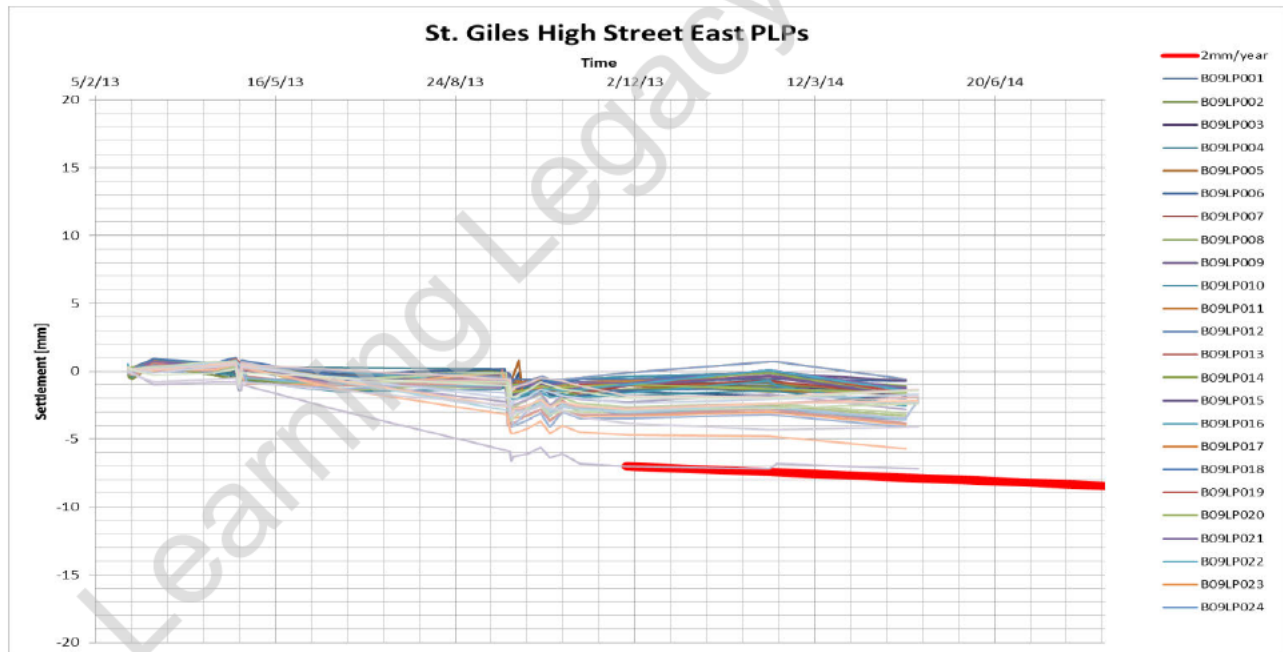


Figure 37: data time-plots - comparison against 2mm/year settlement rate (long-term)

2.12.2. Comments

The points in Saint Giles High Street East settled up to approx. 7mm due to the C300 running tunnels excavation. The effect of the EB TBM is visible from the settlement time-plots. Settlement triggers have not been breached

The time-plots are generally showing very slow settlement trend on some point; the long term behaviour is within 2mm/year.

The residual risk associated with long-term settlements is considered to be negligible.

2.13. Smart's Place

2.13.1. Data

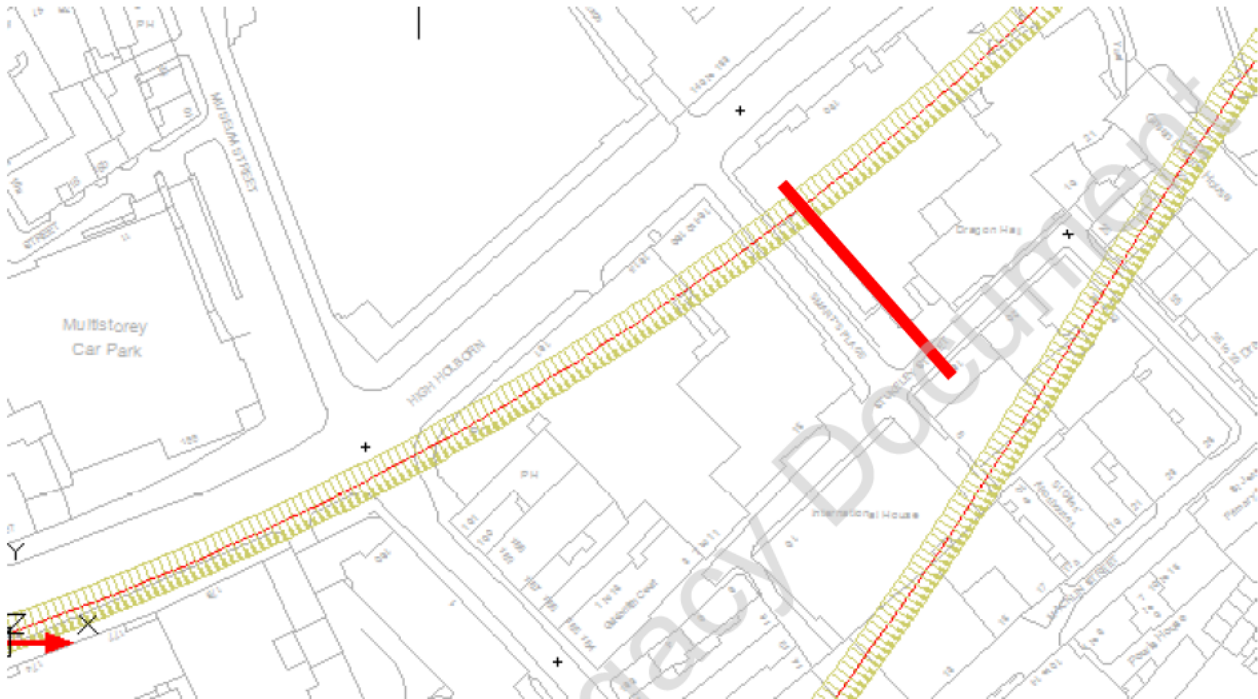


Figure 38: location

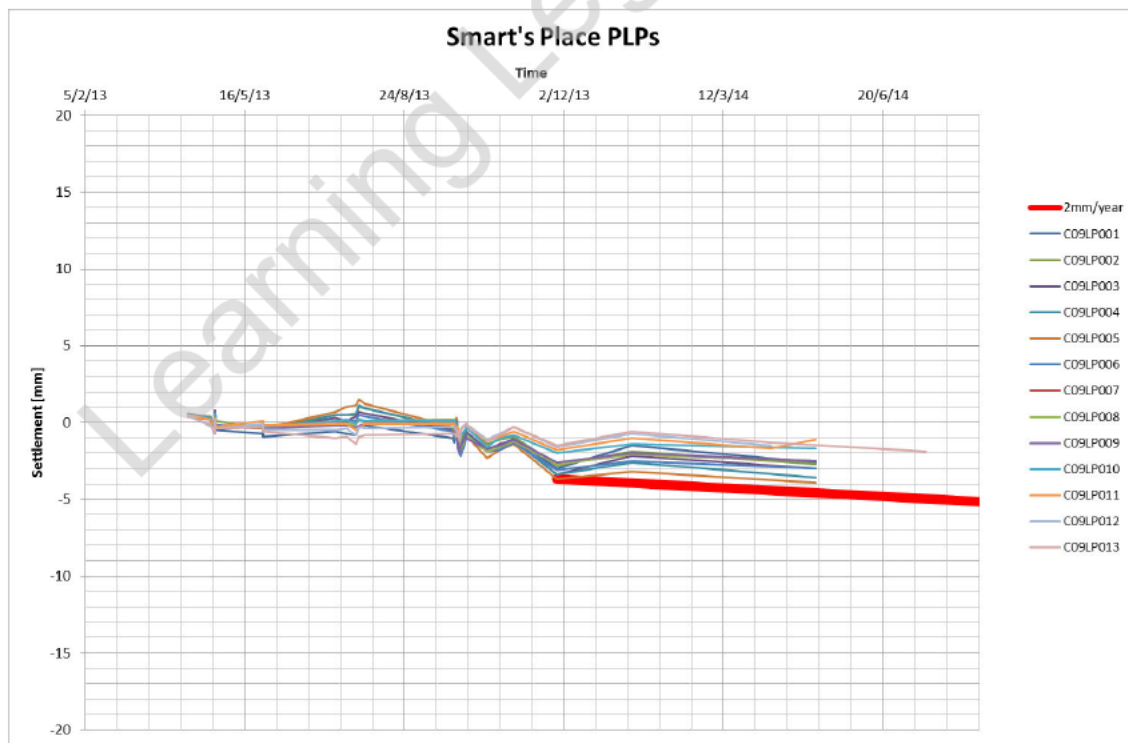


Figure 39: data time-plots - comparison against 2mm/year settlement rate (long-term)



2.13.2. Comments

The points in Smart's Place settled up to approx. 5mm due to the C300 running tunnels excavation. The effect of the EB TBM is visible from the settlement time-plots. Settlement triggers have not been breached

The time-plots are generally showing very slow settlement trend on some point; the long term behaviour is within 2mm/year.

The residual risk associated with long-term settlements is considered to be negligible.

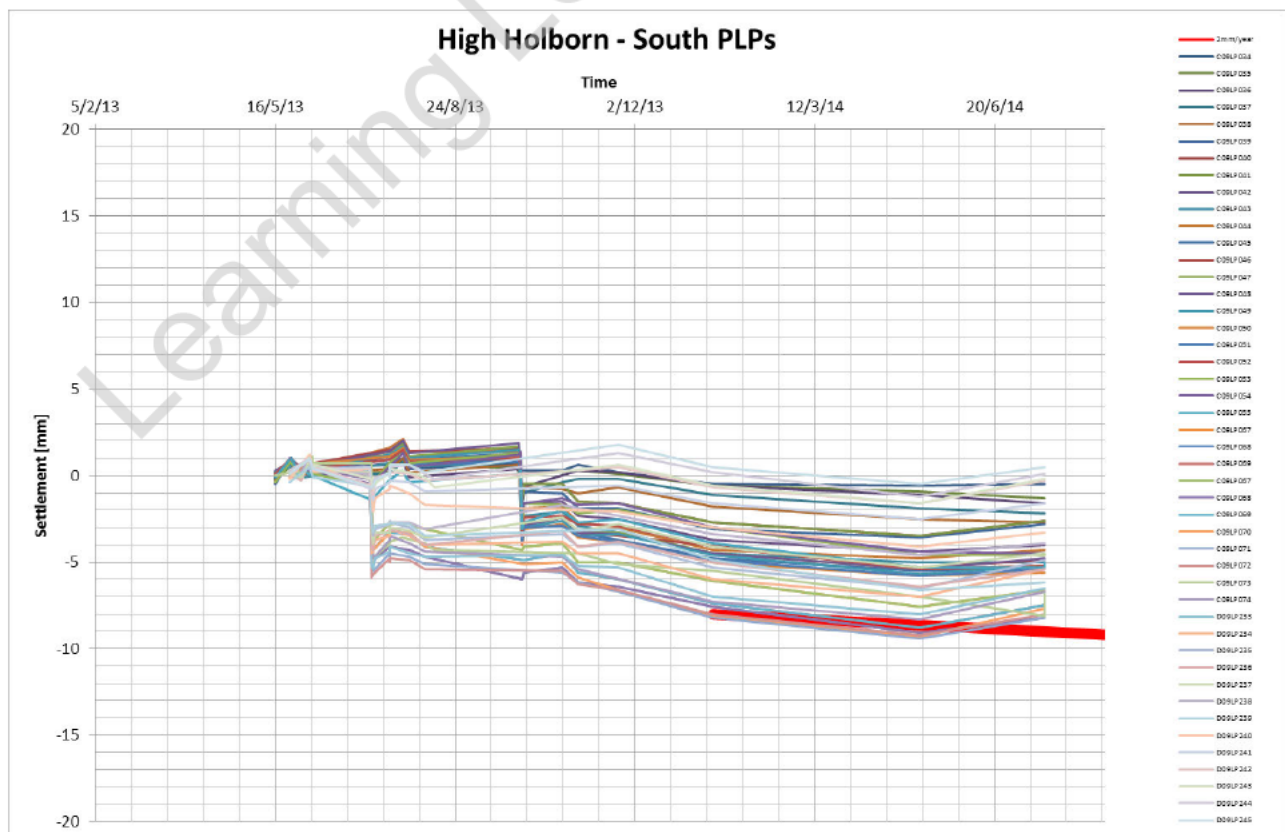
L arning L gacy Document

2.14. High Holborn

2.14.1. Data



Figure 40: location



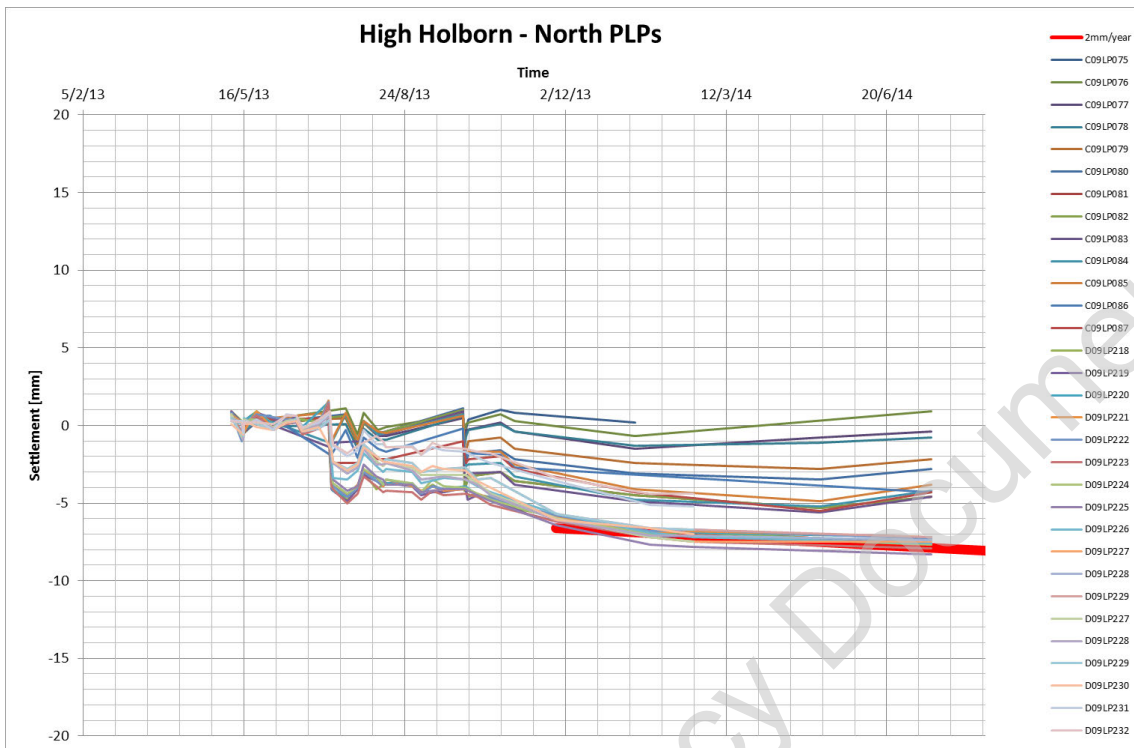


Figure 41a,b: data time-plots - comparison against 2mm/year settlement rate (long-term)

2.14.2. Comments

The points in High Holborn settled up to approx. 9mm due to the C300 running tunnels excavation. The effect of the WB and EB TBMs is visible from the settlement time-plots. Settlement triggers have not been breached

The time-plots are generally showing stabilising data; the long term behaviour is within 2mm/year.

The residual risk associated with long-term settlements is considered to be negligible.

2.15. Southampton Place

2.15.1. Data

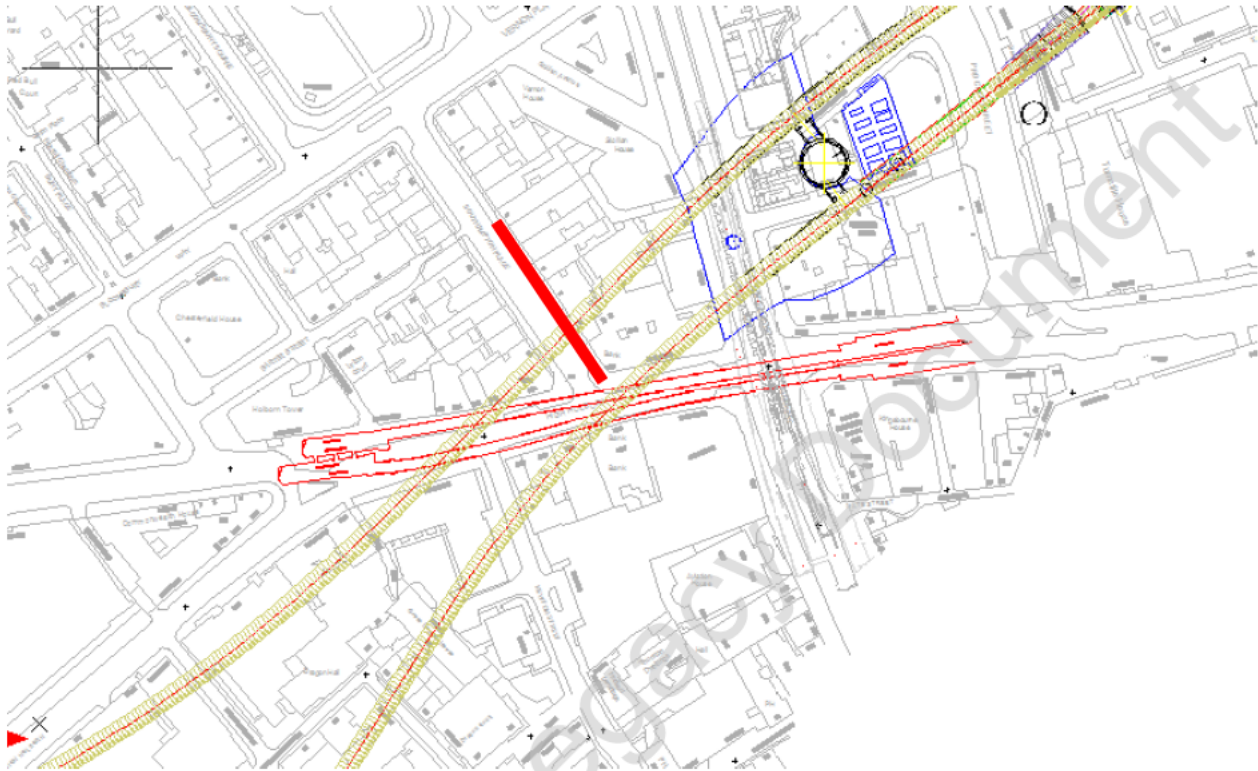


Figure 42: location

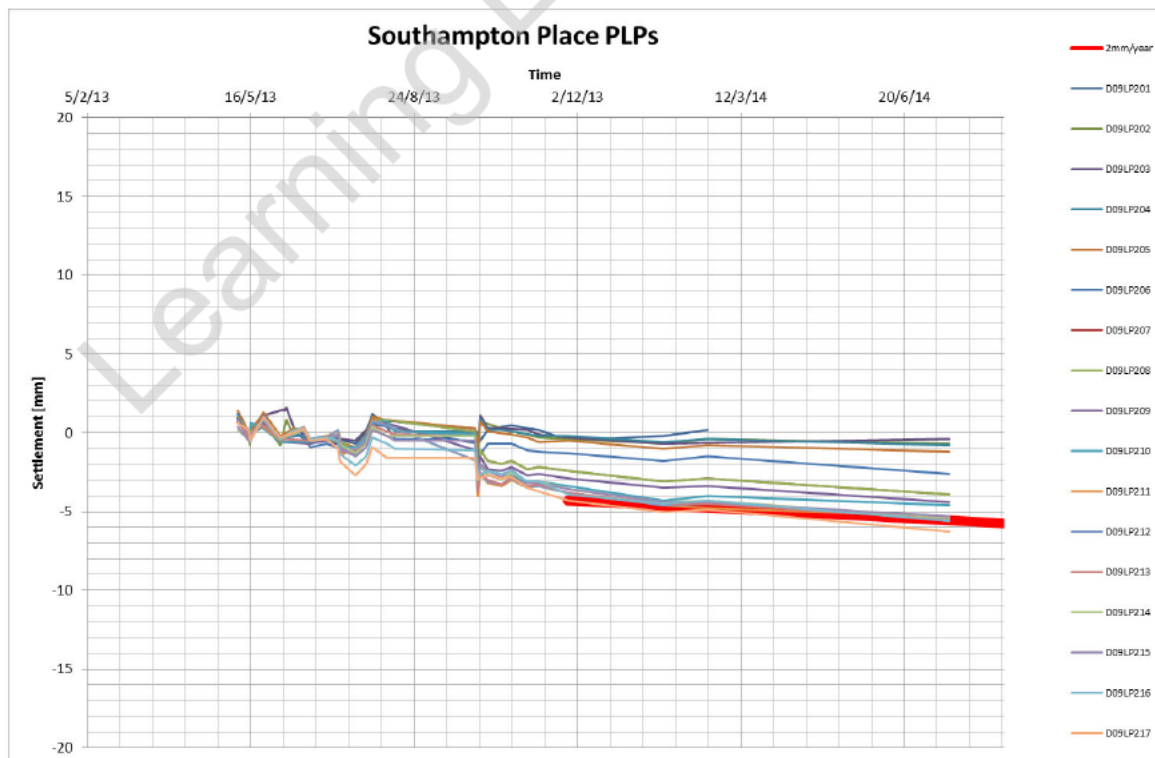


Figure 43: data time-plots - comparison against 2mm/year settlement rate (long-term)

2.15.2. Comments

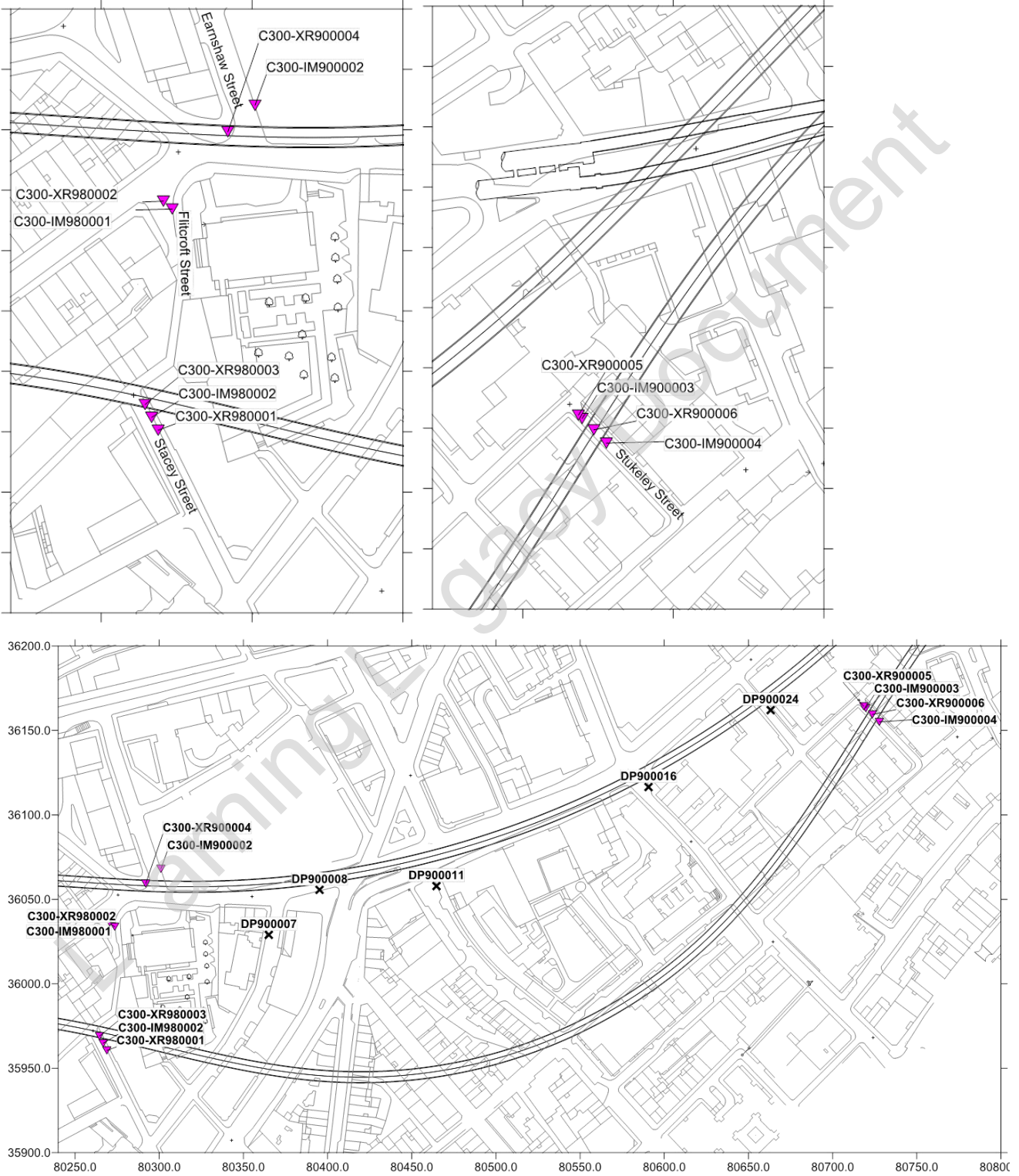
The points in Southampton Place settled up to approx. 7mm due to the C300 running tunnels excavation. The effect of the WB and EB TBMs is visible from the settlement time-plots. Settlement triggers have not been breached

The time-plots are generally showing stabilising data; the long term behaviour is within 2mm/year.

The residual risk associated with long-term settlements is considered to be negligible.

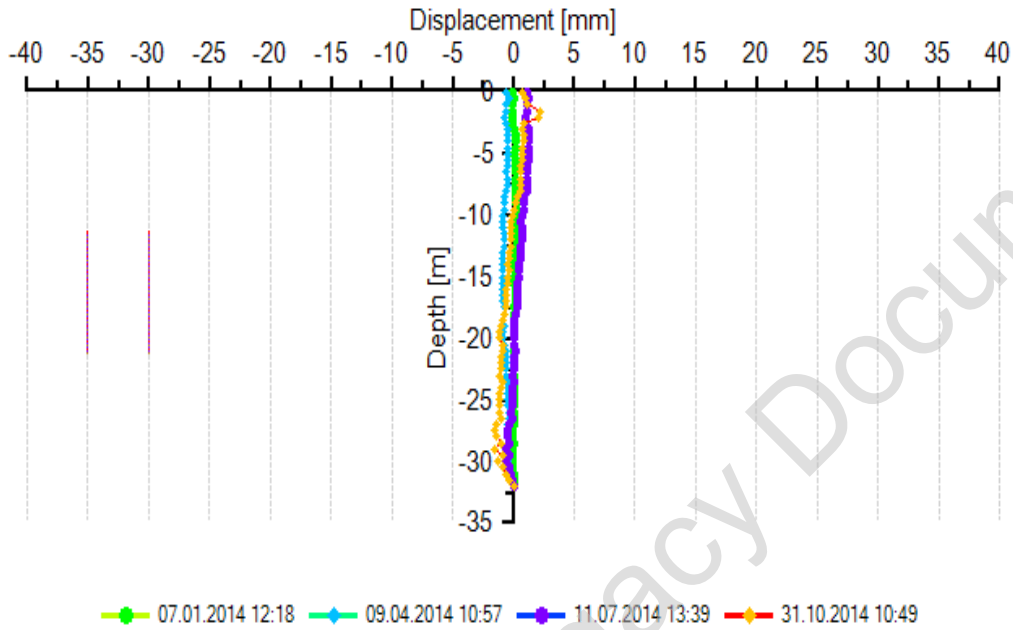
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2.16. Deep Instruments

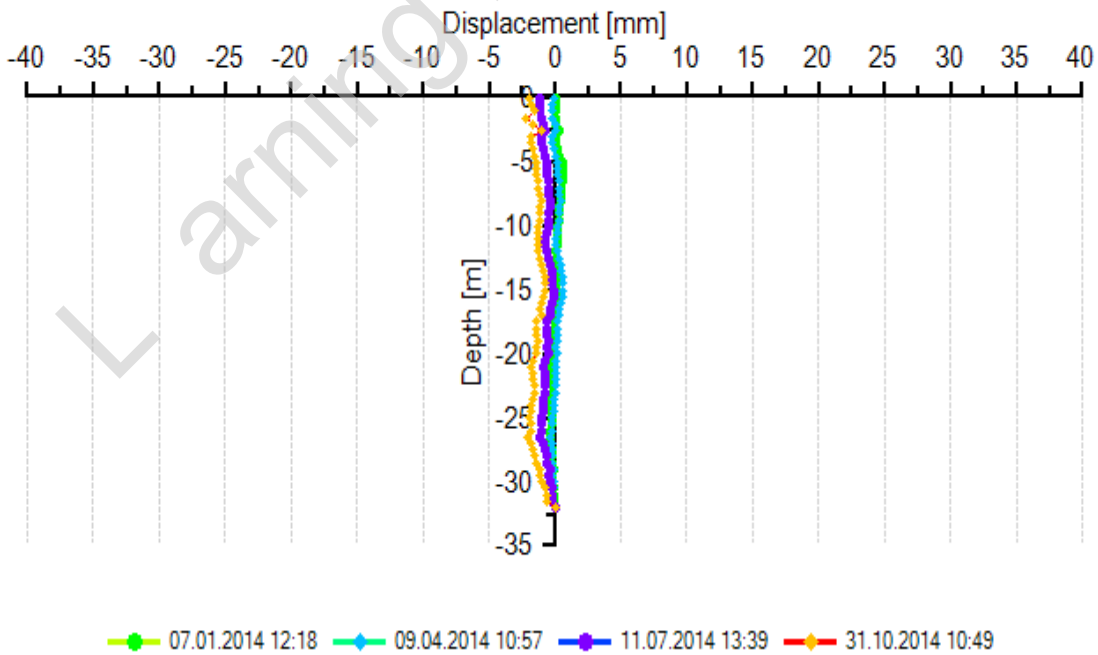


2.16.1. Inclinometers in Stacey Street, Flitcroft Street and Earnshaw Street

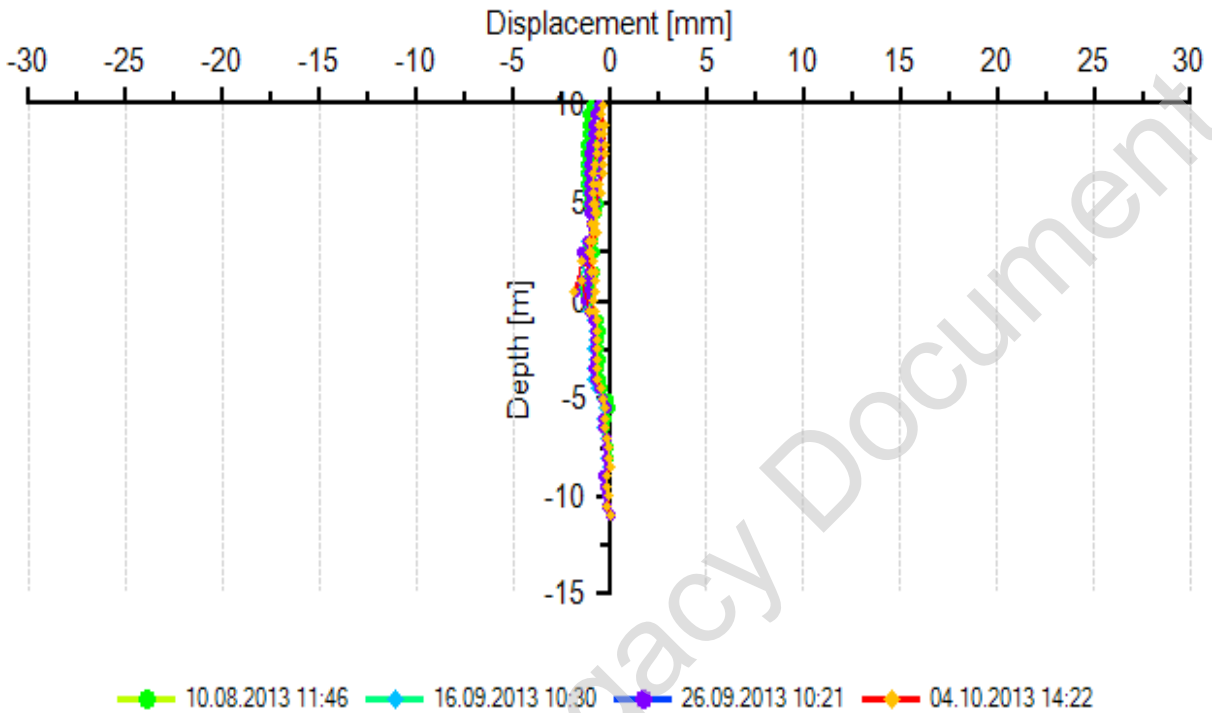
Inclinometer: C300-IM980001 Dir. X 100.0 Grad



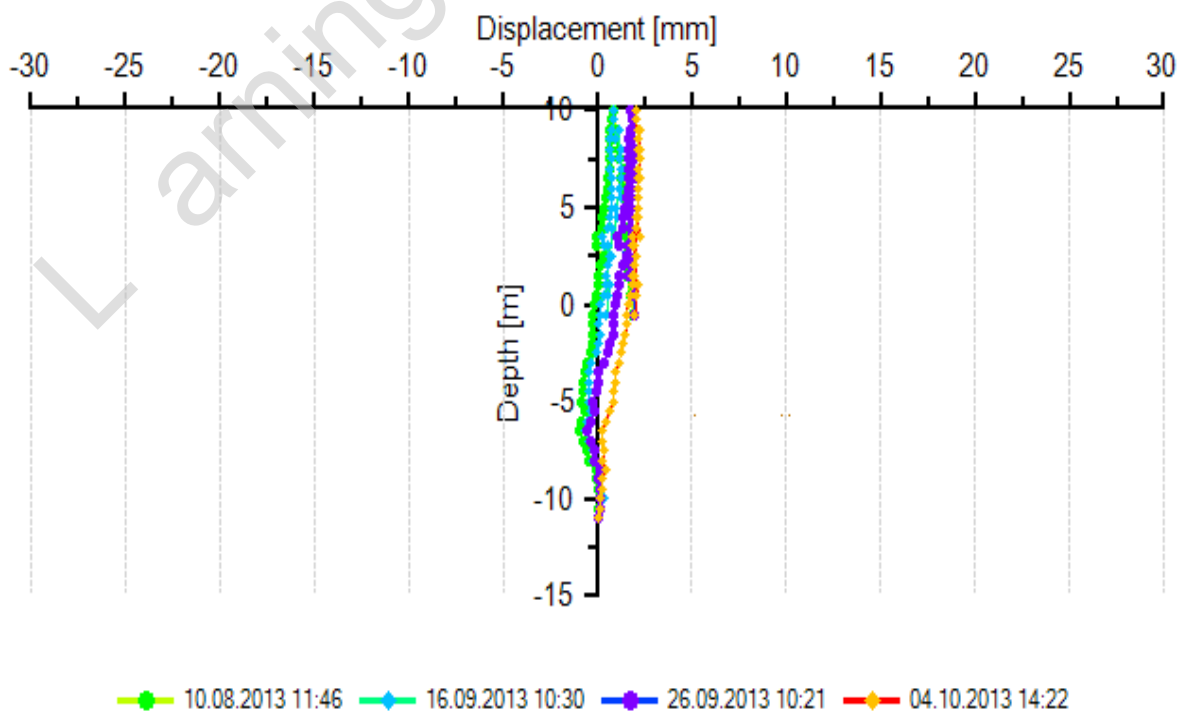
Inclinometer: C300-IM980001 Dir. Y 0.0 Grad



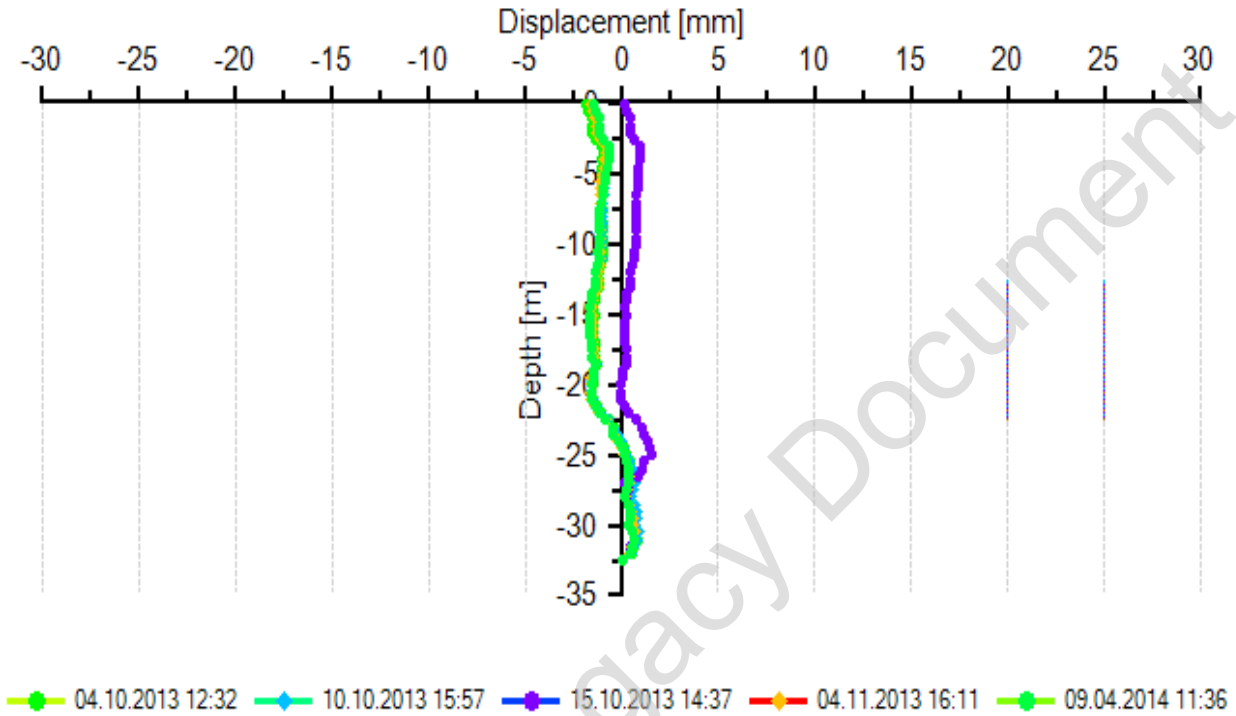
Inclinometer: C300-IM900002 Dir. X 100.0 Grad



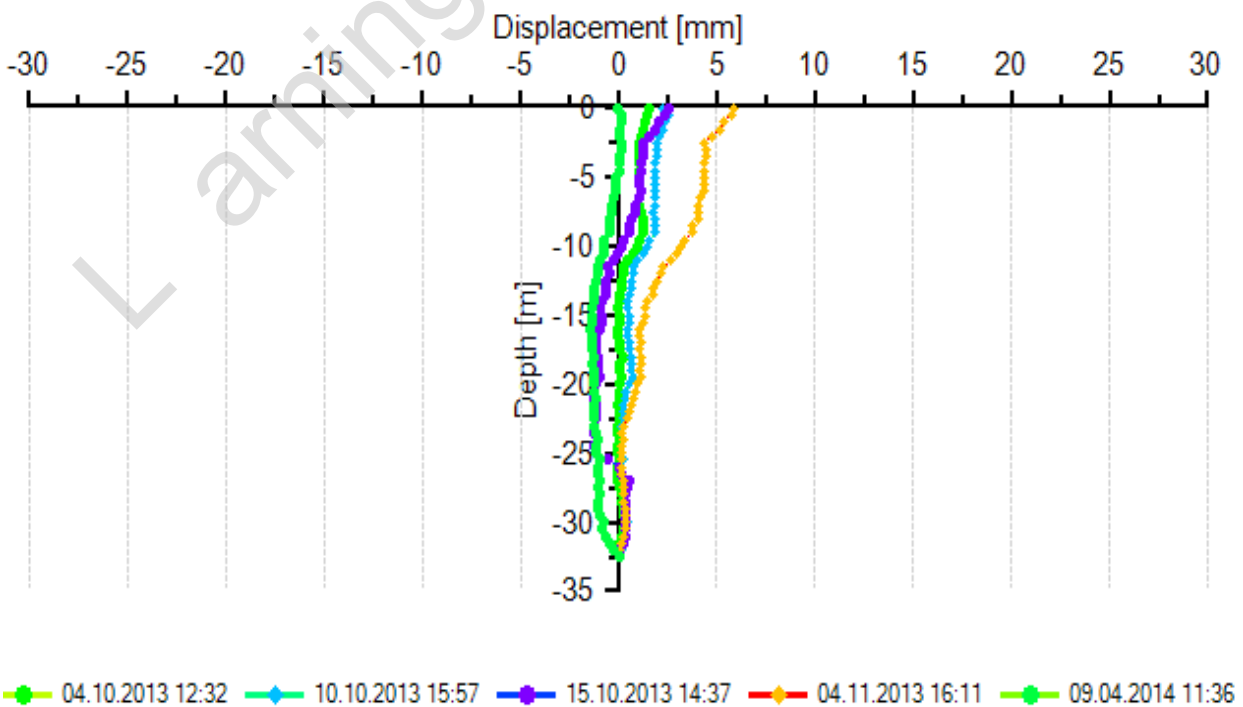
Inclinometer: C300-IM900002 Dir. Y 0.0 Grad



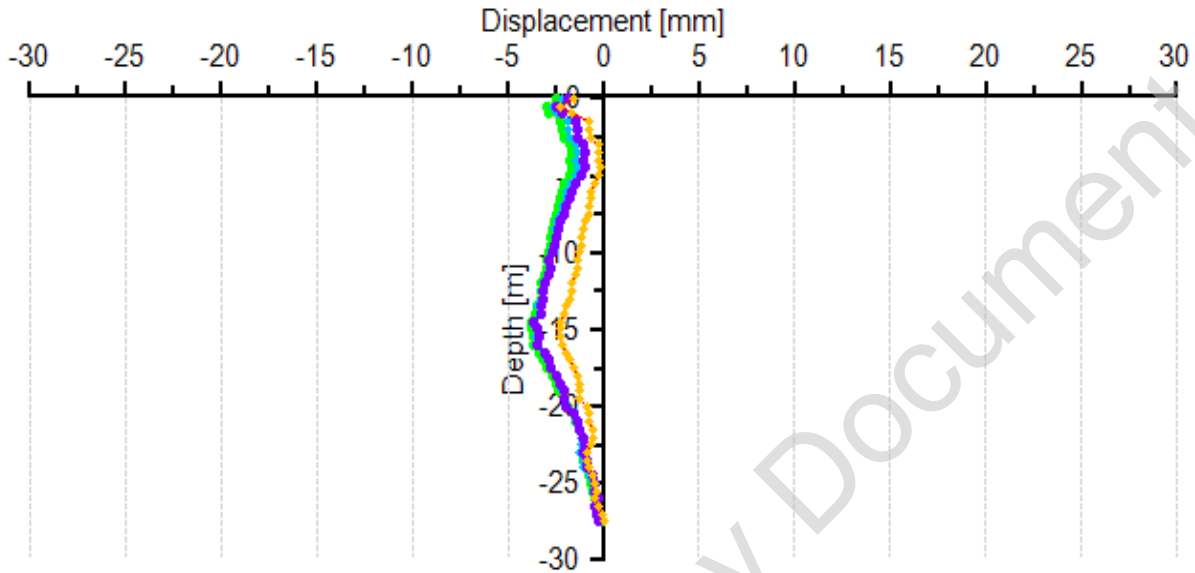
Inclinometer: C300-IM980002 Dir. X 100.0 Grad



Inclinometer: C300-IM980002 Dir. Y 0.0 Grad

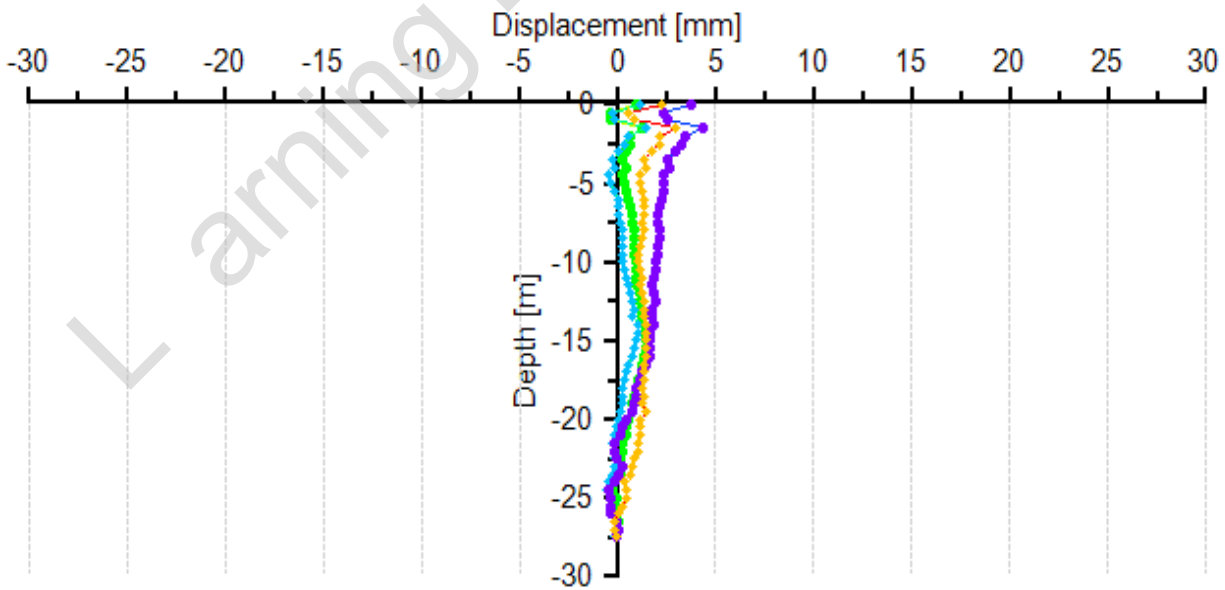


Inclinometer: C300-IM900003 Dir. X 100.0 Grad



07.01.2014 09:58 17.04.2014 13:04 11.07.2014 15:10 31.10.2014 10:25

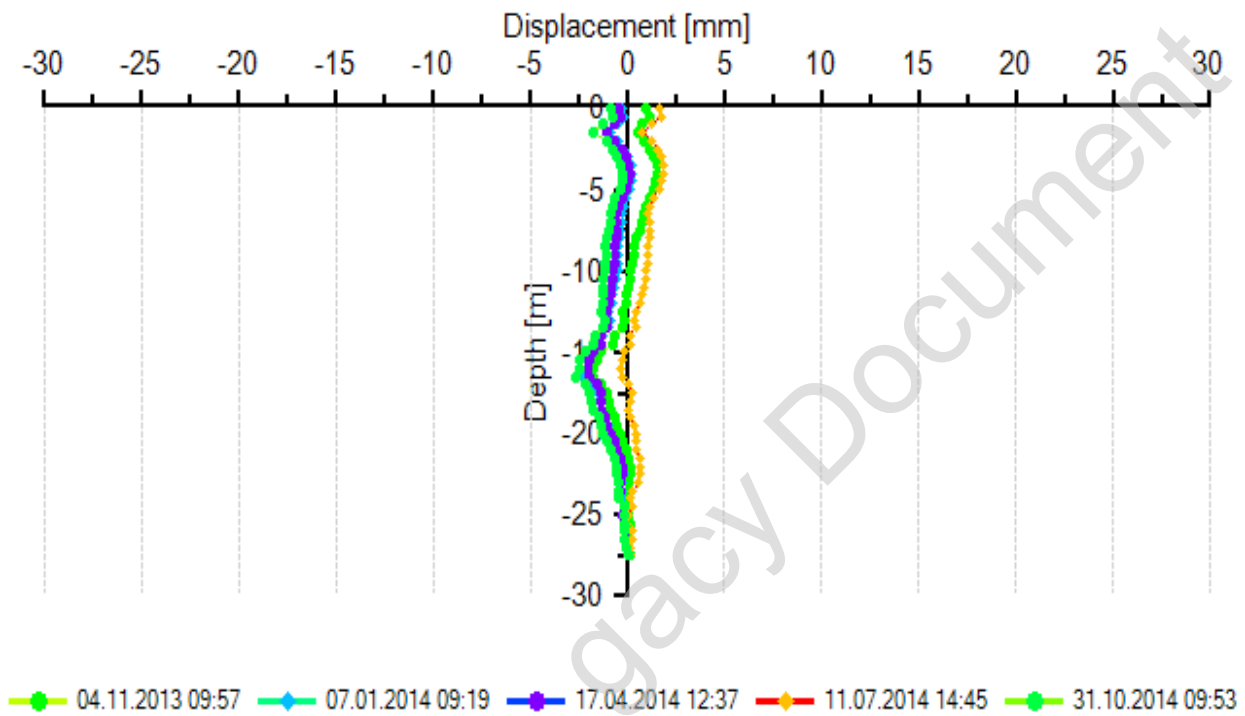
Inclinometer: C300-IM900003 Dir. Y 0.0 Grad



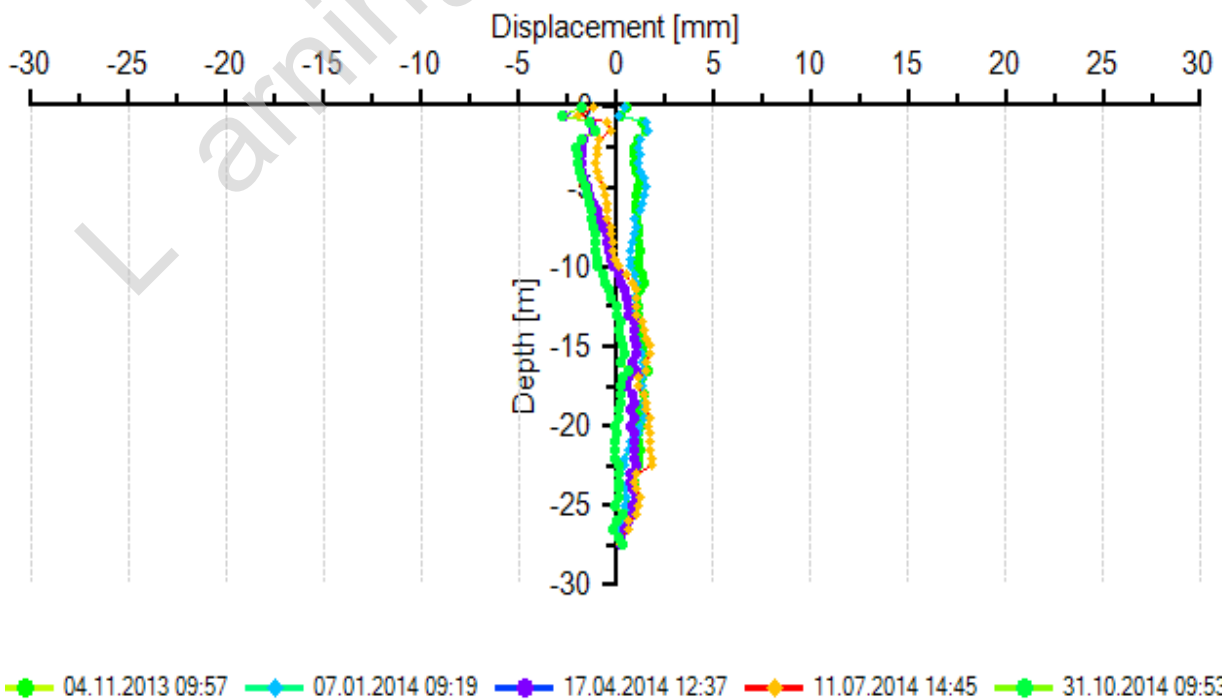
07.01.2014 09:58 17.04.2014 13:04 11.07.2014 15:10 31.10.2014 10:25

2.16.2. Inclinometers in Stukeley Street

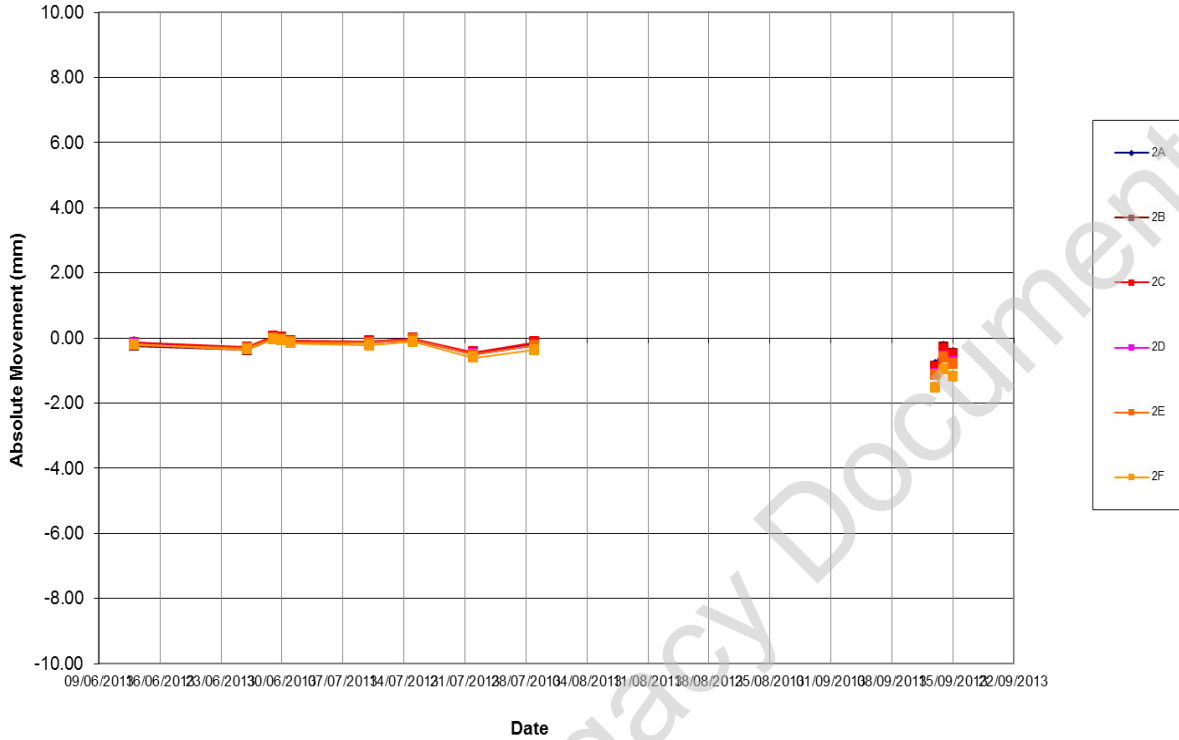
Inclinometer: C300-IM900004 Dir. X 100.0 Grad



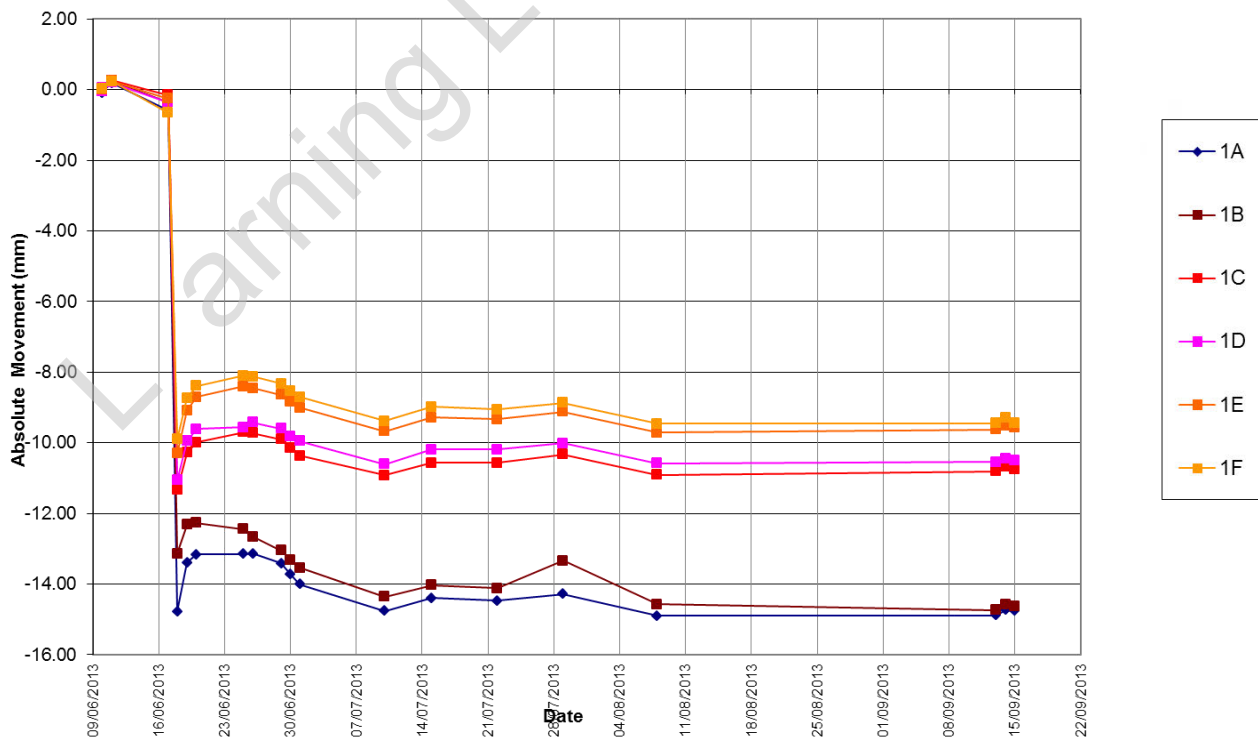
Inclinometer: C300-IM900004 Dir. Y 0.0 Grad



C300 Flitcroft St- Rod Extensometer XR980002
Absolute Movement of Targets Since Commissioning.

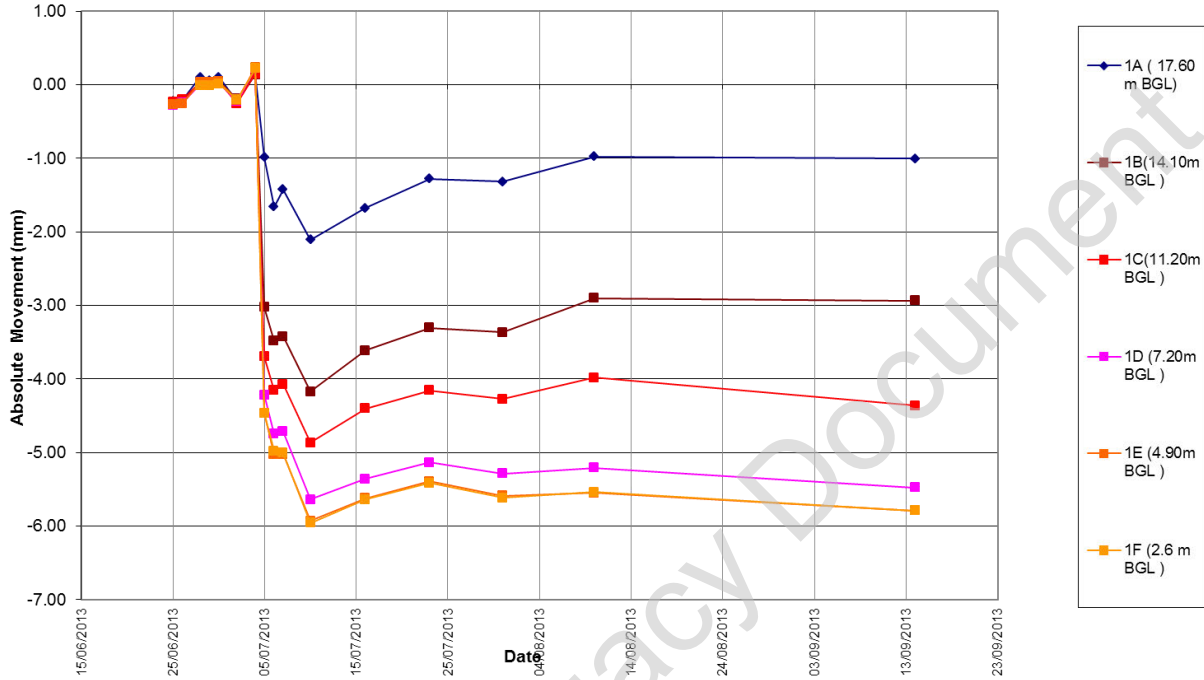


C300 Stacey St Rod Extensometer XR980003
Absolute Movement of Targets Since Commissioning.

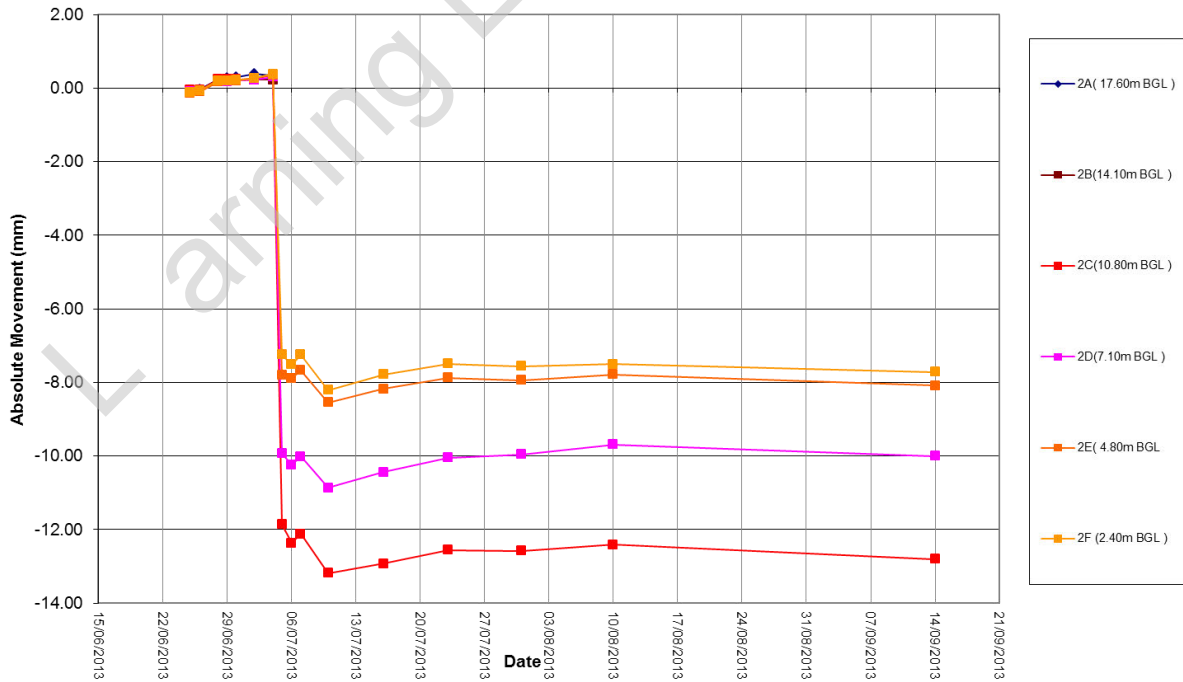


2.16.4. Extensometers in Stukeley Street

C300 Stukeley St Rod Extensometer XR9800005
Absolute Movement of Targets Since Commissioning.

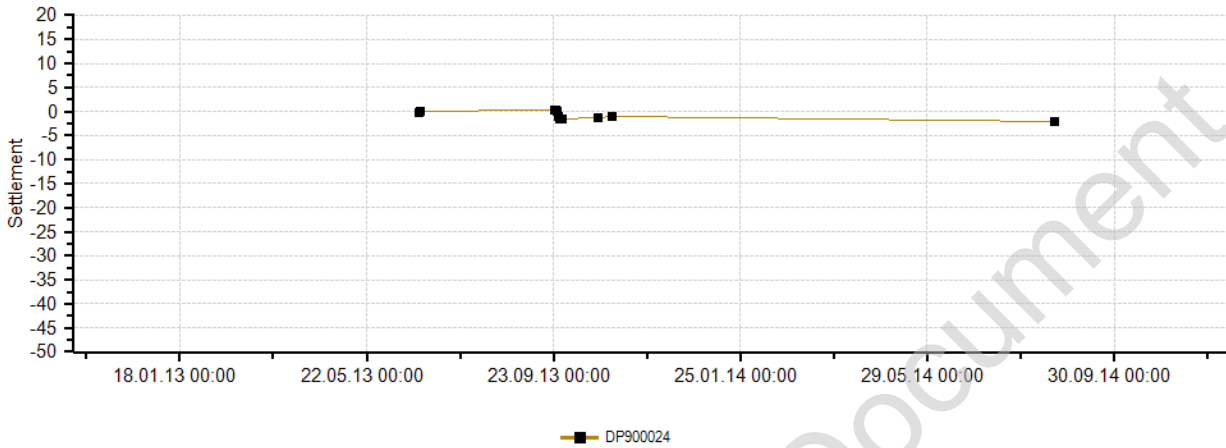


C300 Stukeley St- Rod Extensometer XR9800006
Absolute Movement of Targets Since Commissioning.

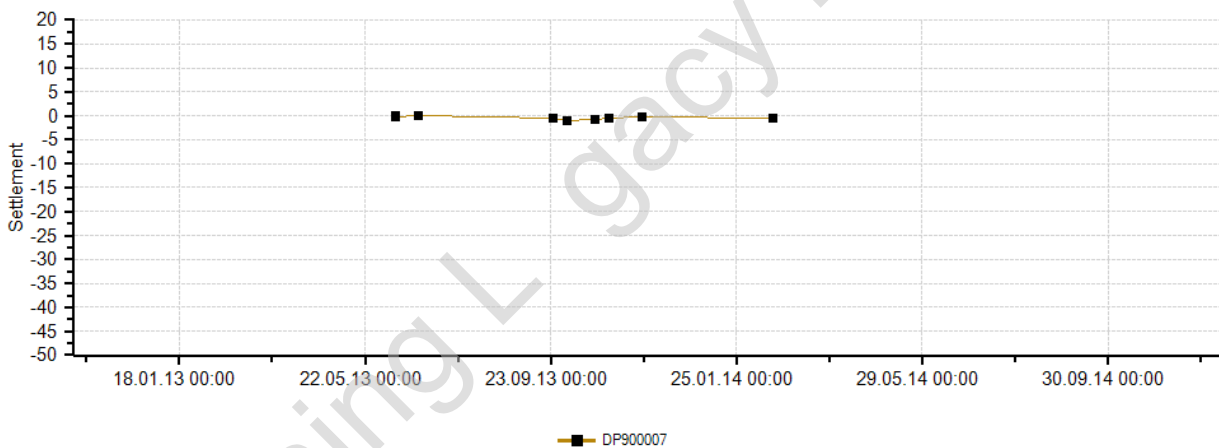


2.16.5. Shallow Datums

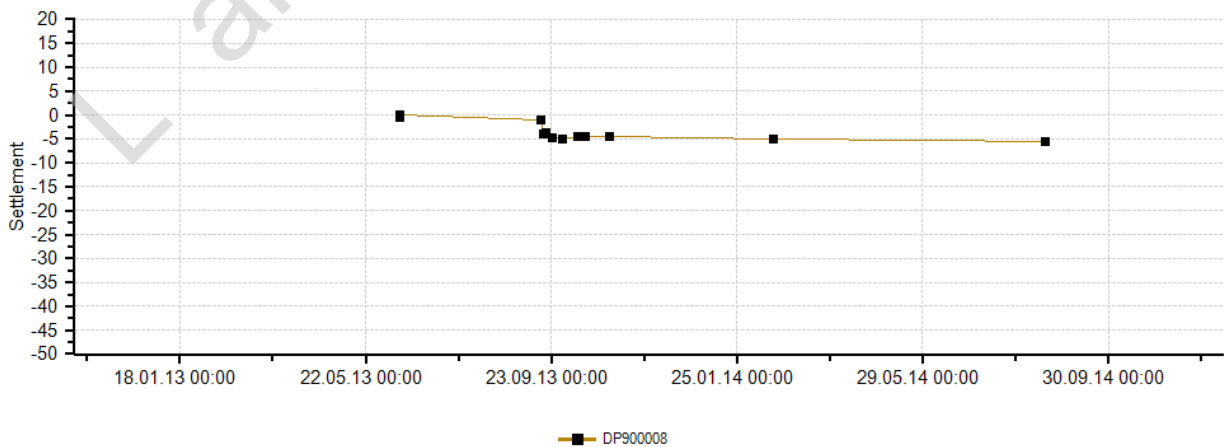
Profile: Measurement Point DP900024



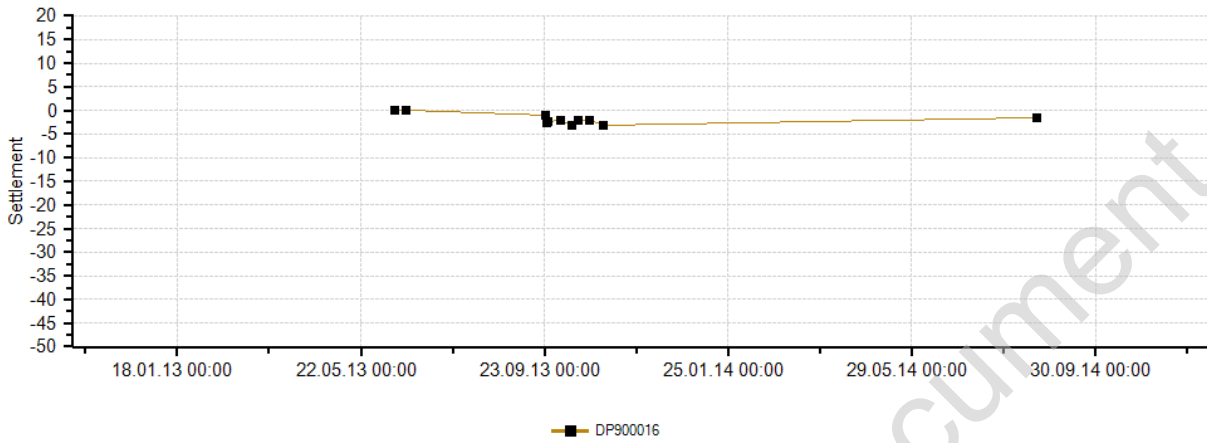
Profile: Measurement Point DP900007



Profile: Measurement Point DP900008



Profile: Measurement Point DP900016



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Appendix 1. TBMs Chainages

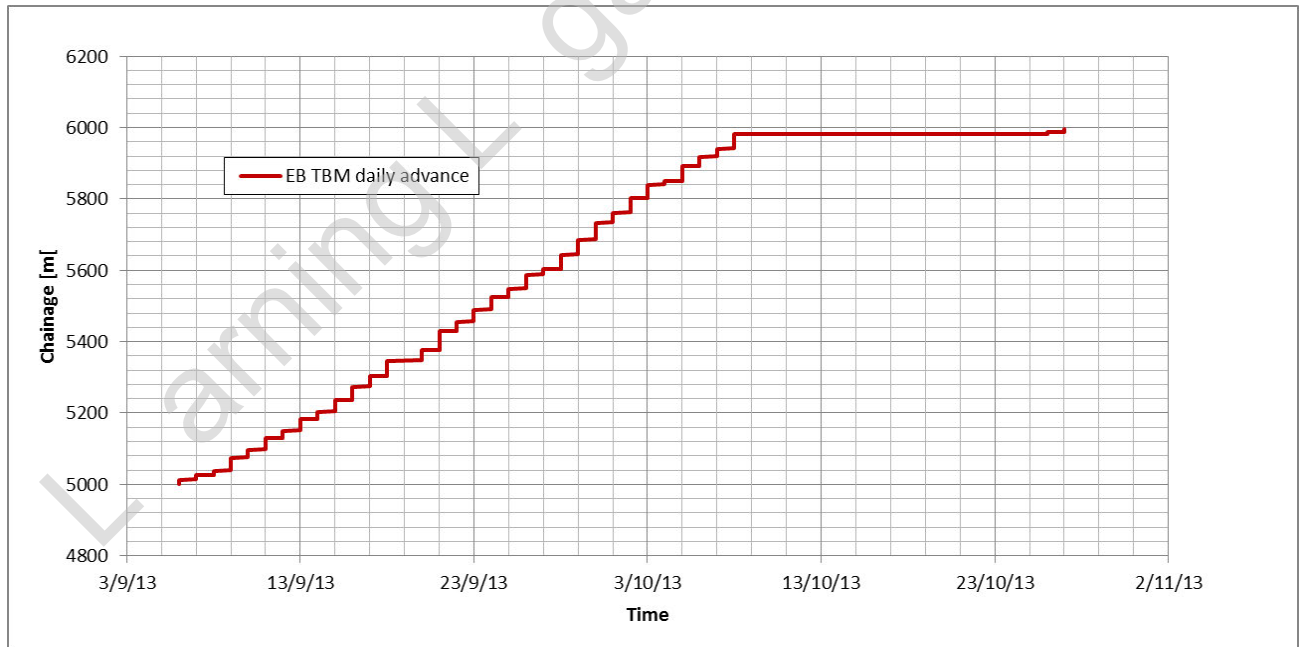
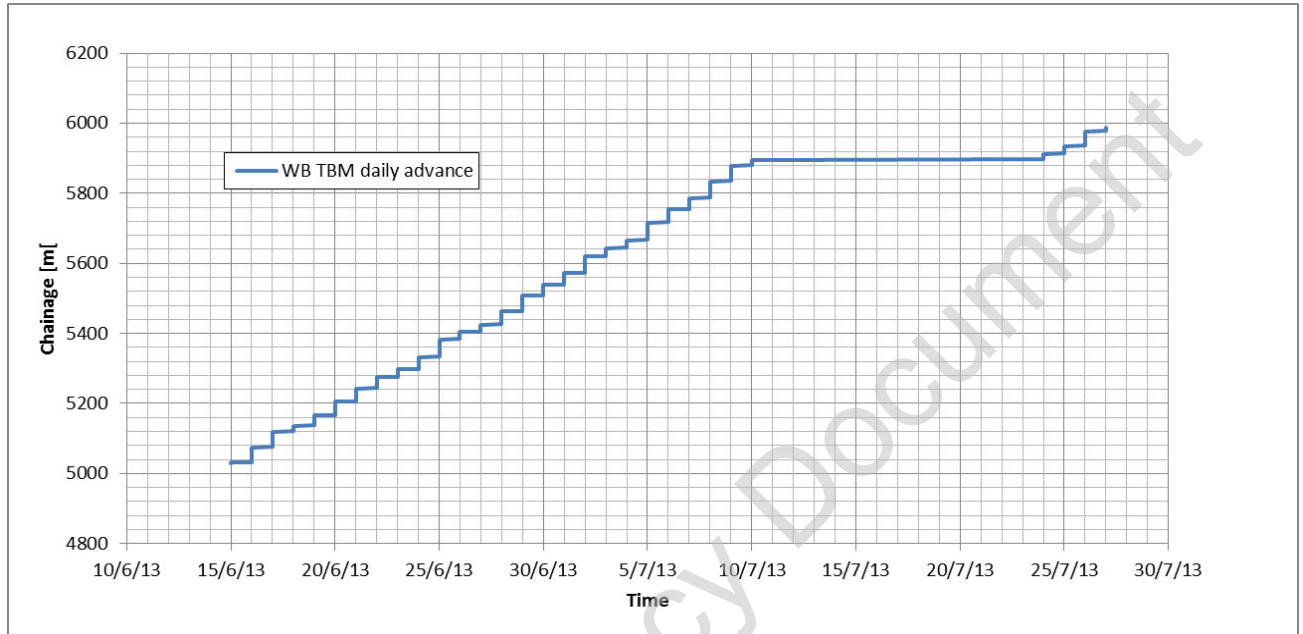


Figure 44a,b: WB and EB TBMs progress charts along TCR-FIS drive

Table 9: Transects chainages

	WB Chainage	EB Chainage
Stacey Street	5112	N/A
New Compton Street	5183	N/A
Shaftesbury Avenue	5219	N/A
Monmouth Street	5258	N/A
Neal Street	5319	N/A
Drury Lane	5522	N/A
Stukeley Street/ Macklin Street	5611	N/A
Newton Street	5739	N/A
Earnshaw Street	N/A	5165
St. Giles High Street West	N/A	5251
St. Giles High Street East	N/A	5346
Smart's Place	N/A	5542
High Holborn	N/A	5653
Southampton Place	N/A	5725
Southampton Row	5853	5793



Appendix 2. BREs, PLPs and Prisms data

Learning L gacy Document

Appendix 3. Reference documents

Code	Document
C300-BFK-C4-STP-CRT00_ST005-	MANAGEMENT PLAN FOR THE CONTROL OF GROUND MOVEMENTS: ADDENDUM
C122-OVE-C2-RGN-CRG01-50076	Instrumentation & Monitoring Plan C300 Running Tunnels Ground Movement And Asset Protection
C122-OVE-U-RGN-CRG01-50003	Instrumentation and Monitoring Plans: Thames Water Assets: Drive X (C300)Instrumentation Plan for large or Deep Sewers
C300-BFK-C4-RGN-CRT00_ST005-50745	As-Built report for subsurface instruments at Shaftsbury
C300-BFK-C4-RGN-CRT00_ST005-50746	As-Built report for subsurface instruments at Smarts Place
C300-BFK-C4-RGN-CRT00_ST005-50753	As Built report for subsurface instruments at Flitcroft Street
C300-BFK-C4-RGN-CRT00_ST005-50754	As-Built report for subsurface instruments at Earnshaw Street
C300-BFK-C4-RGN-CRT00_ST005 50755	As-Built report for subsurface instruments at Stacey Street
C300-BFK-C4-RGN-CRT00_ST005 50760	Installation of Precise level points and Barcodes in Soho Square Gardens TCR (PMI312)
C300-BFK-C4-RGN-CRT00_ST005-50762	Installation Report for Subsurface Instruments at High Street St Giles
C300-BFK-C4 RGN CRT00_ST005-50800	Installation Report for Stukeley Street
C300-BFK C4 RGN-CRT00_ST005-50815	Installation of Geodetic Prisms and BRE's in TCR to FIS
C300-BFK-C4-RGN-CRT00_ST005-50845	TCR station Upgrade Installation Report
C300-BFK-C4-RGN-CRT00_ST005-50854	Installation of Precise level points in Shaftsbury Avenue Pipe Subway TCR-FIS (PMI325)
C300-BFK-C4-RGN-CRT00_ST005-51983	Installation Report for Subsurface Instruments at New Compton Street
C300-BFK-C4-RGN-CRT00_ST005-51984	Installation Report for Subsurface Instruments at Endell Street

Appendix 4. Thames Water Assets summary table

Area	Type	Sewer Name	Address	Alert Value (mm)	Deflection Alert Value	Deflection Amber Trigger Value	Deflection achieved (average of 3 values)
TCR-FIS	Sewer	TW28 Northumberland Street & Shaftsbury Avenue Sewers	New Compton Street				
	Sewer	TW28 Northumberland Street & Shaftsbury Avenue Sewers	St Giles High Street	-	1 in 3800	-	
	Sewer	TW28 Northumberland Street & Shaftsbury Avenue Sewers	Monmouth Street	-	1 in 4100	-	1 in 5400
	Sewer	TW29 Savoy Street Main Line & High Holborn and Drury Lane Sewer	High Holborn	-	1 in 2100	-	
	Sewer	TW29 Savoy Street Main Line & High Holborn and Drury Lane Sewer	Endell Street/Savoy Street	-	1 in 4100	-	1 in 13000
	Sewer	TW29 Savoy Street Main Line & High Holborn and Drury Lane Sewer	Grape Street				
	Sewer	TW29 Savoy Street Main Line & High Holborn and Drury Lane Sewer	Museum Street				
	Sewer	Essex Street Sewer West Branch (TW29)	Dury Lane	-	1 in 4100	-	1 in 5000
	Sewer	Essex Street Sewer East Branch	High Holborn	-	1 in 4300	-	
	Sewer	TW29 Savoy Street Main Line & High Holborn and Drury Lane Sewer	Smarts Place				
	Sewer	TW28 Shaftsbury Avenue Subway Sewer	Shaftsbury Avenue	-	1 in 2000	-	
	Water Main	Shaftsbury Avenue 18in		-	-	1 in 2800	
	Water Main	Shaftsbury Avenue 12in		-	-	1 in 2800	1 in 5000
	Water Main	High Holborn 12/18in		-	1 in 2600	-	
	Sewer	Southampton Road Subway Sewer Eastside	Southampton Row		1 in 3700		1 in 5900
	Sewer	Southampton Road Subway Sewer Westside	Southampton Row		1 in 3800		1 in 5000
	Sewer	Kingsway Subway Sewer Westside	Kingsway/High Holborn		1 in 3000		
Sewer	TW31 Essex Street Sewer east and High Holborn	Newton Street		1 in 4100	-	1 in 2700	



Appendix 5. C300 Buildings Claims

The following sketches show the locations of the buildings for which damages claims were raised. The building addresses are reported in the **yellow boxes** and the position on the plan is indicated with a red arrow. These information were provided by C122. These sketches are reported at the end of this document

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Schedule of Building and Ground Monitoring Installation by C300

Substation Monitoring Change		Total Number of Instruments	Instrument Type	Asset	Building Address
From	To				
74300	74400	1	Sockets - BRE Type - Structure	Piled building	31 Giles Court, 1-13 St Giles High Street
		2	Sockets - BRE Type - Structure	Piled building	31 Giles Court, 1-13 St Giles High Street
		3	Sockets - BRE Type - Structure	Piled building	31 Giles Court, 1-13 St Giles High Street
74400	74500	2	Sockets - BRE Type - Structure	Piled building	181-177 Shaftesbury Avenue
		4	Sockets - BRE Type - Structure	Damage Category 3 Building with Piled Foundations	181-177 Shaftesbury Avenue
		13	Sockets - BRE Type - Structure	Damage Category 3 Building with Piled Foundations	181-177 Shaftesbury Avenue
		4	Sockets - BRE Type - Structure	Damage Category 3 Building with Piled Foundations	5-5 & 36-40 Duffry Court
		3	Sockets - BRE Type - Structure	Damage Category 3 Building with Piled Foundations	36 Enniskillen, WC2NR6RG
		13	Sockets - BRE Type - Structure	Damage Category 3 Building with Piled Foundations	36 Enniskillen, WC2NR6RG
		4	Sockets - BRE Type - Structure	Damage Category 3 Building with Piled Foundations	Hastings House, 1, 11, 12 & 16 Drury Lane & 180 High Holborn, WC2B8RE
74600	74700	3	Sockets - BRE Type - Structure	Damage Category 3 Building with Piled Foundations	177-178 High Holborn
		3	Sockets - BRE Type - Structure	Piled building	174 High Holborn
		3	Sockets - BRE Type - Structure	Structures with I & M Commitments	69-72 Shorts Gardens, WC2H 9AH
		3	Sockets - BRE Type - Structure	Structures with I & M Commitments	69-72 Shorts Gardens, WC2H 9AH
		1	Sockets - BRE Type - Structure	Grade 2 Listed Building	Strawberry House, 24 Bedford Street
		1	Sockets - BRE Type - Structure	Piled building	14 Shawbury Street
74700	74800	1	Sockets - BRE Type - Structure	Piled building	International House (West), 14 Shawbury Street
		2	Sockets - BRE Type - Structure	Damage Category 3 Piled Building	11-60 & Newton Street
74900	74900	14	Sockets - BRE Type - Structure	Grade 2 Listed Building	258-260 High Holborn South Side
74900	75000	2	Sockets - BRE Type - Structure	Grade 2 Listed Building	258-260 High Holborn South Side

Ground Monitoring Change		Total Number of Instruments	Instrument Type	Traverse Type
From	To			
74300	74400	3	Shells - Precise Ground Levelling	N
		3	Shells - Precise Ground Levelling	N
		2	Inclinometer - Rod	A2
74300	74500	16	Shells - Precise Ground Levelling	N
74300	74700	2	Shells - Precise Ground Levelling	N
74300	74900	1	Shells - Precise Ground Levelling	N
74300	74900	1	Shells - Precise Ground Levelling	N
74400	74500	3	Shells - Precise Ground Levelling	N
		3	Shells - Precise Ground Levelling	N
		1	Inclinometer - Rod	A1
		1	Extensometer - Rod	N
74400	74600	1	Shells - Precise Ground Levelling	N
		1	Shells - Precise Ground Levelling	N
		1	Shells - Precise Ground Levelling	N
74600	74700	23	Shells - Precise Ground Levelling	N
74600	74700	13	Shells - Precise Ground Levelling	N
74700	74800	3	Shells - Precise Ground Levelling	N
		14	Shells - Precise Ground Levelling	N
		14	Shells - Precise Ground Levelling	N
74700	74900	13	Shells - Precise Ground Levelling	N
		13	Shells - Precise Ground Levelling	N
74900	75000	2	Inclinometer	N
		1	Extensometer - Rod	N
75000	75100	1	Shells - Precise Ground Levelling	N
75000	75100	128	Shells - Precise Ground Levelling	N
75100	75300	11	Shells - Precise Ground Levelling	N

Number of BRE sockets	Number of 3D Geodetic Prisms	Number of Precise Ground Levelling Shells	Number of Rod Extensometers	Number of Inclinometers	Number of Shallow Datums	Total Number
168	176	128	12	12	8	404

Asset Monitoring Change		Total Number of Instruments	Instrument Type	Asset
From	To			
75000	75100	10	3D Geodetic Prisms	Kingway Train Tunnel
		5	3D Geodetic Prisms	Moorhouse Street, Shaftesbury Avenue and St. Giles High Street Sewer
75000	75100	15	Sockets - BRE Type - Structure	Thames Water Easement Sewer
75000	75100	15	Sockets - BRE Type - Structure	Thames Water Easement Sewer

Internal monitoring @ 20m c/c Refer to Section E1-E1 on Drg No. C122-OVE-C2-008-CR001 Z-32022

Shaftesbury Avenue and St. Giles High Street Sewers

Disused British Museum Station Manual monitoring of I & M installed by C701

Disused Kingsway Tram Tunnel Automated Total stations with 3D Geodetic Prisms and BRE sockets by C300 No details of structure assumed See Section M in drawing no. C122-OVE-C2-008-CR001 Z-32003

Central Line Tunnels Manual track monitoring by C300. Tunnel intersect real-time data logged monitoring (e.g. 3D geodetic prism/electrolevels etc.) installed, monitored and reported by C701. C300 to undertake manual monitoring of tunnel traverses during TBM passage. See Section C-C in drawing no. C122-OVE-C2-008-CR001 Z-32003

Thames Water Easement Sewer internal monitoring section E1-E1 on drawing C121-OVE-C2-004-CR001 Z-32022

Building monitoring within this boundary line is not shown on this drawing. Refer to Drg No. C122-OVE-C2-004-CR001 Z-31053 for building monitoring

Internal monitoring @ 20m c/c Refer to Section E1-E1 on Drg No. C122-OVE-C2-008-CR001 Z-32022

Moorhouse Street Sewer

Eastbound Running Tunnel

Westbound Running Tunnel

Disused Kingsway Tram Tunnel

Piccadilly Line E'B & Disused Aldwych Spur (upper level)

Shaftesbury Avenue and St. Giles High Street Sewers

Disused British Museum Station

Disused Kingsway Tram Tunnel

Central Line Tunnels

Thames Water Easement Sewer

Building monitoring

Internal monitoring

Moorhouse Street Sewer

Eastbound Running Tunnel

Westbound Running Tunnel

Disused Kingsway Tram Tunnel

Piccadilly Line E'B & Disused Aldwych Spur

Shaftesbury Avenue and St. Giles High Street Sewers

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Piccadilly Line Tunnels (including slip-plate junctions) Manual track monitoring by C300. Tunnel intersect real-time data logged monitoring (e.g. 3D geodetic prism/electrolevels etc.) installed, monitored and reported by C701. C300 to undertake manual monitoring of tunnel traverses during TBM passage. See Section C-C in drawing no. C122-OVE-C2-008-CR001 Z-32003

Disused Kingsway Tram Tunnel Automated Total stations with 3D Geodetic Prisms and BRE sockets by C300 No details of structure assumed See Section M in drawing no. C122-OVE-C2-008-CR001 Z-32003

Central Line Tunnels Manual track monitoring by C300. Tunnel intersect real-time data logged monitoring (e.g. 3D geodetic prism/electrolevels etc.) installed, monitored and reported by C701. C300 to undertake manual monitoring of tunnel traverses during TBM passage. See Section C-C in drawing no. C122-OVE-C2-008-CR001 Z-32003

Thames Water Easement Sewer internal monitoring section E1-E1 on drawing C121-OVE-C2-004-CR001 Z-32022

Legend

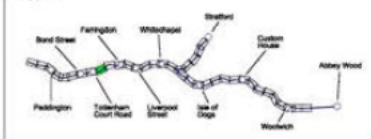
- Parties Responsible for the installation of the I & M
 - By C300
 - By Others
- General
 - Tunnel Alignment
 - Track shoe monitoring at 2m centres
 - Track shoe monitoring at 3m centres
- Settlement Contours
 - 1mm Settlement Contour
 - 10mm Settlement Contour
- Existing Structures
 - Structures with I & M Commitments
 - Buildings with damage category 3
 - Listed Buildings
 - Bored Tunnels
 - Cut & Cover Tunnels
 - Main Sewer (greater than Ø1.5m)
 - Deep Tunnel assets
- Instruments and Monitors
 - Automated Total Station
 - Basest Convergence System
 - Electrolevel Beams
 - Extensometer - Rod
 - Inclinometer
 - Inclinometer - Electrolevels
 - Piezometer - Vibrating Wire
 - 3D Geodetic Prisms
 - Sockets - BRE Type - Structure
 - Shells - Precise Ground Levelling
 - Spare Monitoring Point
 - Monitoring Traverse in Tunnels @ 10m c/c
 - Deep Datum
 - Shallow Datum - Utilities
 - Internal monitoring Traverse in TWJL asset @ 20m c/c

Safety Health and Environmental Information:
 1. C122 Design Team consider that over and above the general C300 Drive X specific hazards and risks presented in the General Notes Drawing (folded in item 3 below), there are no location-specific hazards and risks additional to those normally associated with the work covered by this drawing which a competent contractor would not be readily aware of.
 2. For SHE information relevant to all C300 Tunnel Drive X, see CDM Risk Register: C122-OVE-A3-LRG-CR001-00003.
 3. All location-specific drawings should be read in conjunction with the SHE content of General Notes Drawing No C122-OVE-C2-DDJ-CR001 Z-31000.
 4. These notes are based on operational and competent contractors carrying out the works using an approved safe method of working.

Rev.	Date	Issued as	Description	By	Check	App	Auth
P01	06/11/2009	Issued for Tender Purpose		AB	AN	RM	
P02	20/11/2009	Issued for Tender Purpose		AB	AN	RM	
P03	10/02/2010	Issued for Tender Purpose		AB	AN	RM	
P04	20/06/2010	Issued for Tender Acknowledgement Purpose		AB	AN	RM	
P05	14/12/2010	Issued for Confirmed Set		JJ	AS	RM	
P06	11/05/2011	Geogary's Recommendations for Use by Contractors		JJ	GC	PC	
P07	24/05/2011	Minimum Requirements for Instrumentation and Monitoring		JJ	AS	RM	
P08	03/02/2012	Minimum Requirements for Instrumentation and Monitoring		GP	JA	RM	
C01	17/02/2012	Issued as F1 for construction		GP	JA	RM	
C02	02/04/2012	Minimum Requirements for Instrumentation and Monitoring		GP	JA	PC	
C03	28/06/2012	Issued as F1 for construction		GP	JA	PC	

- Notes
- For instrumentation and monitoring general notes, monitoring frequencies and summary schedule, refer to Drg No. C122-OVE-C2-DDJ-CR001 Z-31000, C122-OVE-C2-DDJ-CR001 Z-32002 and C122-OVE-C2-DDJ-CR001 Z-32003 respectively.
 - For C121 SCL IMM requirements and details by C300, refer to Drg No. C121-IMM-C4-000-CR006, S1603-05001.
 - For more details of the installations of the deep datum for TWJL assets, refer to drg no. C122-OVE-C2-DDJ-CR001 Z-32022.

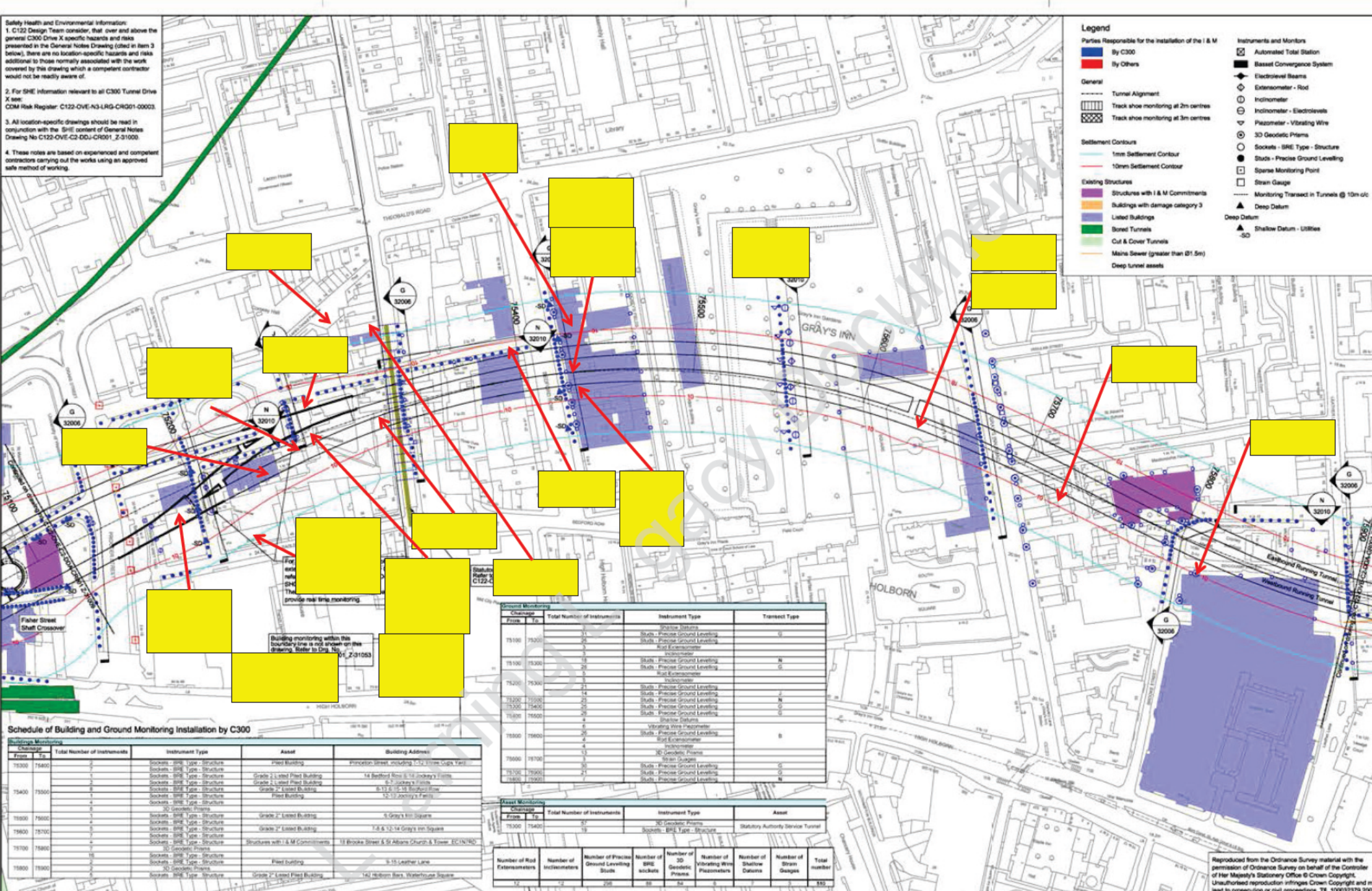
Key Plan



General: Bored Tunnels (Alignment and Track)
 Prepared by: Ove Arup & Partners Limited
 Location: Crossrail General
 Title: Instrumentation and Monitoring Combined I & M
 Routemap Plan Sheet 9 of 38
 C300
 Scale: 1:1000 @ A1
 Drawing and CAD File No: C122-OVE-C2-004-CR001 Z-31009
 Date: C02
 Author: G.POTTER
 Checker: JAFFEY
 Approver: P.CHAMLEY
 Status: A

Safety Health and Environmental Information:
 1. C122 Design Team consider that over and above the general C300 Drive X specific hazards and risks presented in the General Notes Drawing (dtd in item 3 below), there are no location-specific hazards and risks additional to those normally associated with the work covered by this drawing which a competent contractor would not be readily aware of.
 2. For SHE information relevant to all C300 Tunnel Drive X see: COM Risk Register: C122-OVE-N3-LRG-CR001-00003.
 3. All location-specific drawings should be read in conjunction with the SH/E content of General Notes Drawing No C122-OVE-C2-DDJ-CR001_2-31000.
 4. These notes are based on experienced and competent contractors carrying out the works using an approved safe method of working.

- Legend**
- Parties Responsible for the installation of the I & M
- By C300
 - By Others
- General
- Tunnel Alignment
 - Track shoe monitoring at 2m centres
 - Track shoe monitoring at 3m centres
- Settlement Contours
- 1mm Settlement Contour
 - 10mm Settlement Contour
- Existing Structures
- Structures with I & M Commitments
 - Buildings with damage category 3
 - Listed Buildings
 - Bored Tunnels
 - Cut & Cover Tunnels
 - Main Sewer (greater than Ø1.5m)
 - Deep tunnel assets
- Instruments and Monitors
- Automated Total Station
 - Basest Convergence System
 - Electrolevel Beams
 - Extensometer - Rod
 - Inclinometer
 - Inclinometer - Electrolevels
 - Piezometer - Vibrating Wire
 - 3D Geodetic Prisms
 - Sockets - IRE Type - Structure
 - Studs - Precise Ground Levelling
 - Sparse Monitoring Point
 - Strain Gauge
 - Monitoring Transact in Tunnels @ 10m etc
 - Deep Datum
 - Shallow Datum - Utilities



Ground Monitoring

Chordance	Zone	Total Number of Instruments	Instrument Type	Transact Type
75100	75200	11	Shallow Datum	
75100	75200	28	Studs - Precise Ground Levelling	
75100	75200	30	Studs - Precise Ground Levelling	
75100	75200	18	Studs - Precise Ground Levelling	N
75100	75200	30	Studs - Precise Ground Levelling	G
75200	75300	14	Extensometer	
75200	75300	23	Studs - Precise Ground Levelling	N
75200	75300	23	Studs - Precise Ground Levelling	G
75300	75400	2	Shallow Datum	
75300	75400	2	Vibrating Wire Piezometer	
75300	75400	29	Studs - Precise Ground Levelling	
75300	75400	29	Studs - Precise Ground Levelling	B
75400	75500	13	3D Geodetic Prisms	
75400	75500	30	Studs - Precise Ground Levelling	
75500	75600	21	Studs - Precise Ground Levelling	G
75500	75600	21	Studs - Precise Ground Levelling	G

Asset Monitoring

Chordance	Zone	Total Number of Instruments	Instrument Type	Asset
75300	75400	27	3D Geodetic Prisms	Statutory Authority Service Tunnel
75300	75400	19	Sockets - IRE Type - Structure	

Number of Rod Extensometers	Number of Inclinometers	Number of Precise Ground Levelling Studs	Number of IRE Sockets	Number of 3D Geodetic Prisms	Number of Vibrating Wire Piezometers	Number of Shallow Datums	Number of Strain Gauges	Total number
12	228	228	228	228	2	2	2	550

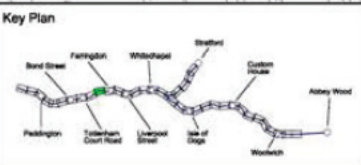
Schedule of Building and Ground Monitoring Installation by C300

From	To	Total Number of Instruments	Instrument Type	Asset	Building Address
75300	75400	2	Sockets - IRE Type - Structure	Piled Building	Princes Street, including 1-12 Stone Lane East
75300	75400	2	Sockets - IRE Type - Structure	Piled Building	14 Bedford Row & 14 Jockey's Lane
75300	75400	2	Sockets - IRE Type - Structure	Grade 2 Listed Piled Building	6-7 Jockey's Lane
75400	75500	1	Sockets - IRE Type - Structure	Grade 2 Listed Building	8-11 & 13 Bedford Row
75400	75500	4	Sockets - IRE Type - Structure	Piled Building	12-13 Jockey's Lane
75400	75500	1	3D Geodetic Prisms		
75400	75500	1	Sockets - IRE Type - Structure	Grade 2 Listed Building	5 Gray's Inn Square
75400	75500	7	Sockets - IRE Type - Structure	Grade 2 Listed Building	7 & 8 & 12-14 Gray's Inn Square
75400	75500	7	Sockets - IRE Type - Structure	Grade 2 Listed Building	7 & 8 & 12-14 Gray's Inn Square
75500	75600	1	Sockets - IRE Type - Structure	Structures with I & M Commitments	11 Brooke Street & 50 Adams Church & Lower, EC1N 8DQ
75500	75600	1	3D Geodetic Prisms		
75500	75600	30	Sockets - IRE Type - Structure	Piled Building	3-15 Leathers Lane
75500	75600	30	Sockets - IRE Type - Structure	Grade 2 Listed Piled Building	141 Holborn Bars, Waterhouse Square

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Rev.	Date	Issued as	Description	By	Check	App	Auth
P01	20/11/2008	Issued for Tender Purposes		AB	AH	RM	
P02	10/03/2010	Revised for Tender Purposes		JC	AB	RM	
P03	28/04/2010	Revised for Tender Addendum Purposes		AB	AB	RM	
P04	14/12/2010	Revised for Tender Addendum Purposes		JF	AB	RM	
P05	14/12/2010	Issued for Construction		JF	AB	RM	
P06	11/05/2011	Designer's Revision		GP	JC	PC	
P07	03/02/2012	Minimum Requirement		GP	JA	RM	
P08	17/02/2012	Issued as I1 for construction		GP	JA	RM	IF

- Notes**
- For instrumentation and monitoring general notes, monitoring frequencies and summary schedule, refer to Dig. No. C122-OVE-C2-DDJ-CR001_2-31000, C122-OVE-C2-DDJ-CR001_2-30002 and C122-OVE-C2-DDJ-CR001_2-30005 respectively.
 - For C121 SCL I&M requirements and details by C300, refer to Dig No. C121-I&M-C4-DDJ-CR006_2-31000-05001.
 - For more details of the installations of the deep datums for TWJL assets, refer to dig no. C122-OVE-C2-DDJ-CR001_2-33302.



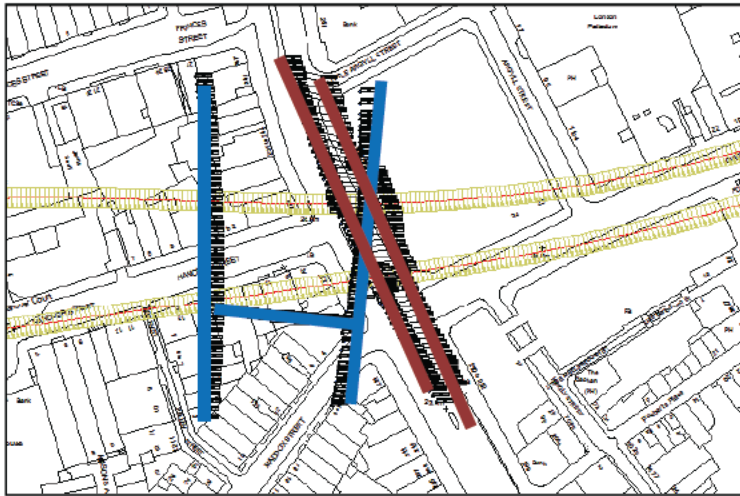
Bored Tunnels (Alignment and Track)
 Prepared by: Ave Anup & Partners Limited
 Location: Crossrail General
 Title: Instrumentation and Monitoring Combined I & M
 Routemap Plan Sheet 10 of 38
 C300
 Scale: 1:1000 @ A1
 Drawing and CAD Rev No: C122-OVE-C2-DDJ-CR001_2-31010
 Date: 01/11/2015
 Rev: C01



Appendix 6. LU data

Larning L gacy Document

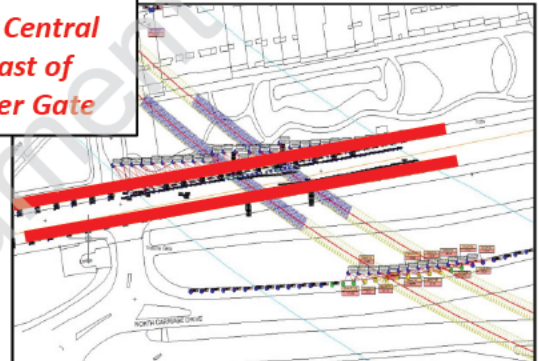
LU-TBMs Interfaces Manual Track Readings decommissioning



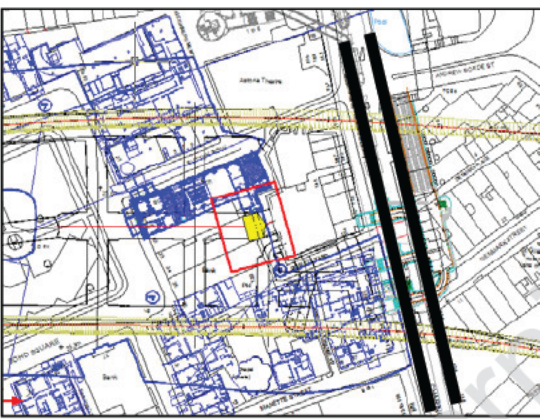
LU/08 – Victoria Line South of Oxford Circus

LU/09 – Bakerloo Line South of Oxford Circus

LU/05 – Central Line East of Lancaster Gate



- Electrolevels data
 - Time-settlement plots
 - Cuts
- Rails Geometry
 - Cant
 - 2m base Twist
 - 10m base Twist

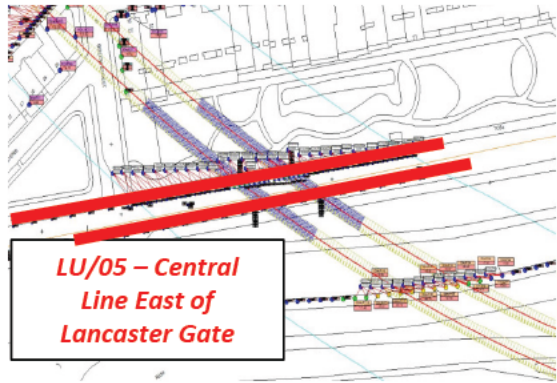


LU/11 – Tottenham Court Road Northern Line Station

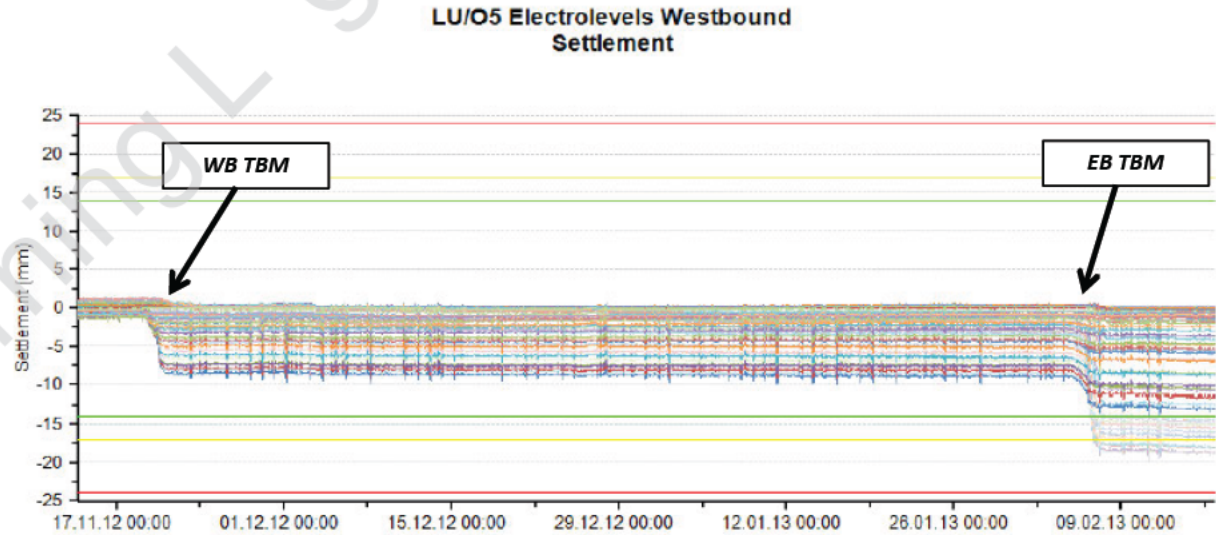
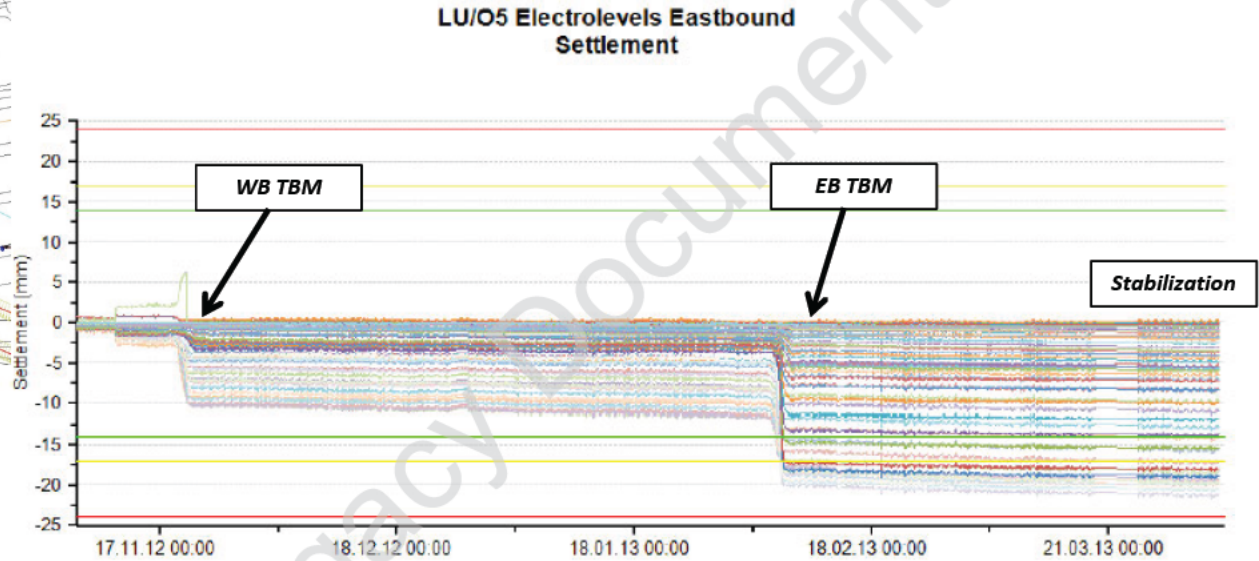
LU/13 – Central Line West of Holborn



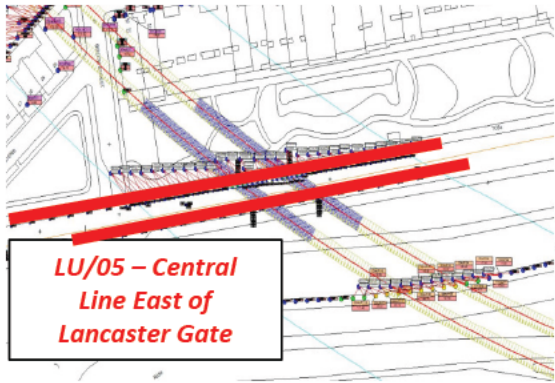
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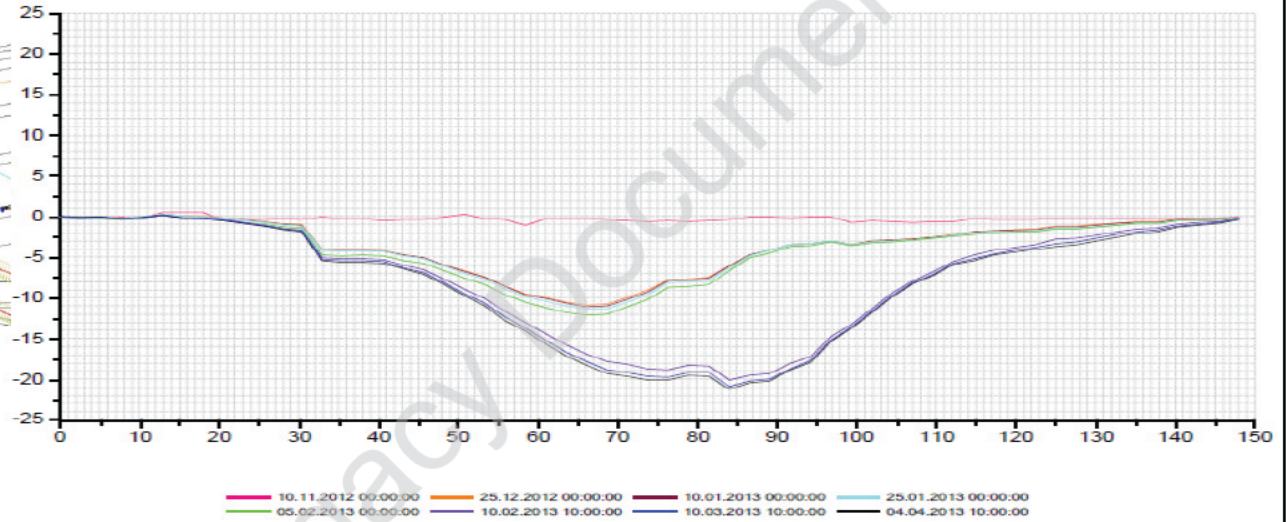


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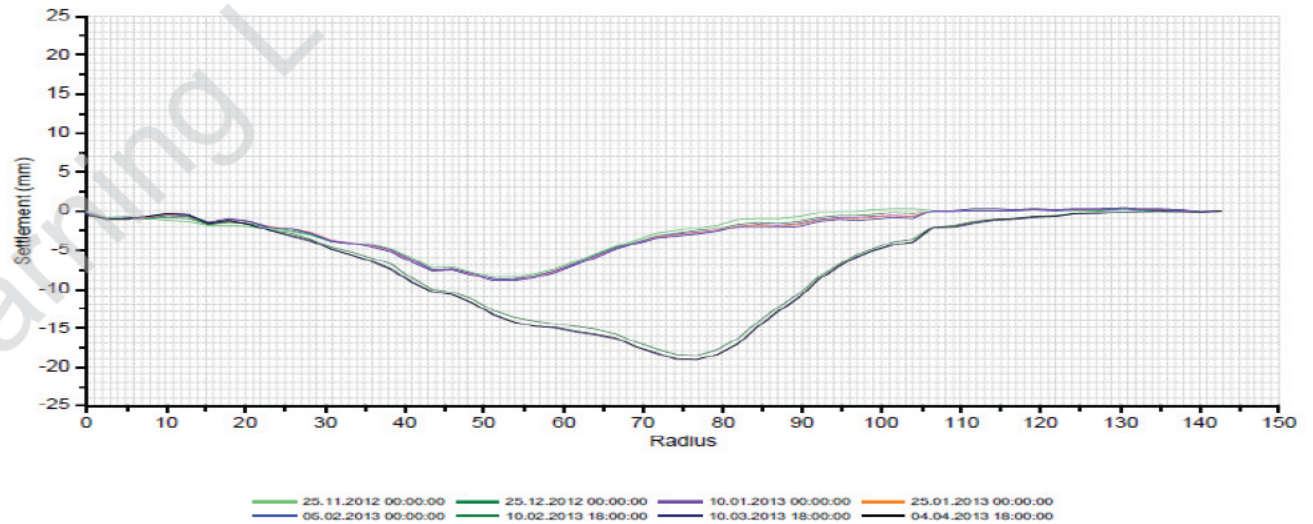


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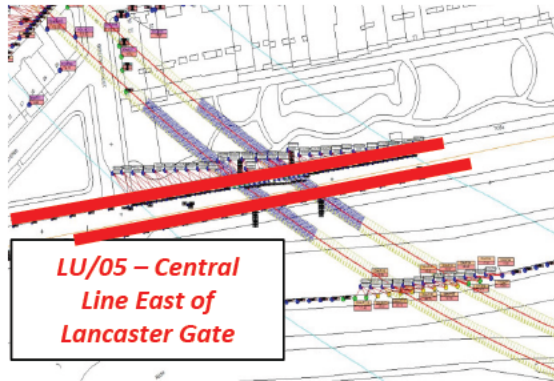
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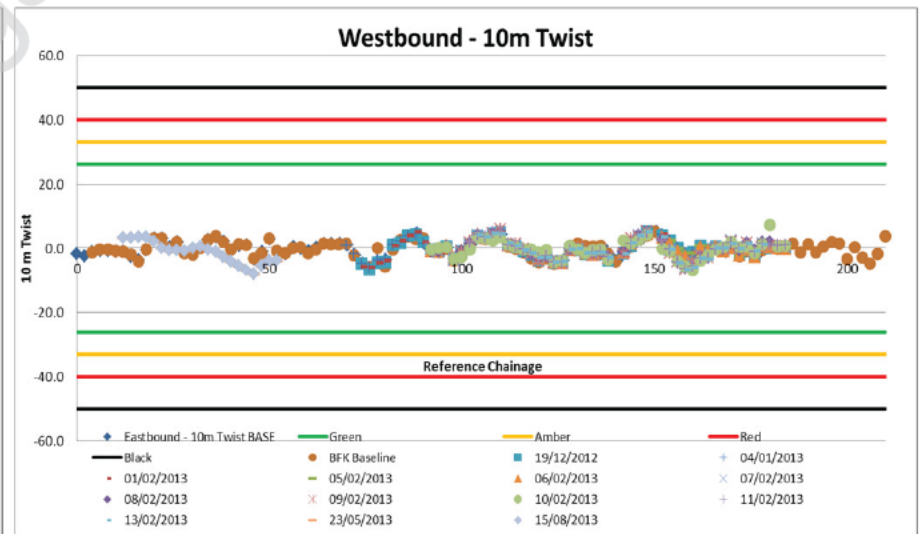
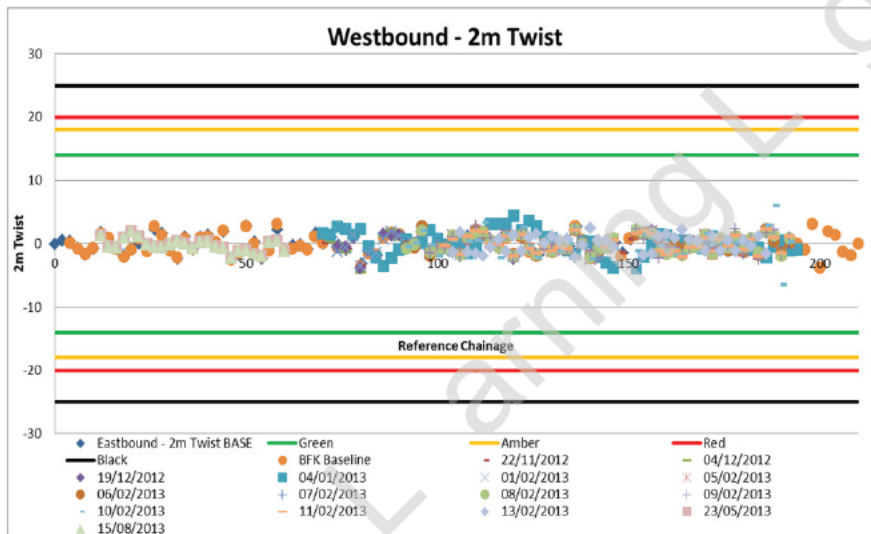
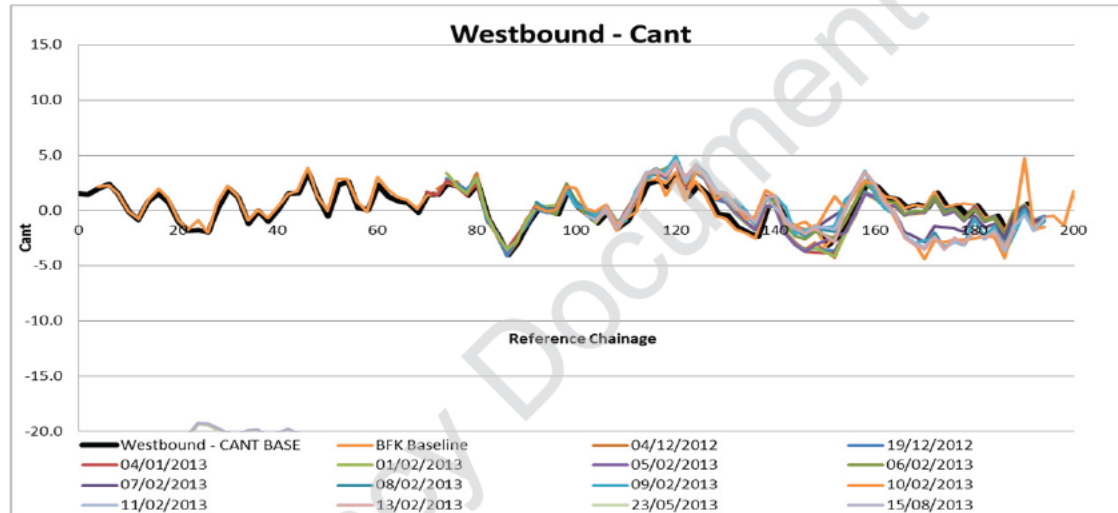
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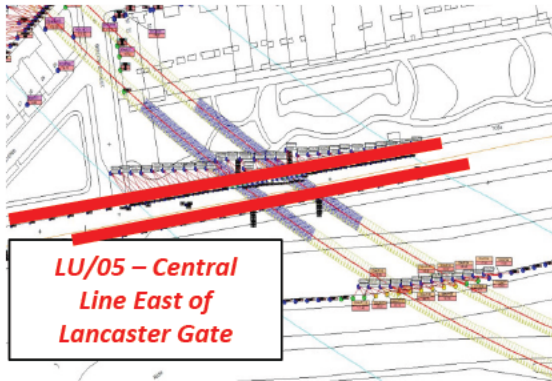
LU-TBMs Interfaces Manual Track Readings decommissioning



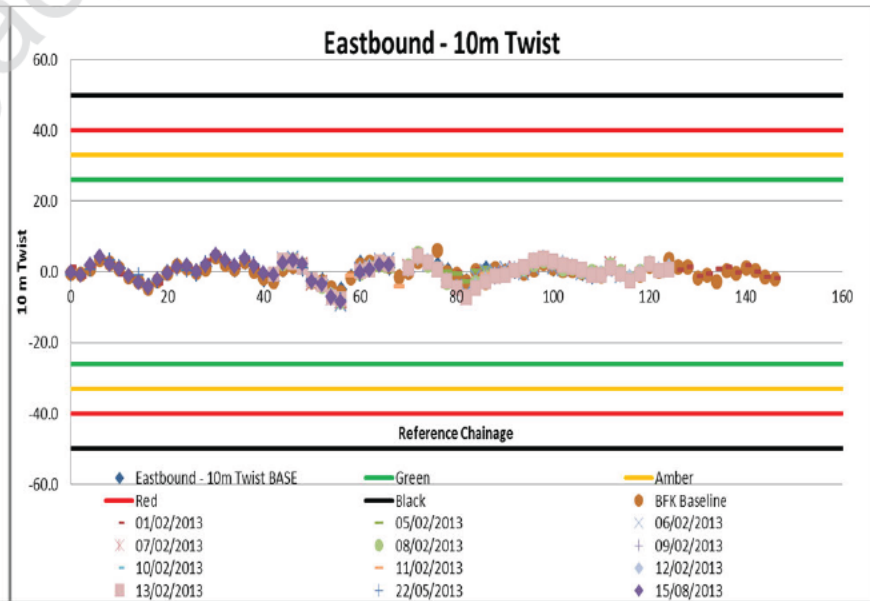
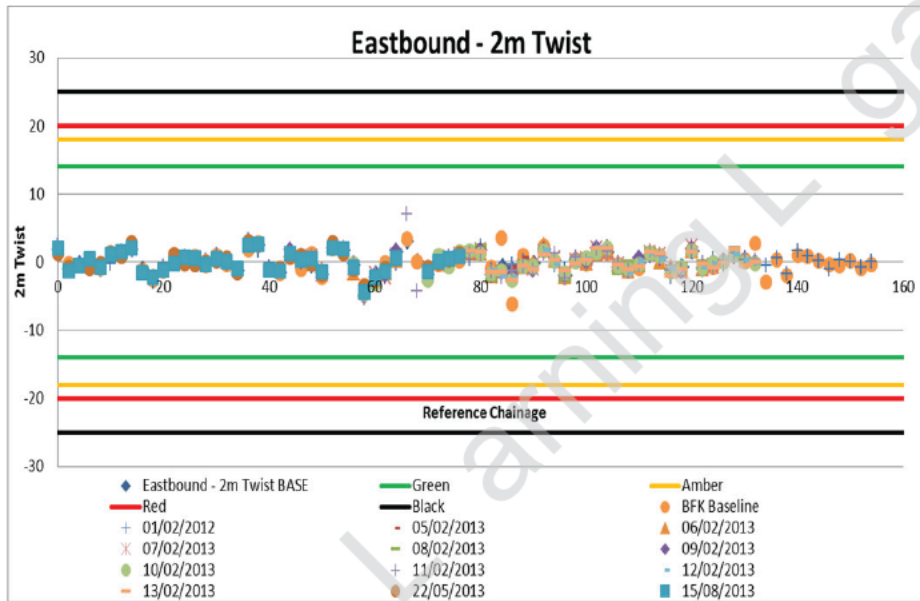
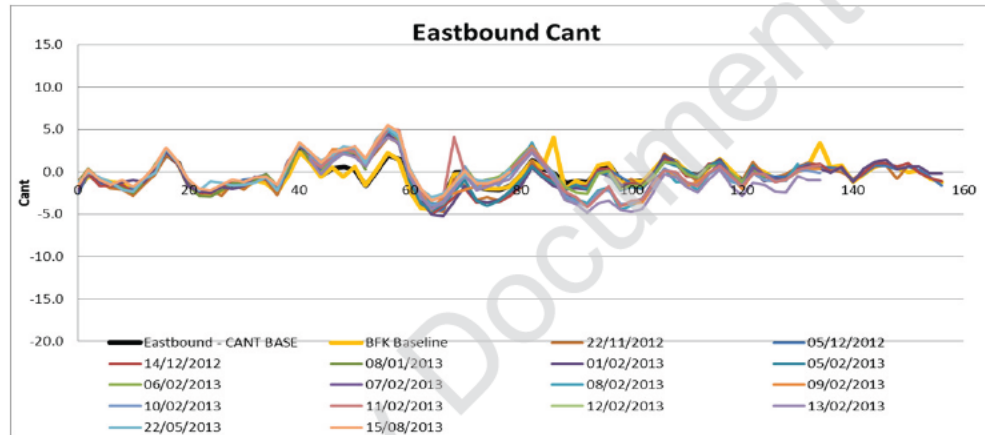
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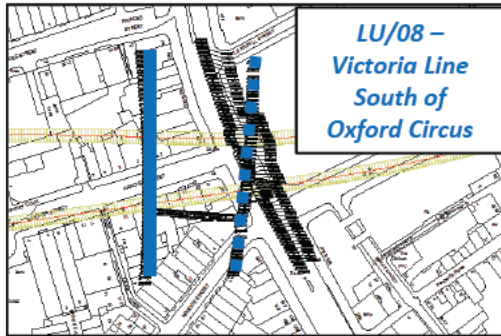
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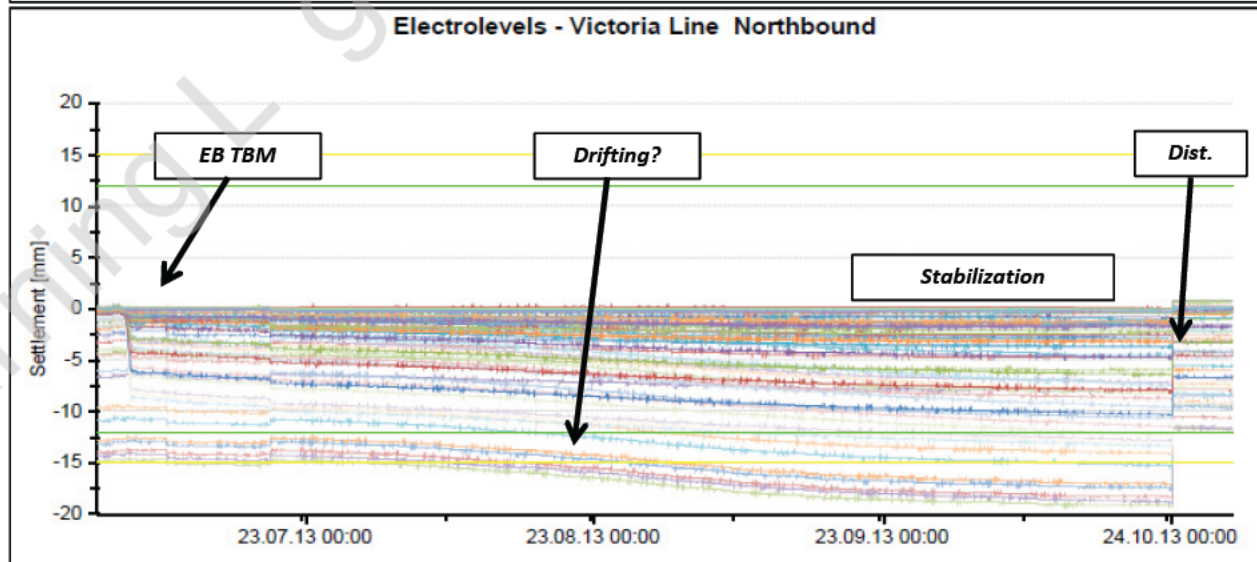
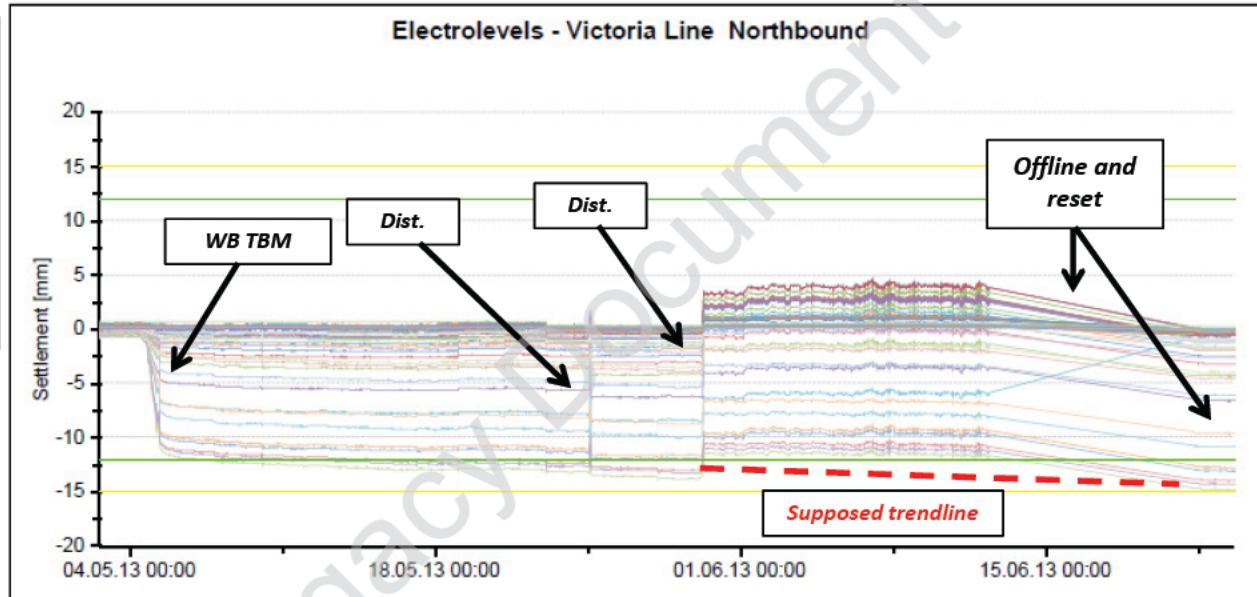
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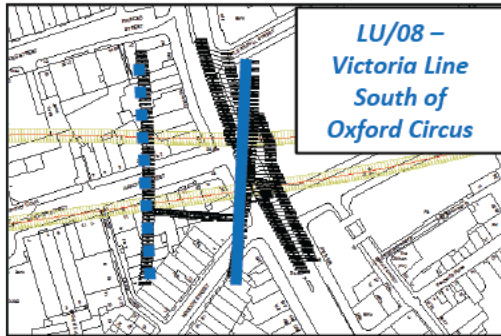
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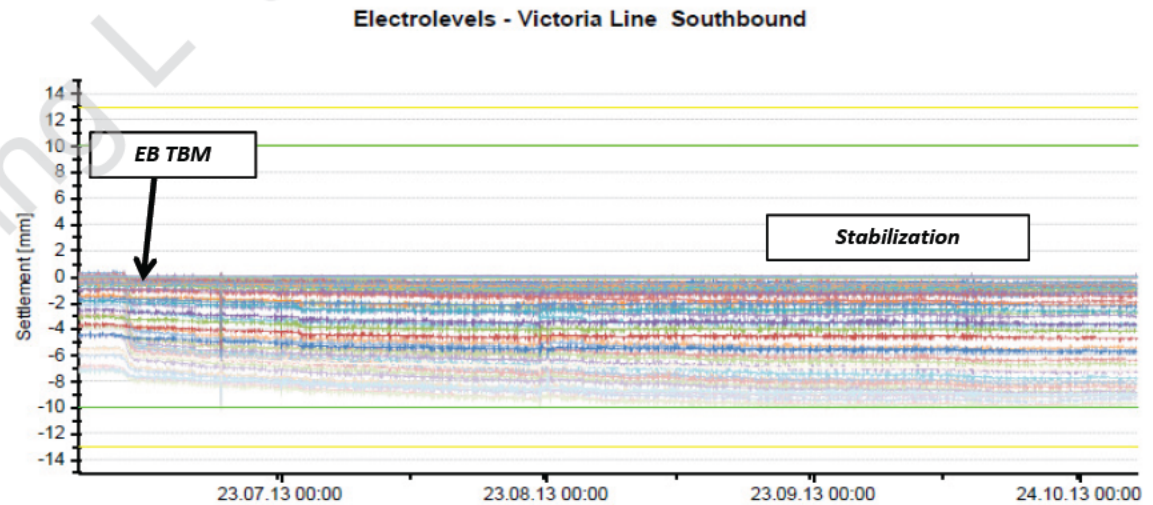
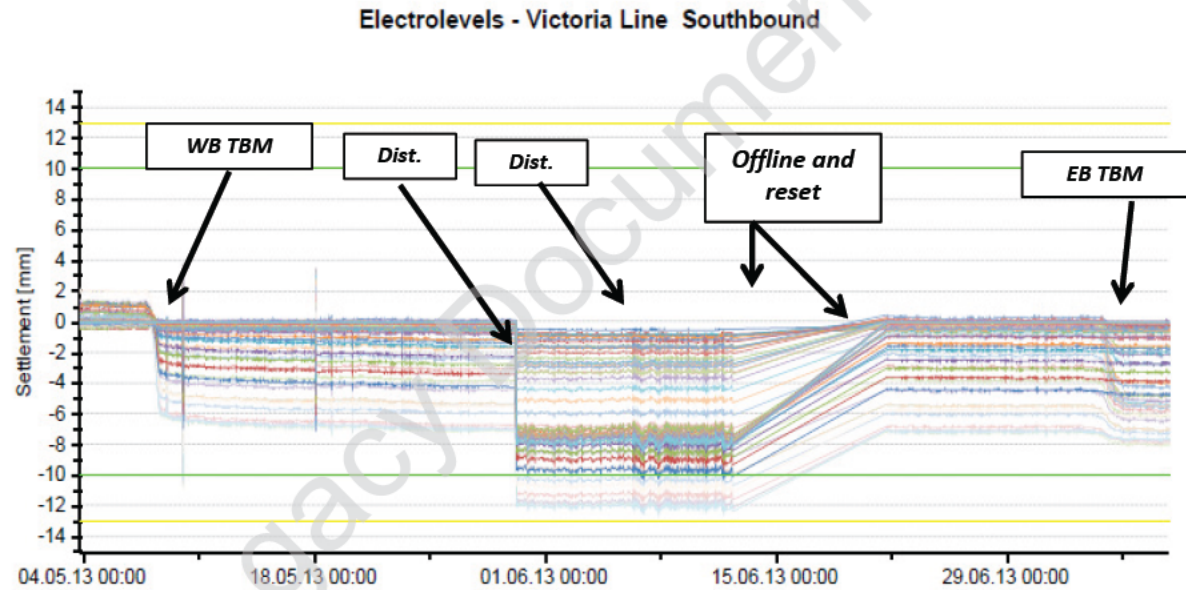
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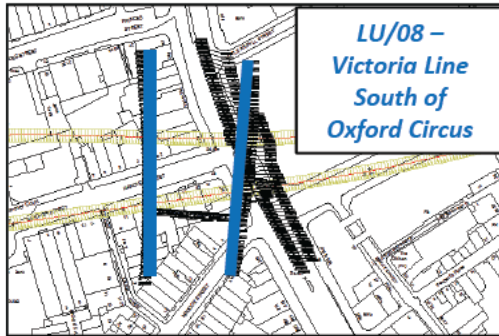
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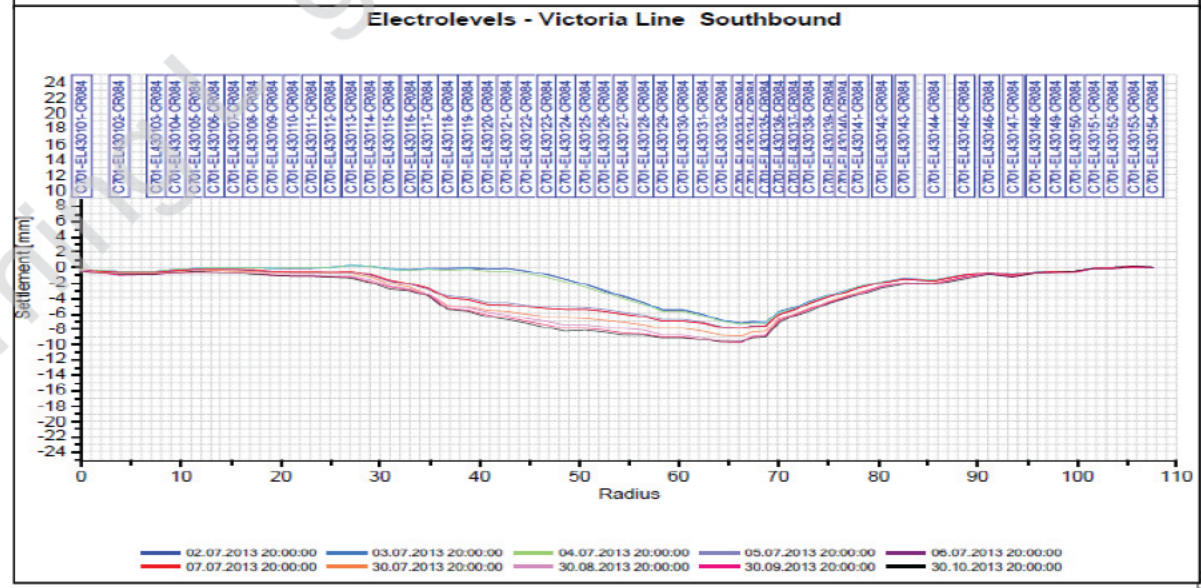
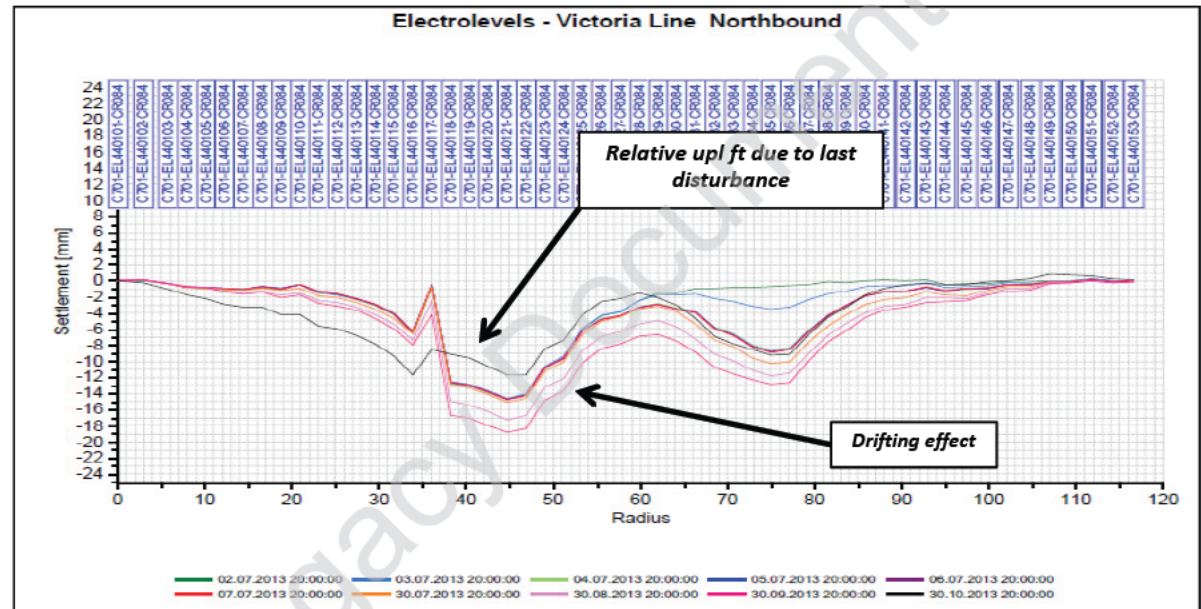


LU-TBMs Interfaces Tracks' Manual Survey decommissioning

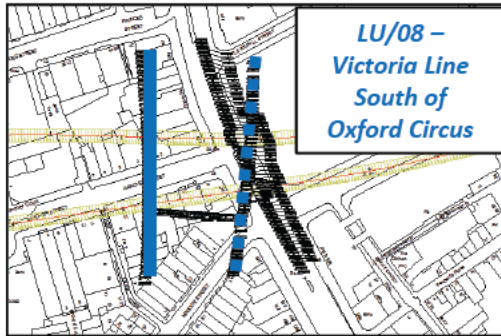


LU/08 -
Victoria Line
South of
Oxford Circus

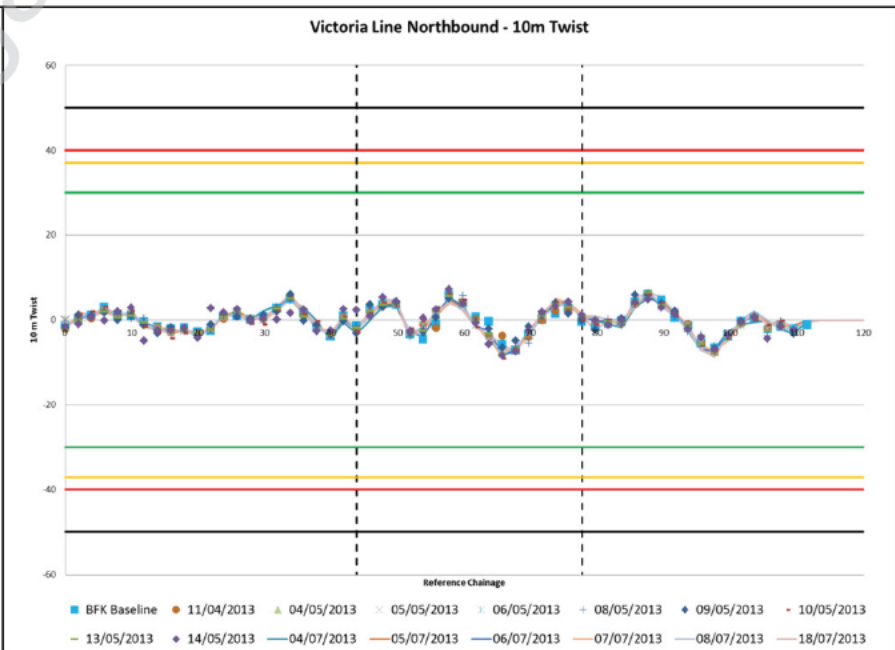
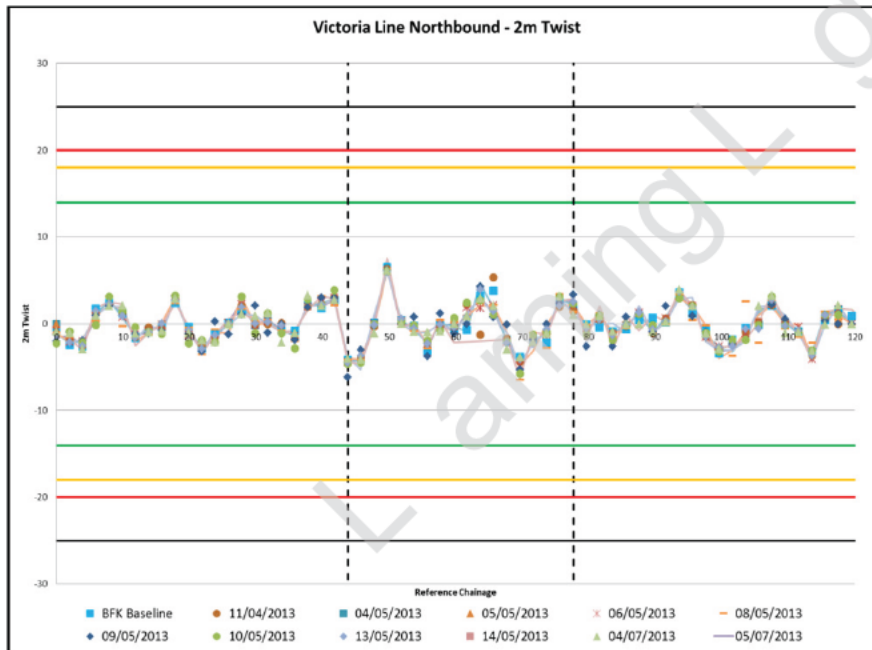
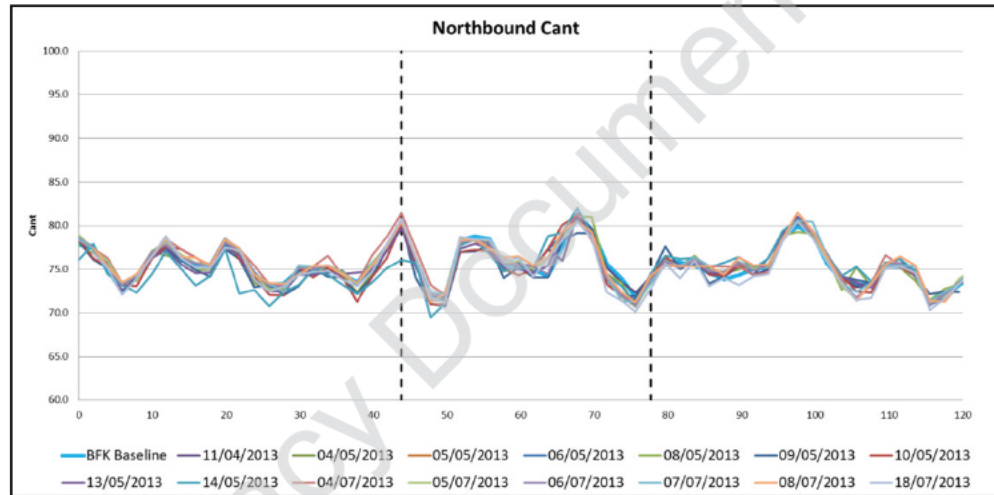
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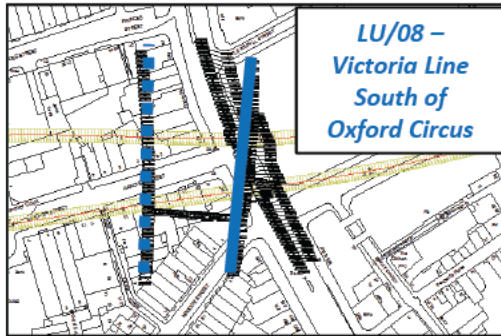
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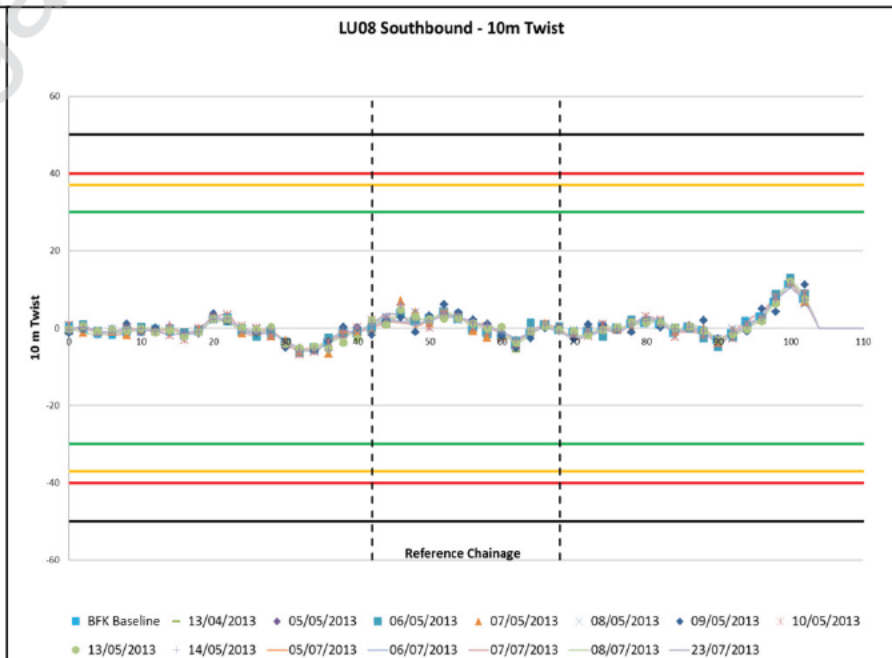
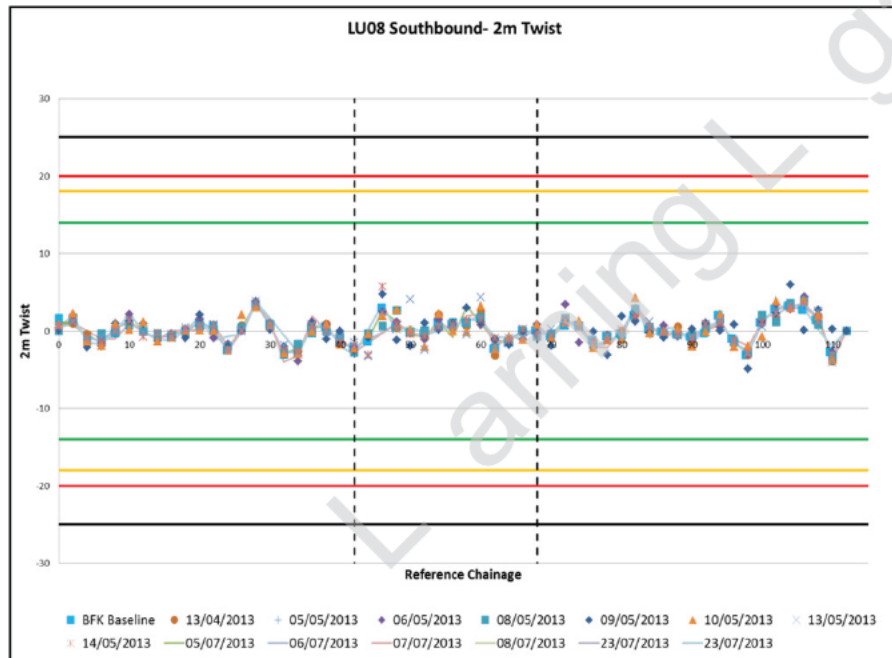
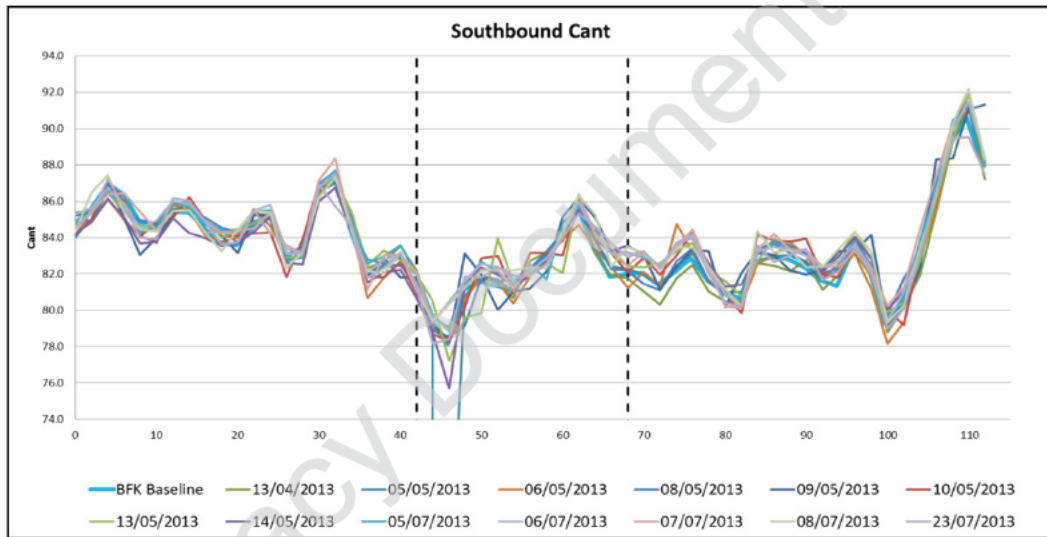
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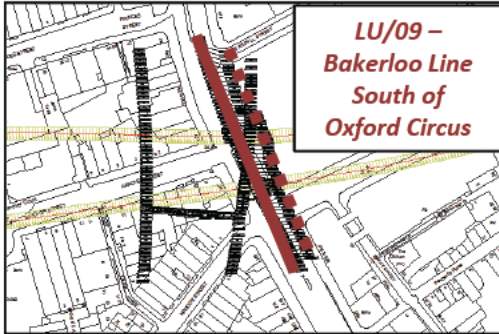
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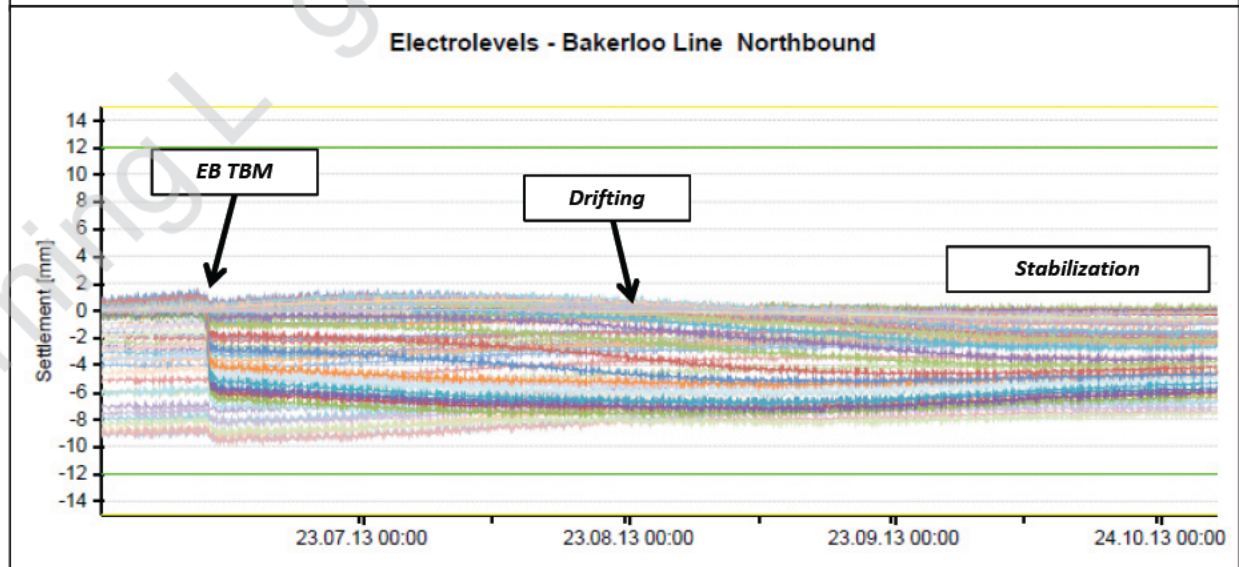
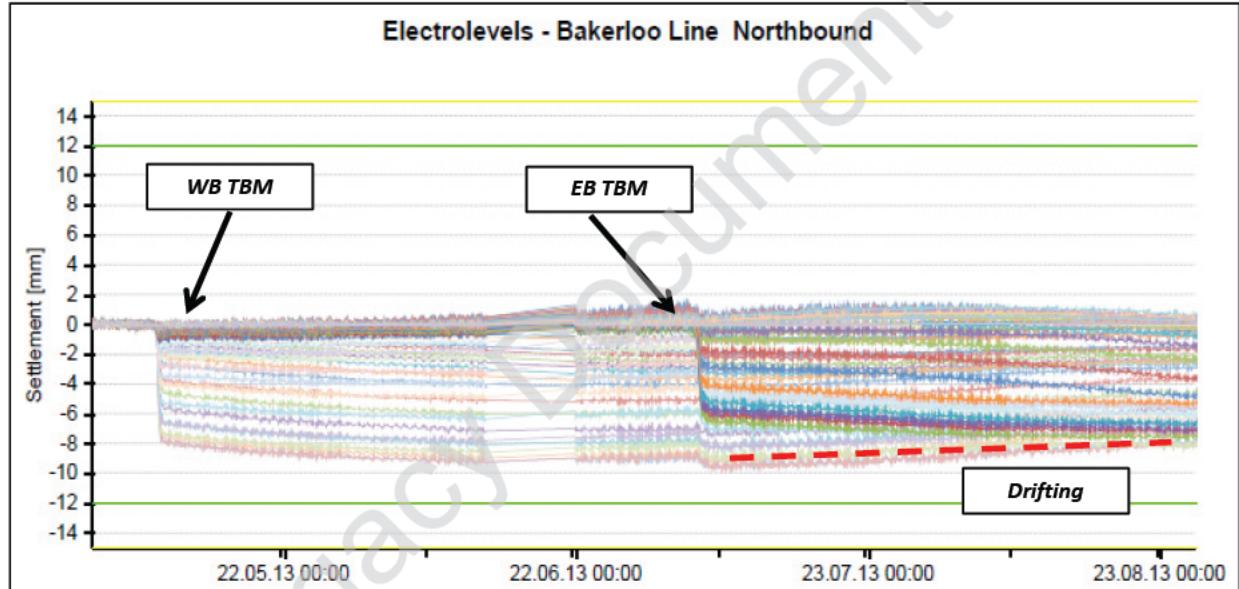
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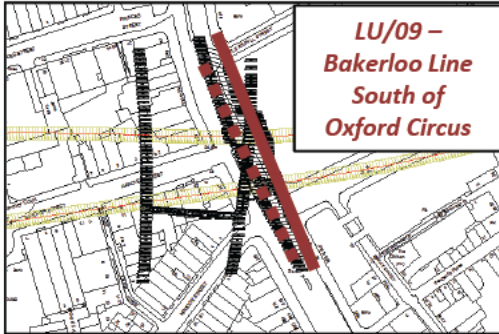
LU-TBMs Interfaces Manual Track Readings decommissioning



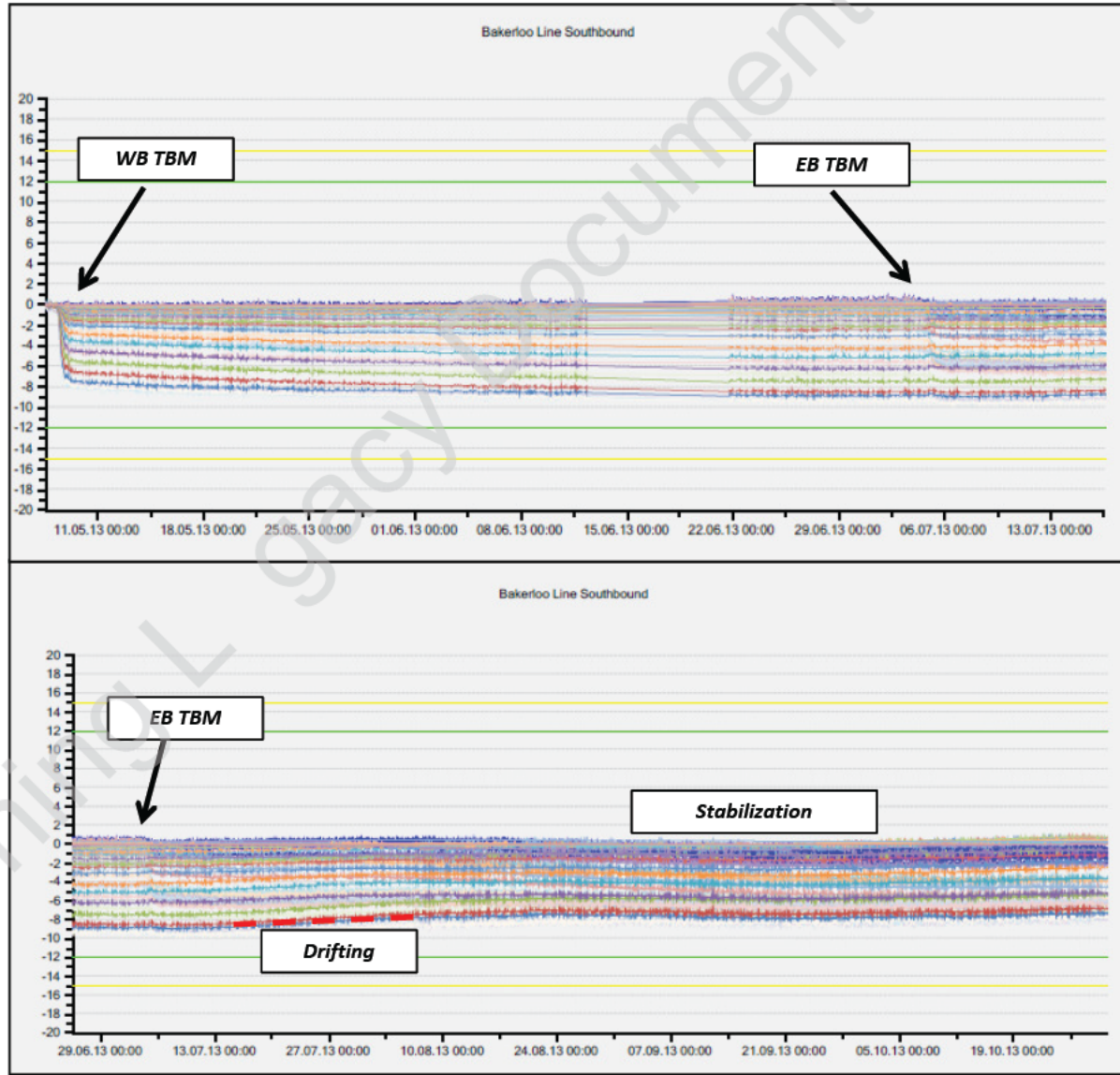
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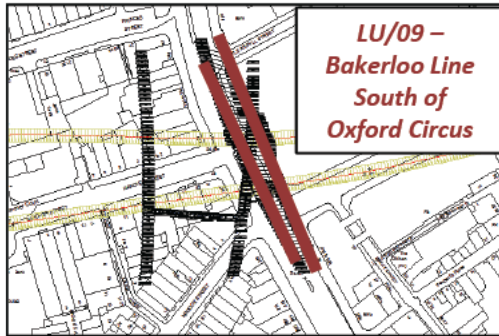
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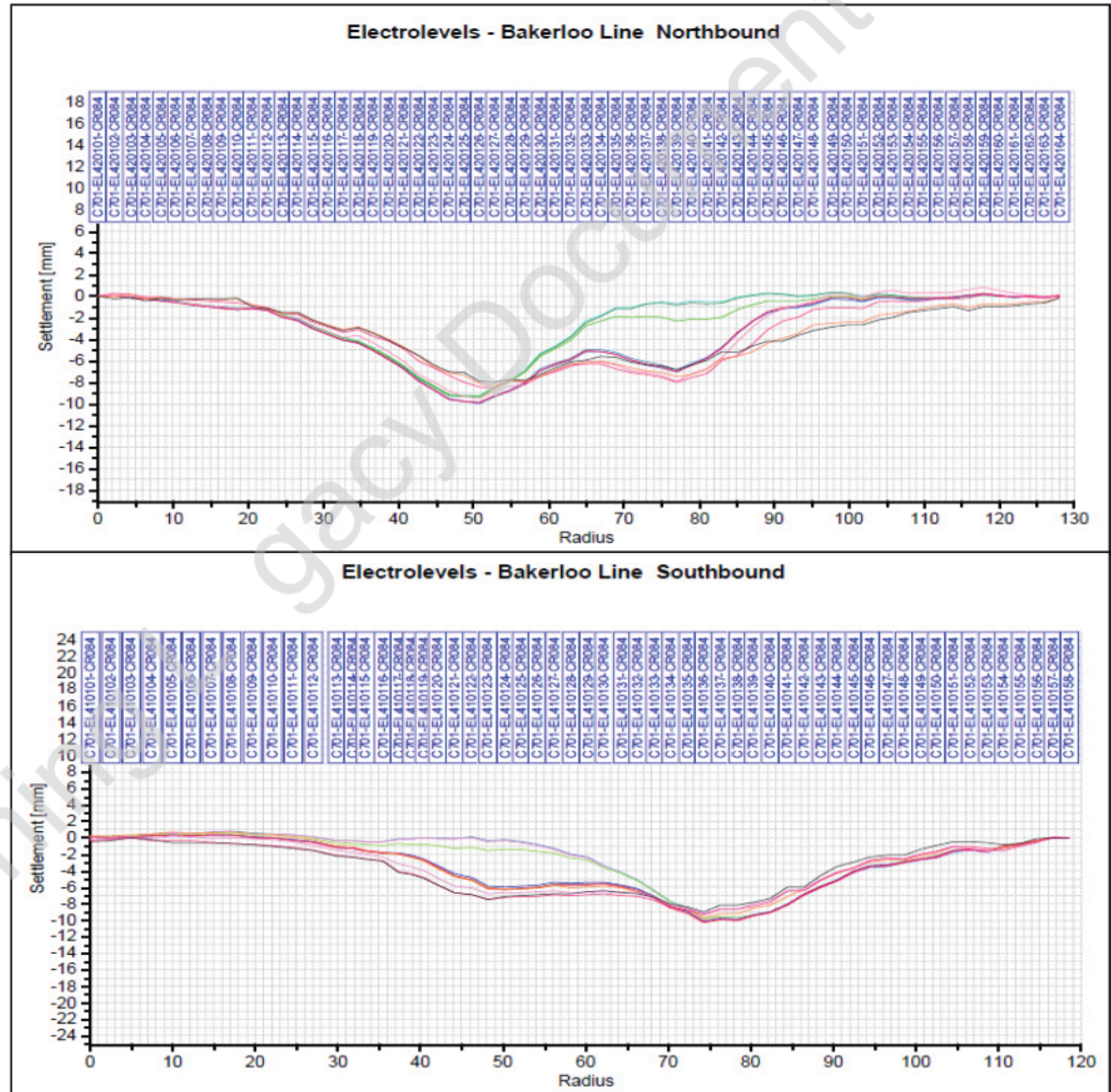
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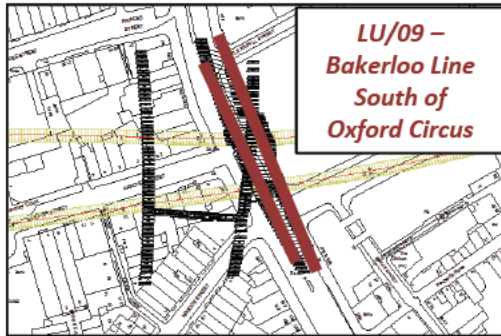
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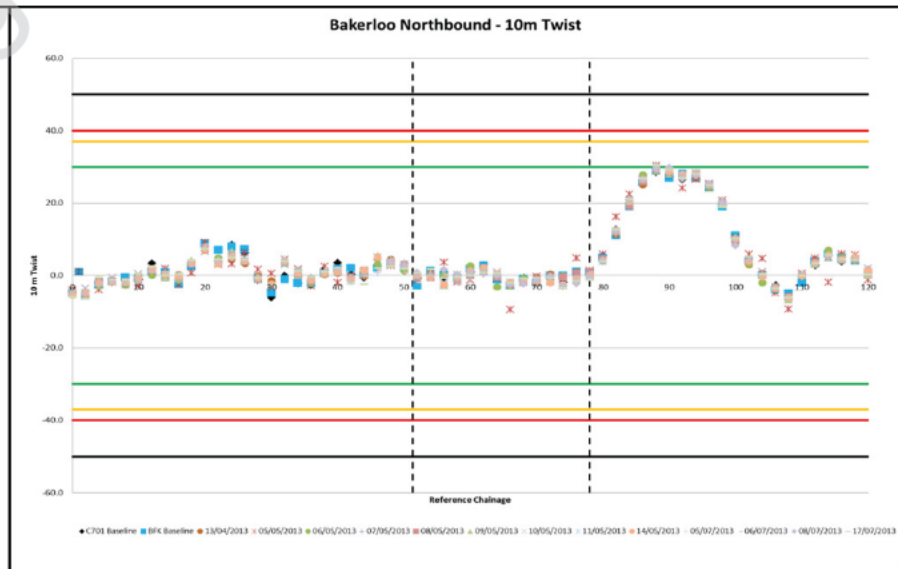
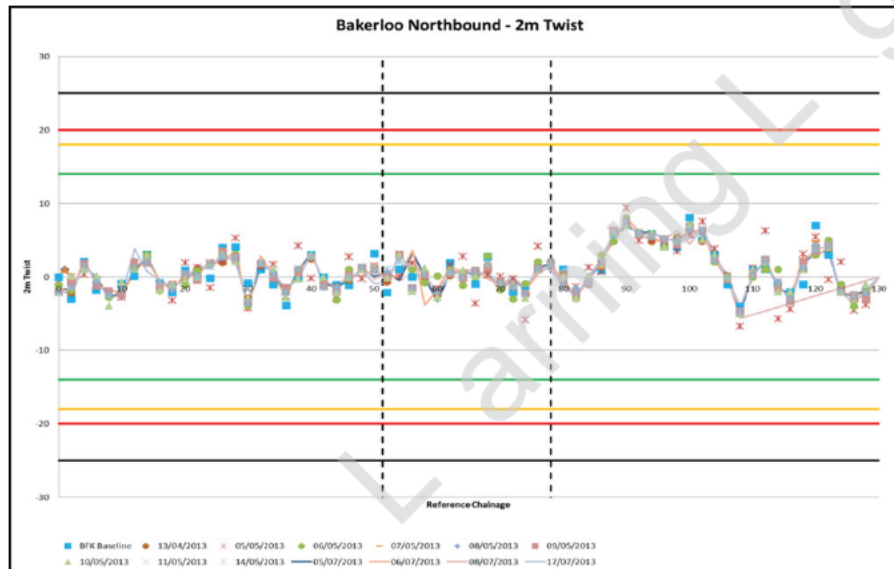
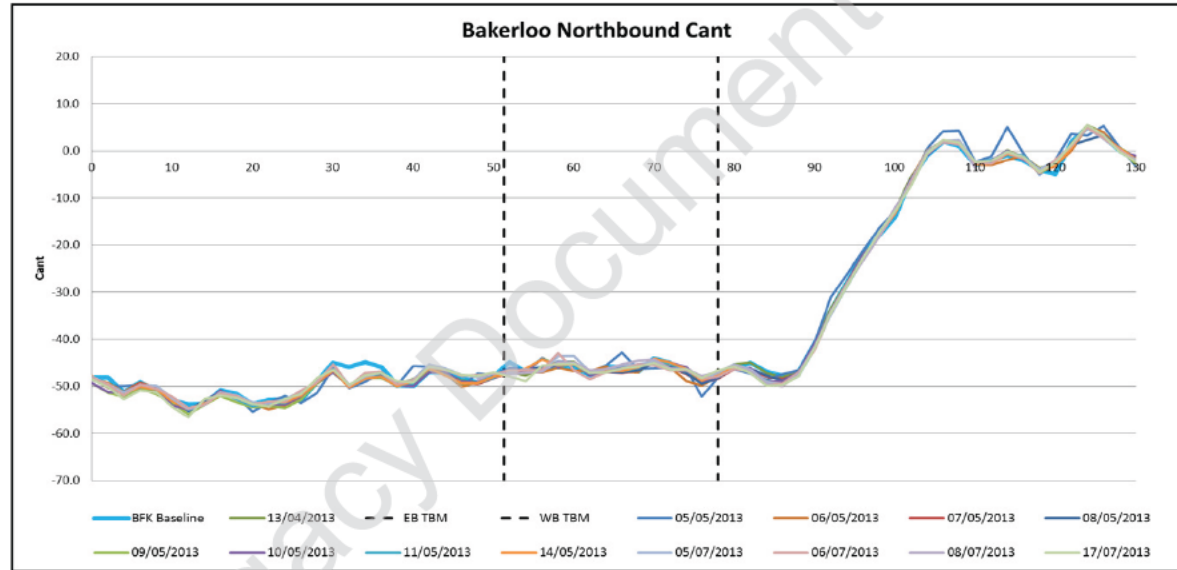
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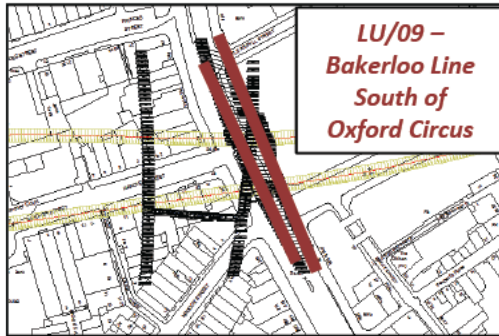
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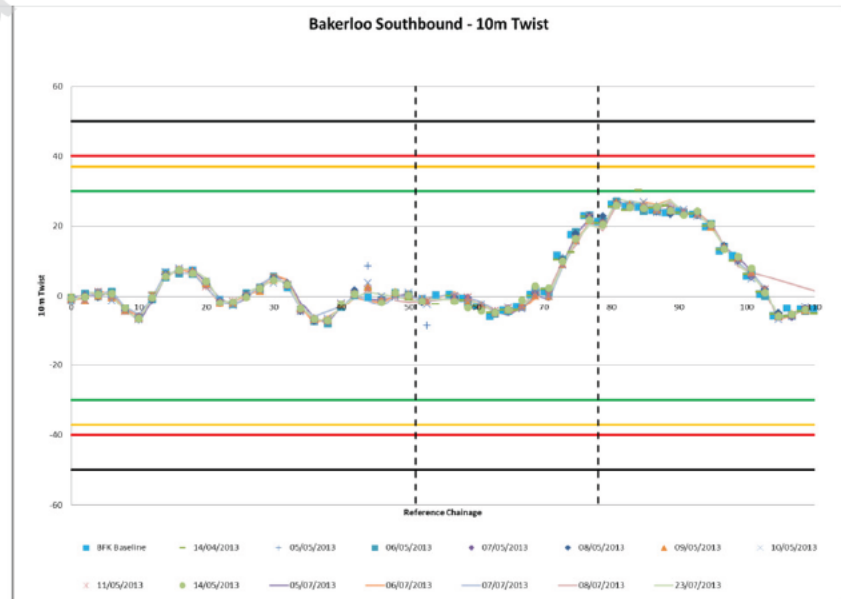
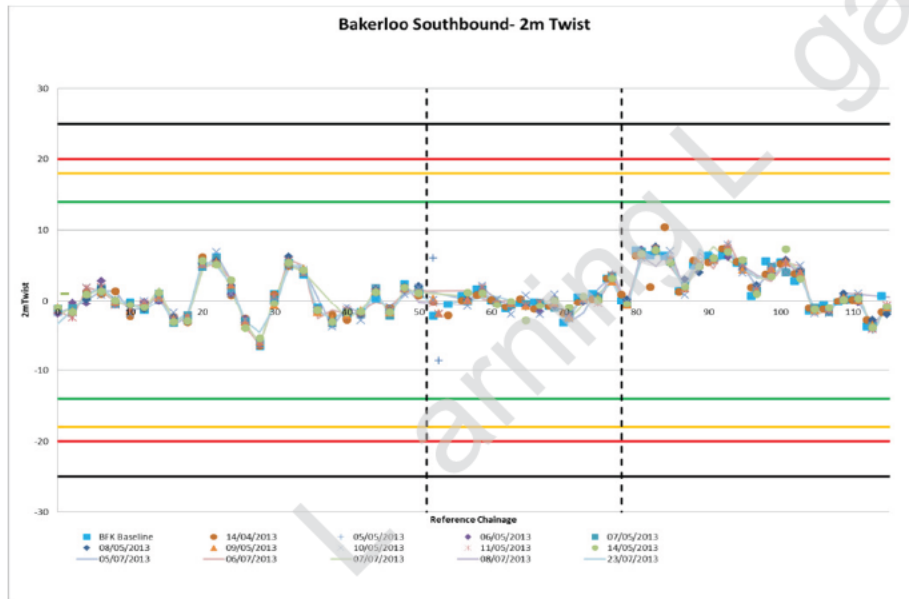
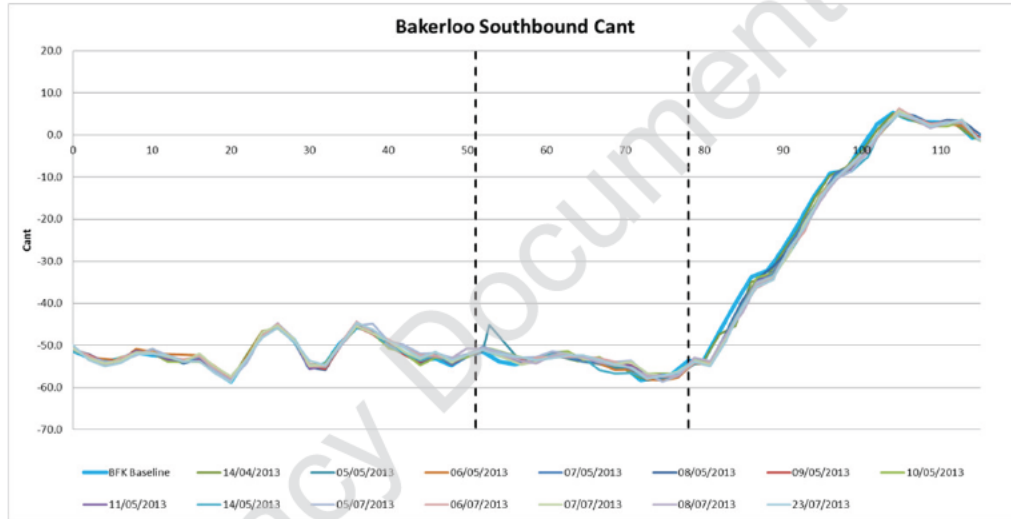
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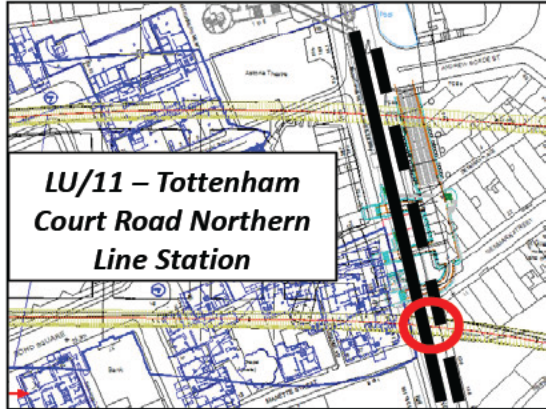
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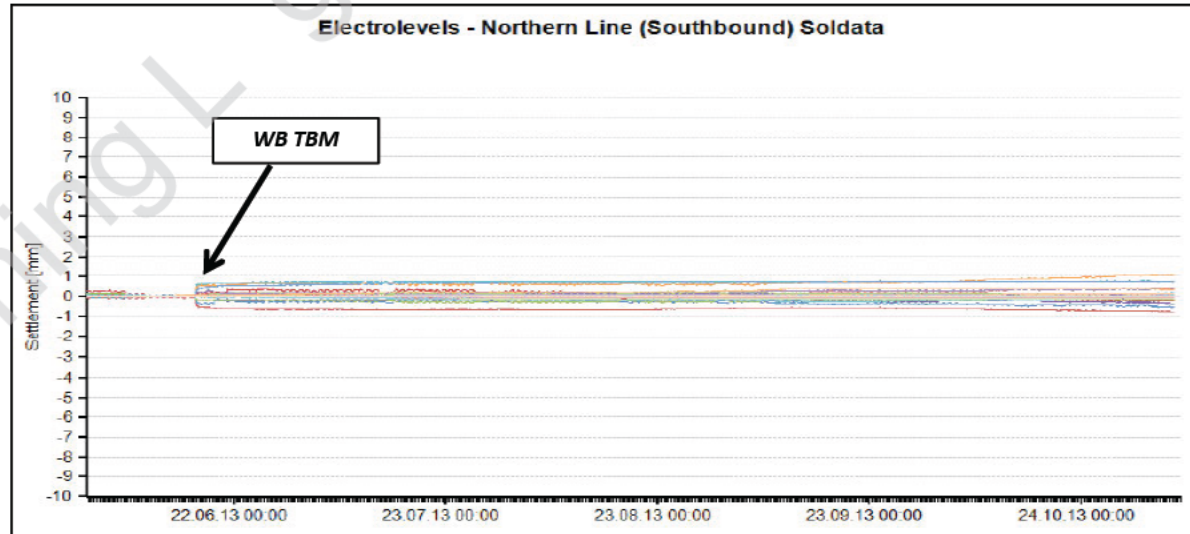
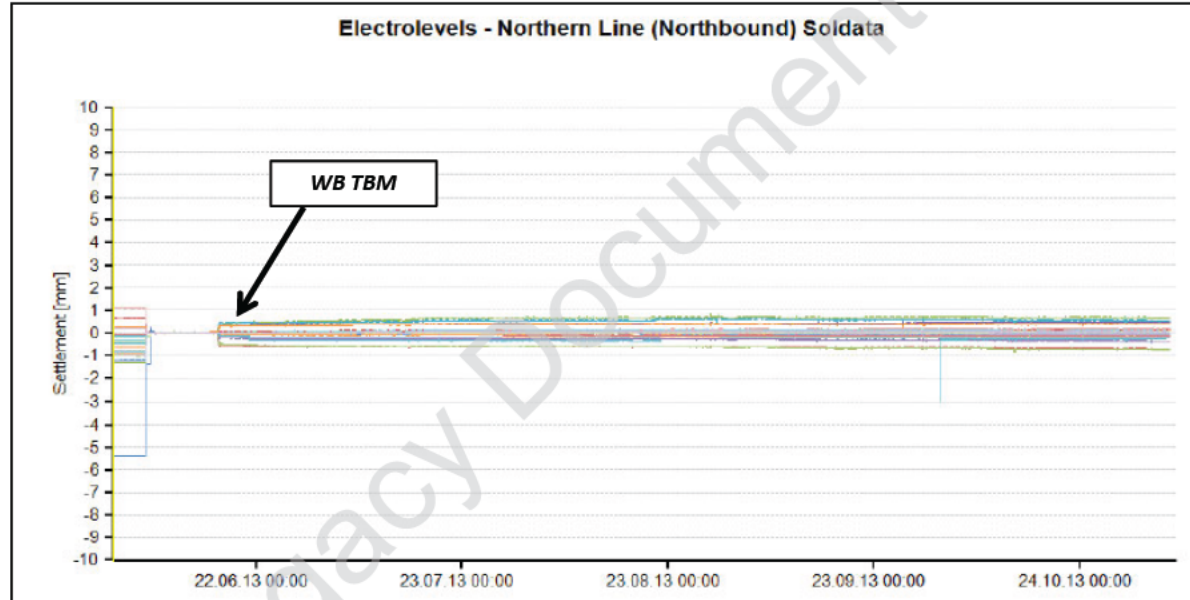
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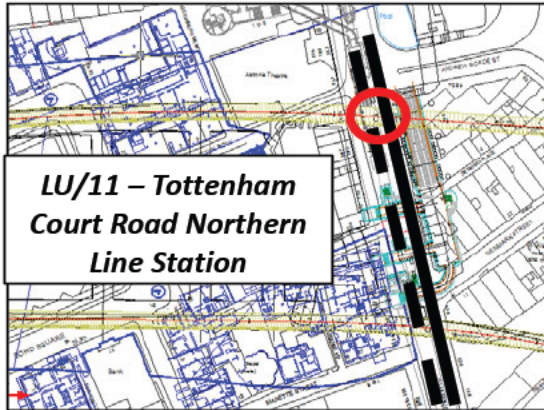
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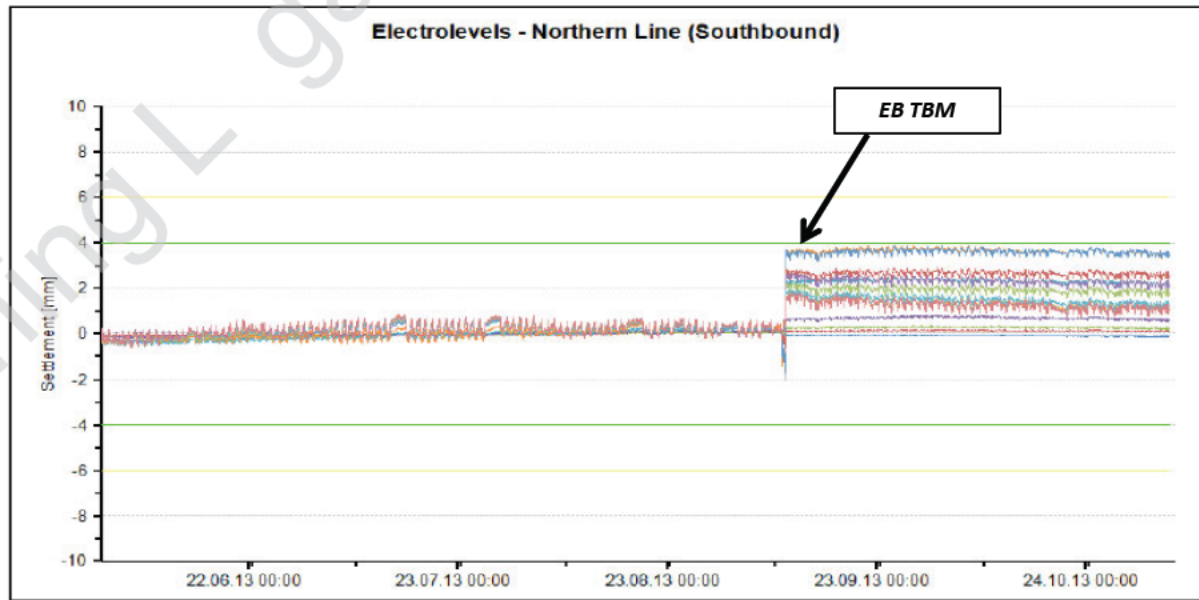
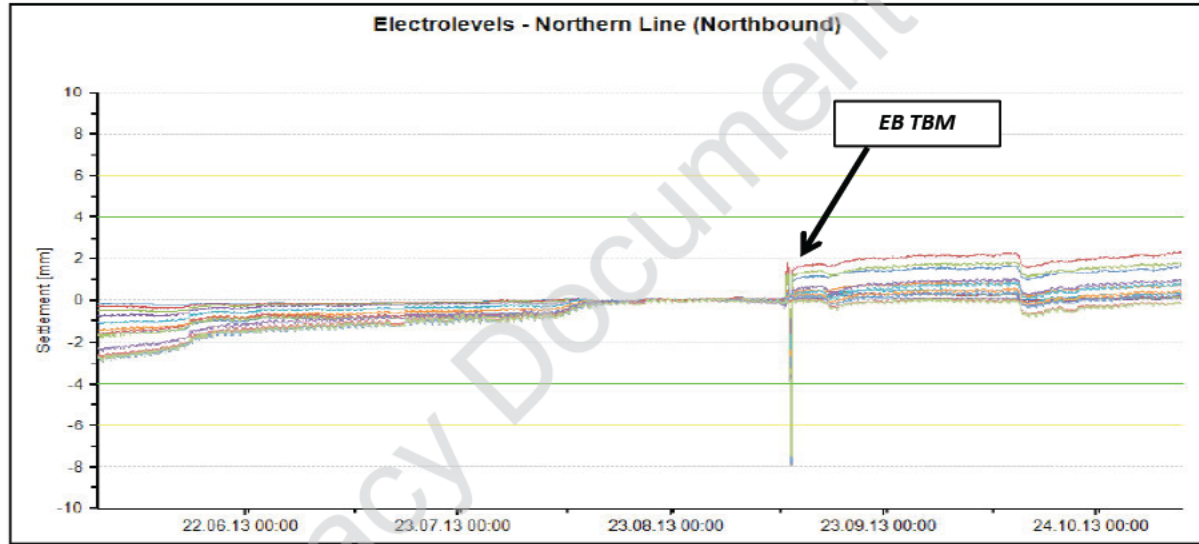
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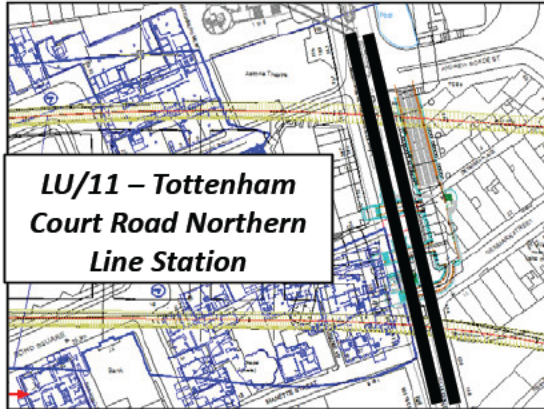
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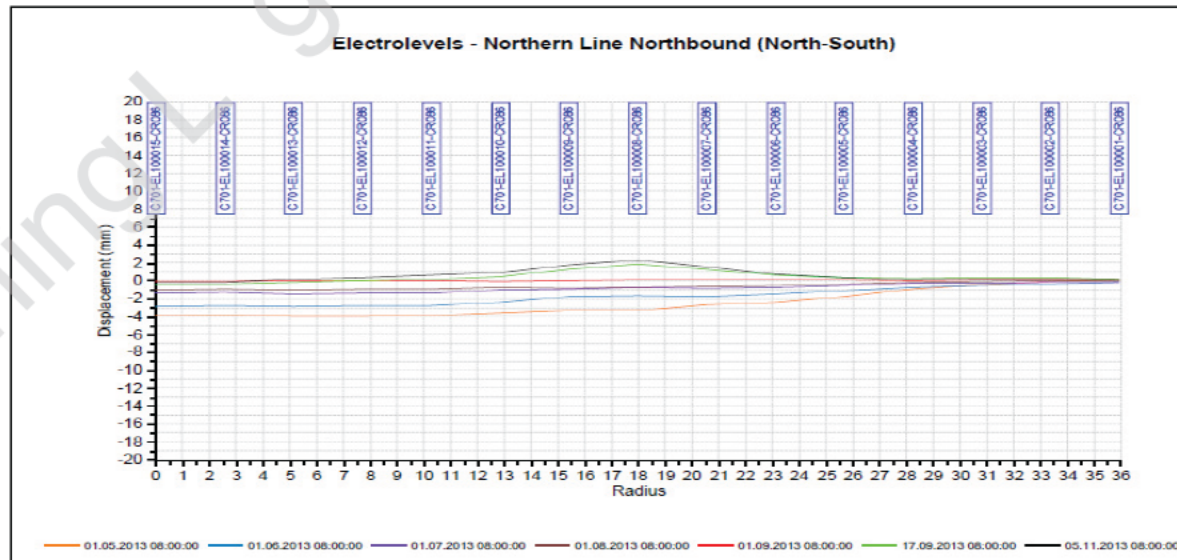
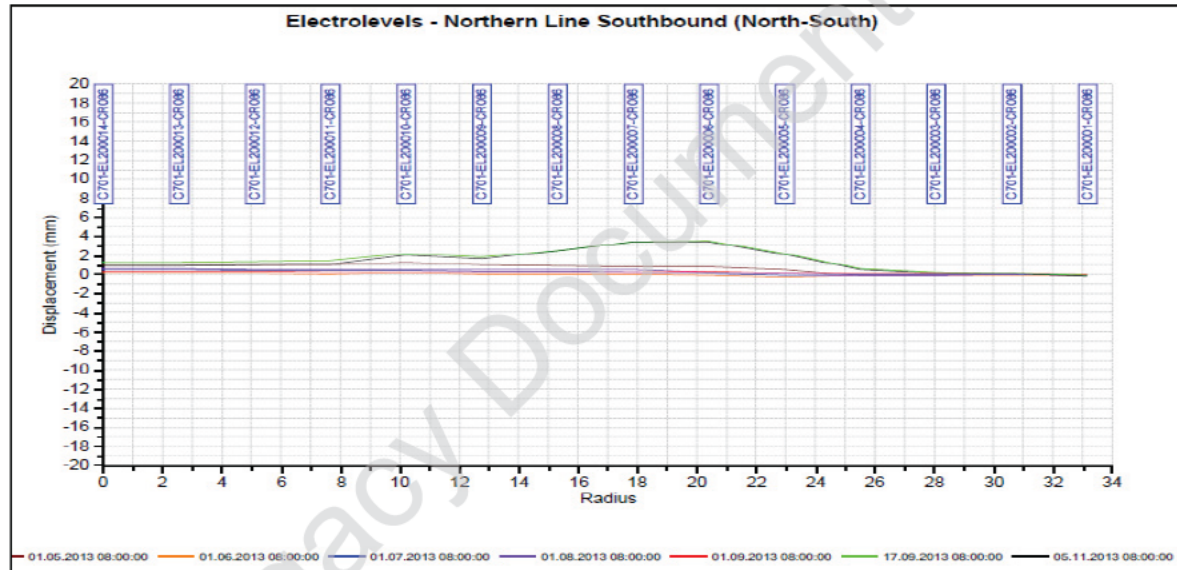
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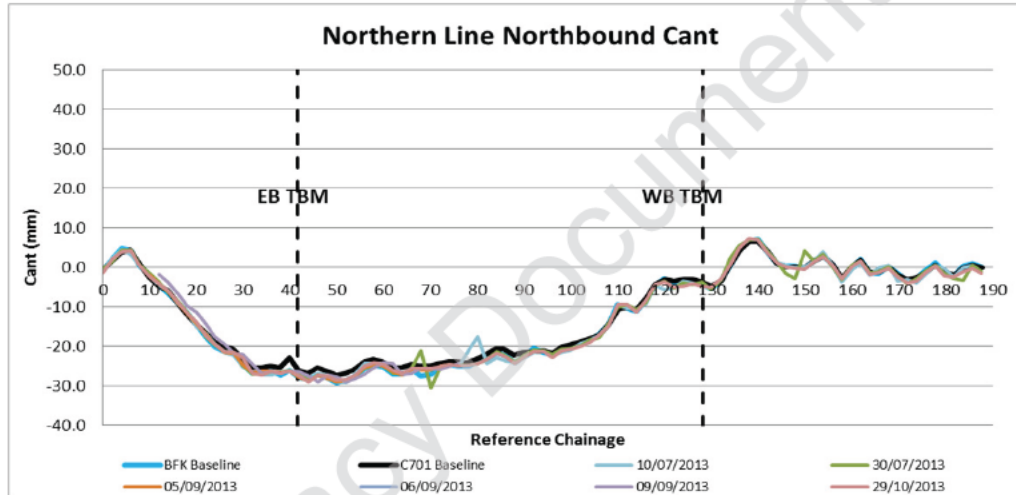
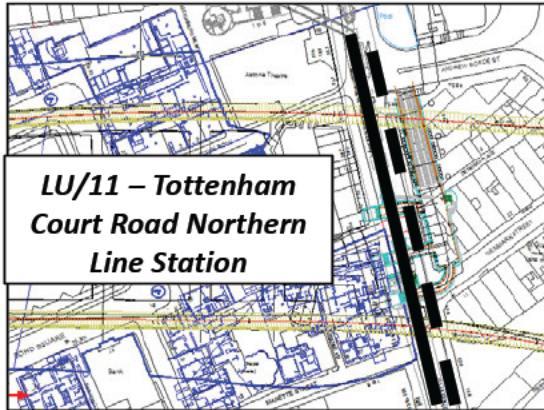
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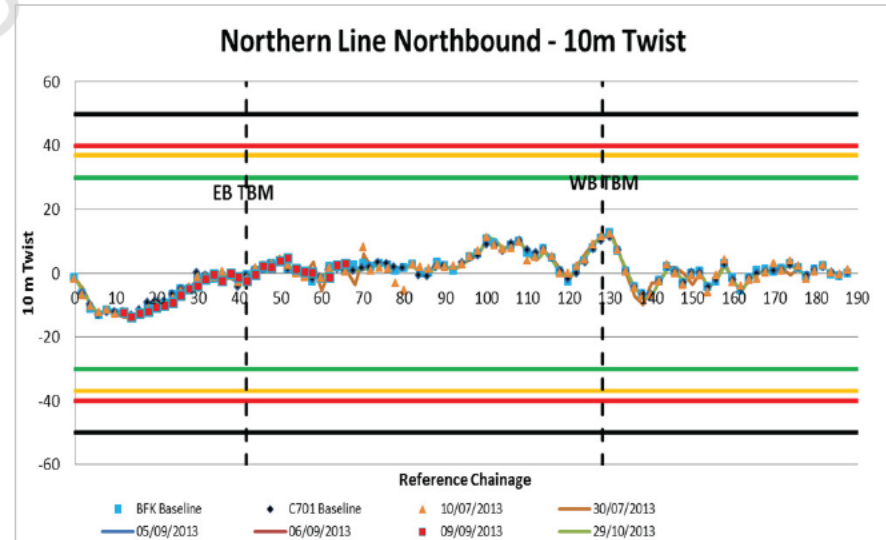
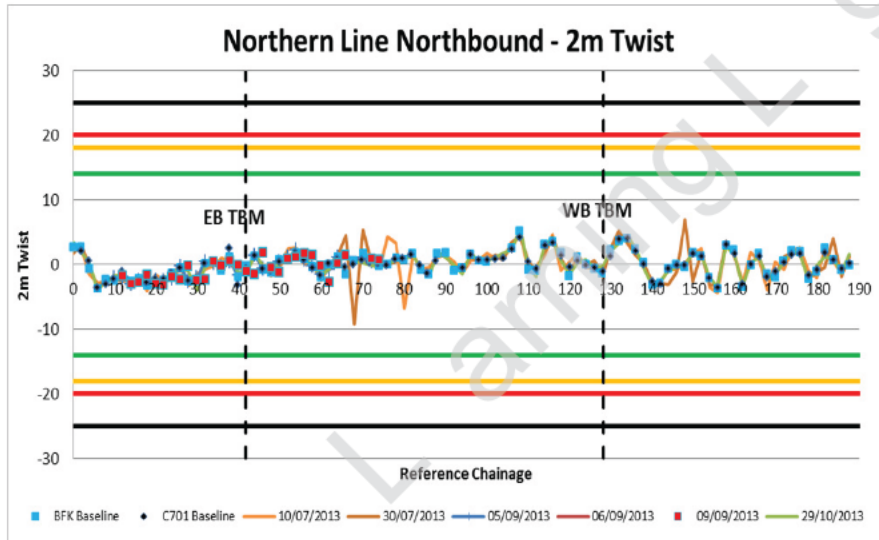
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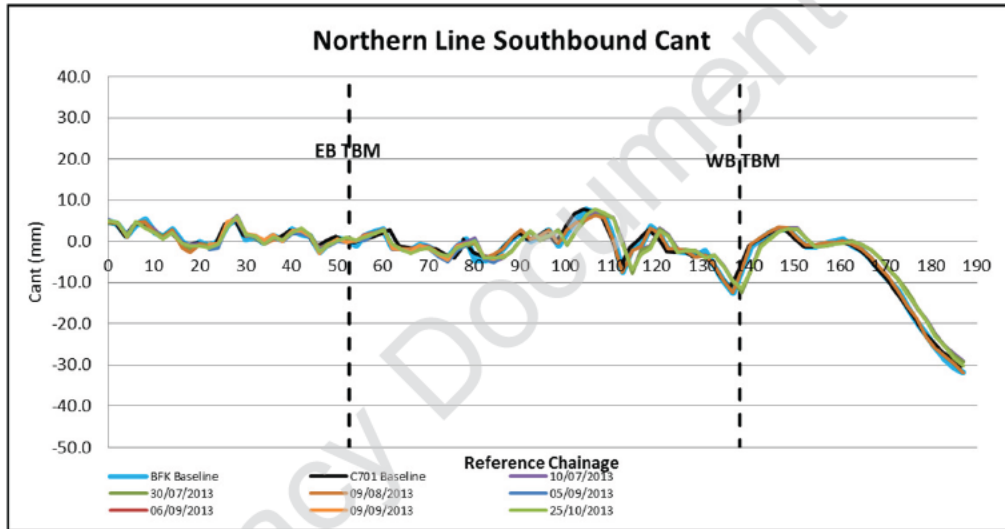
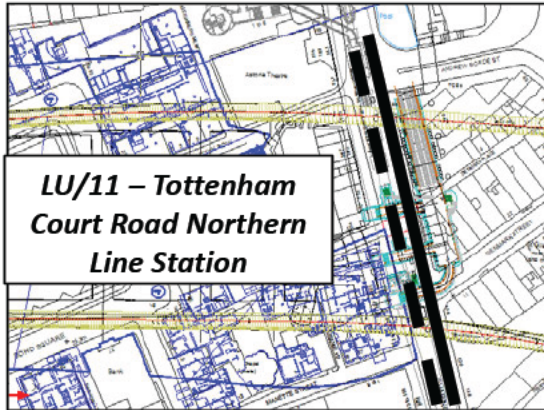
LU-TBMs Interfaces Manual Track Readings decommissioning



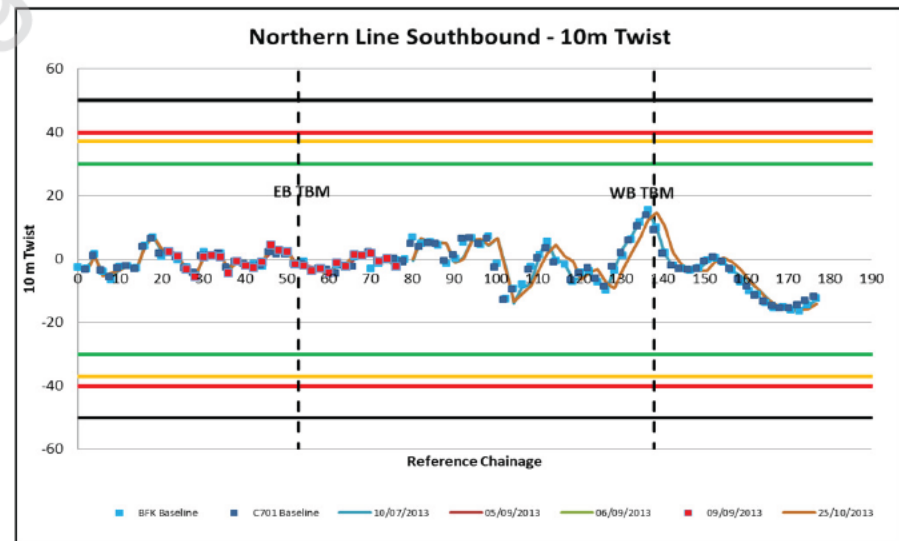
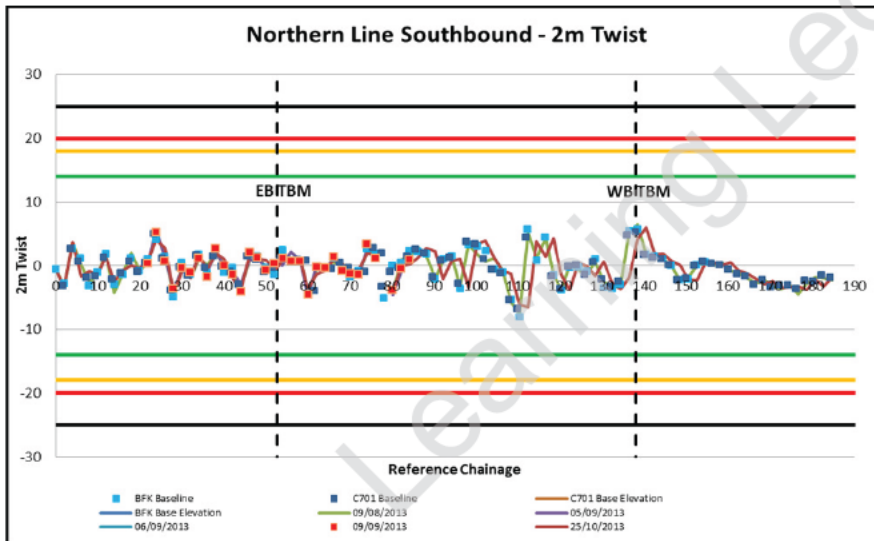
2. Manual Survey results – Northbound



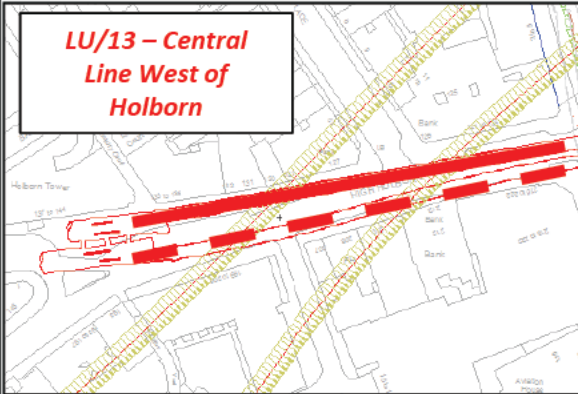
LU-TBMs Interfaces Manual Track Readings decommissioning



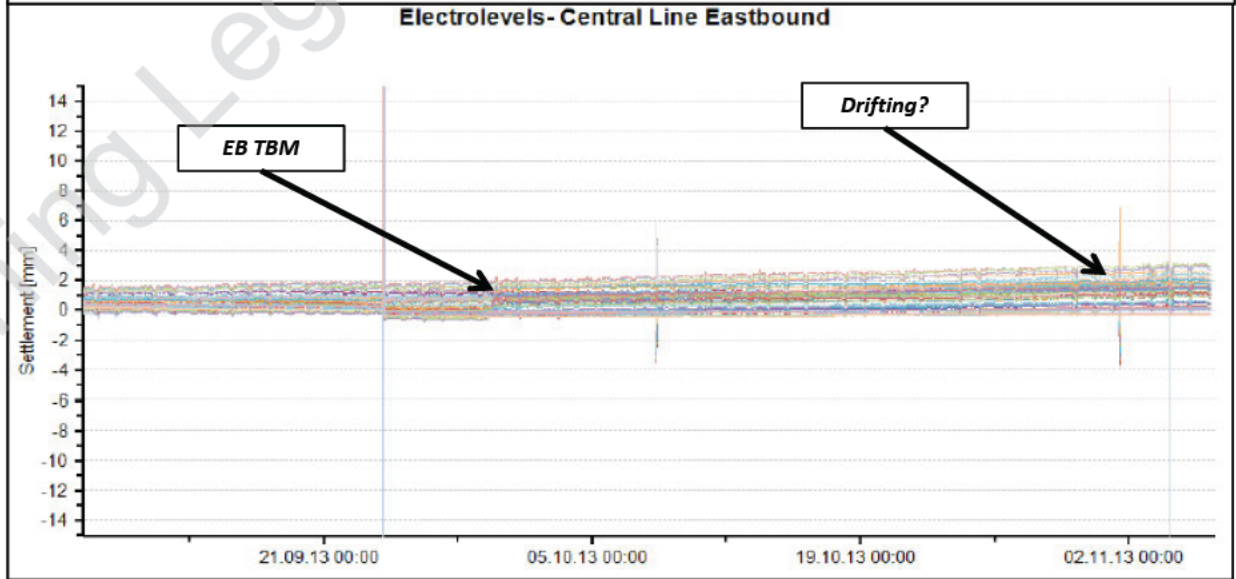
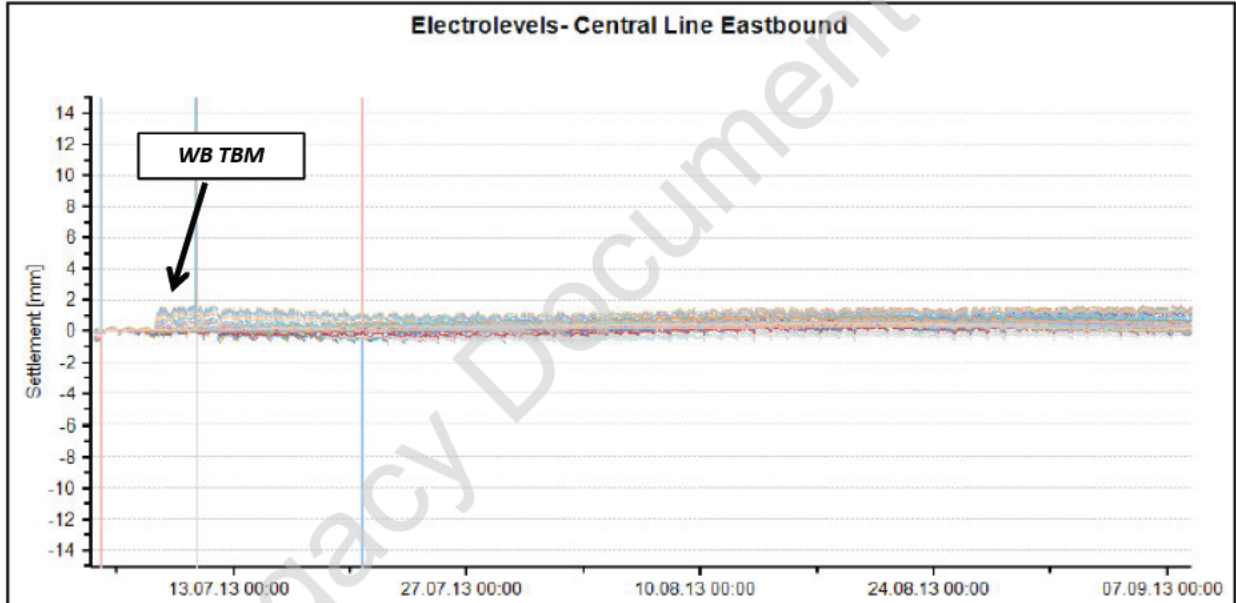
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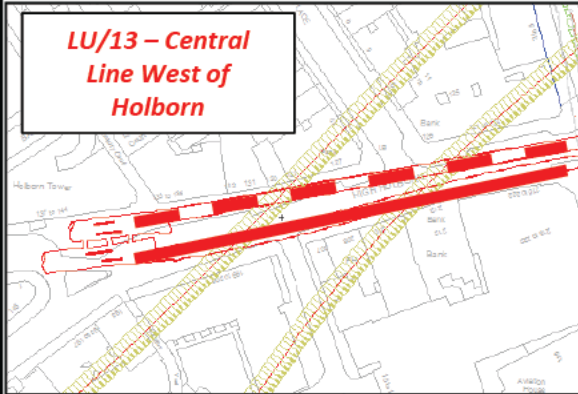
LU-TBMs Interfaces Manual Track Readings decommissioning



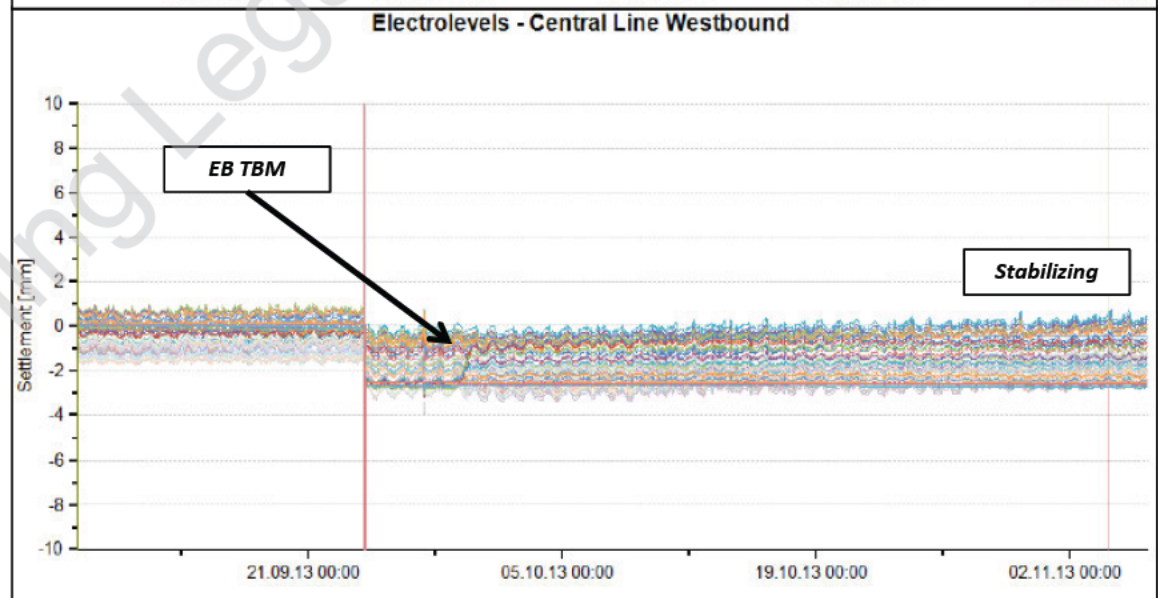
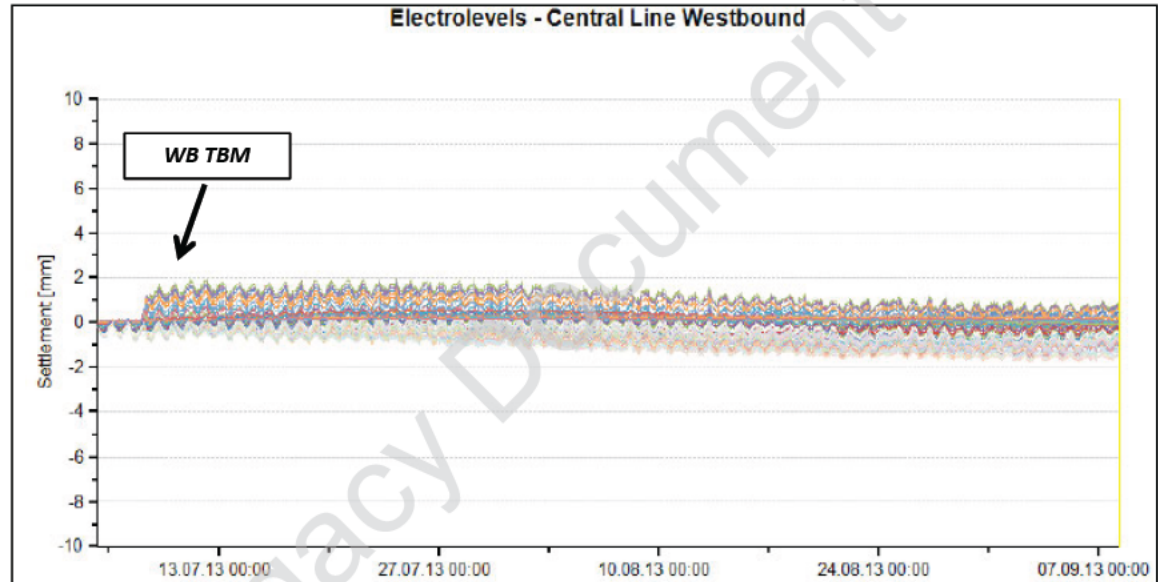
1. Electrollevels data



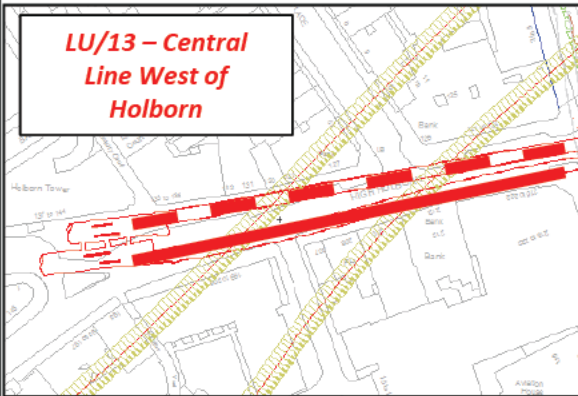
LU-TBMs Interfaces Manual Track Readings decommissioning



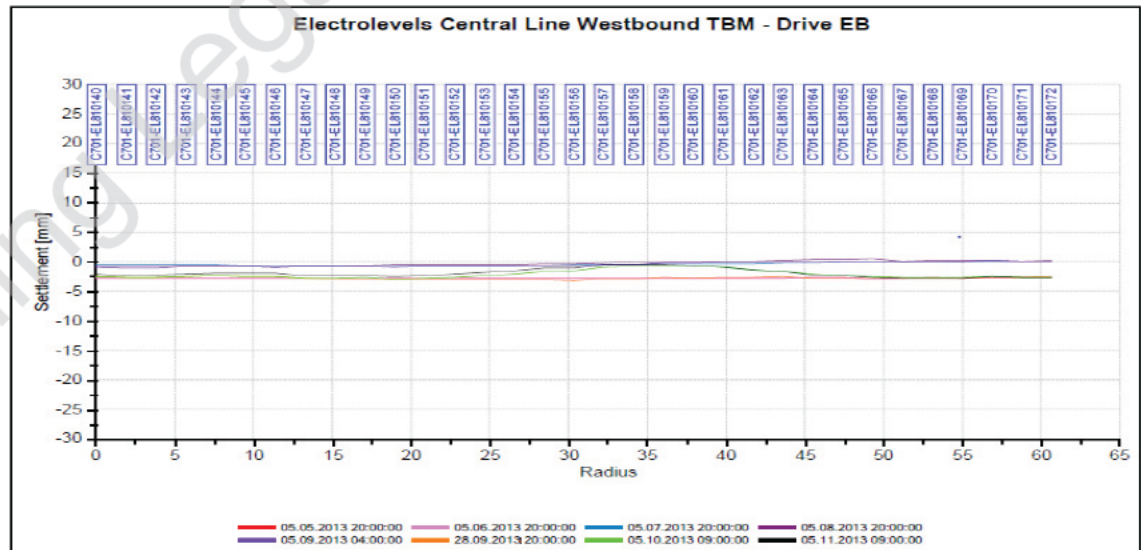
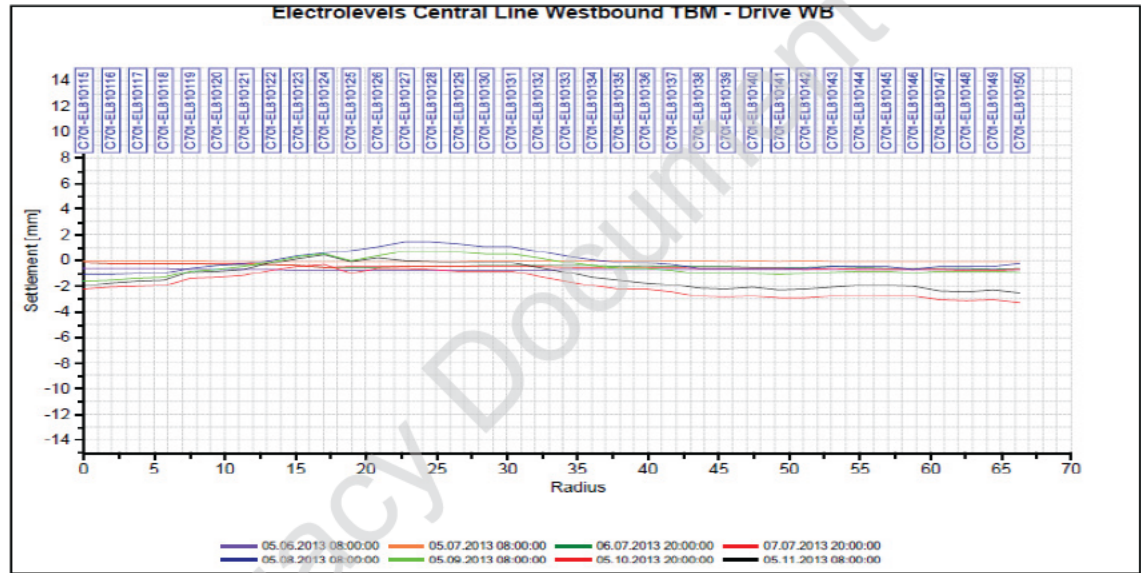
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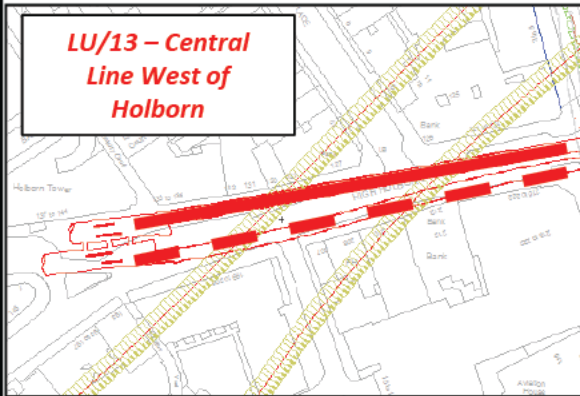
LU-TBMs Interfaces Manual Track Readings decommissioning



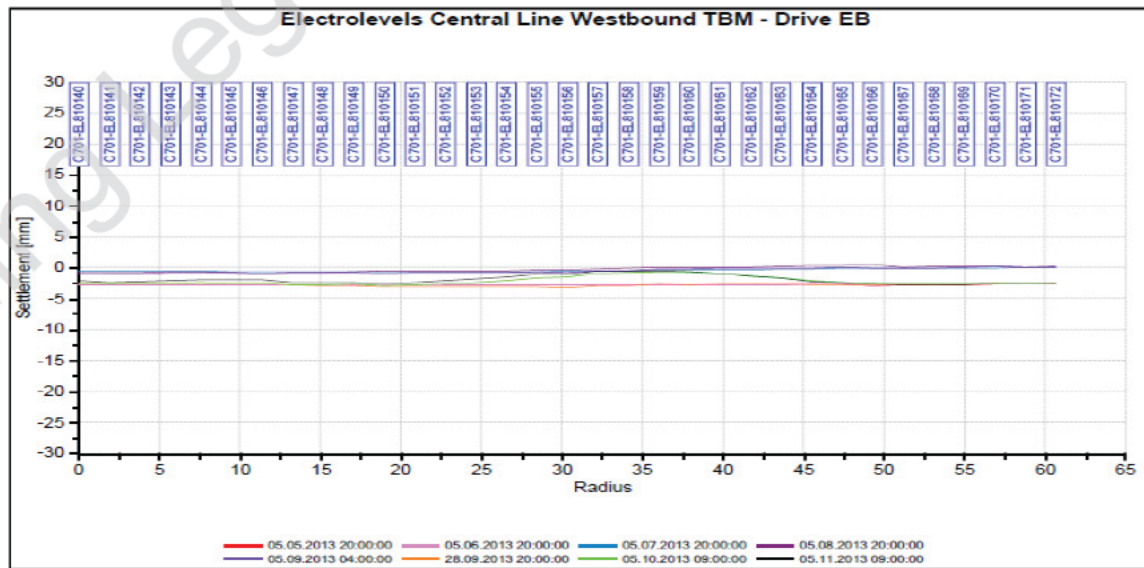
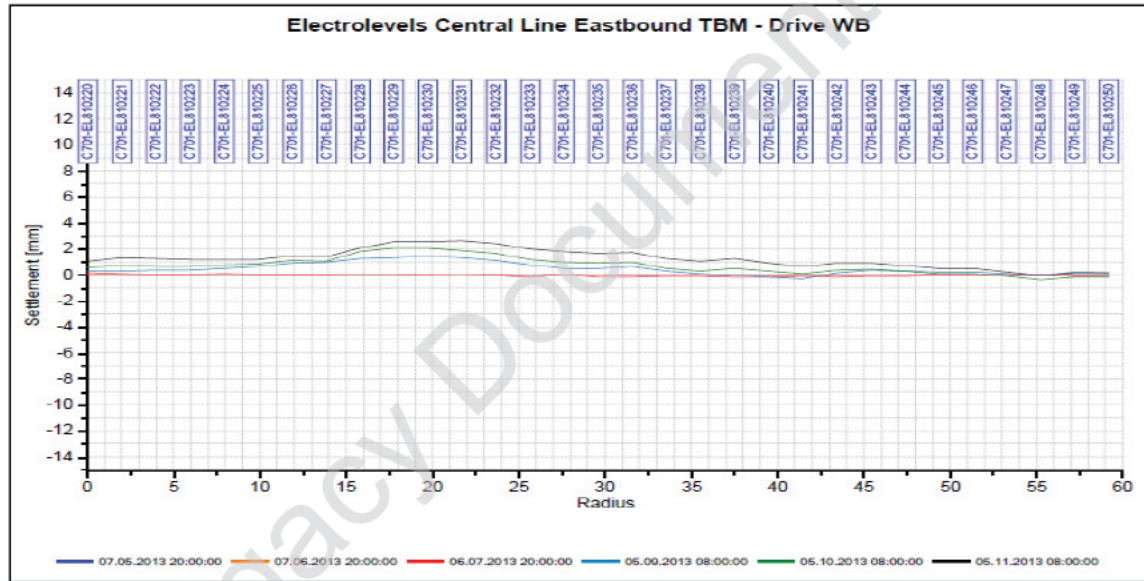
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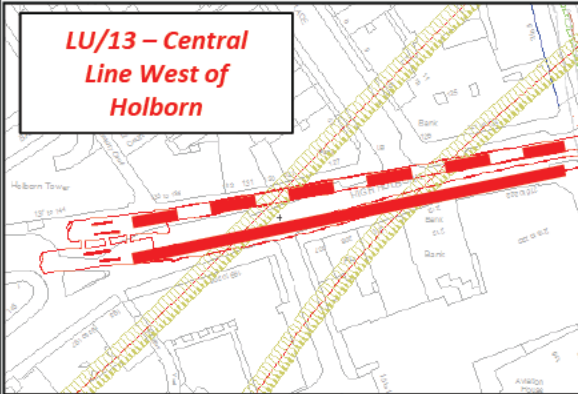
LU-TBMs Interfaces Manual Track Readings decommissioning



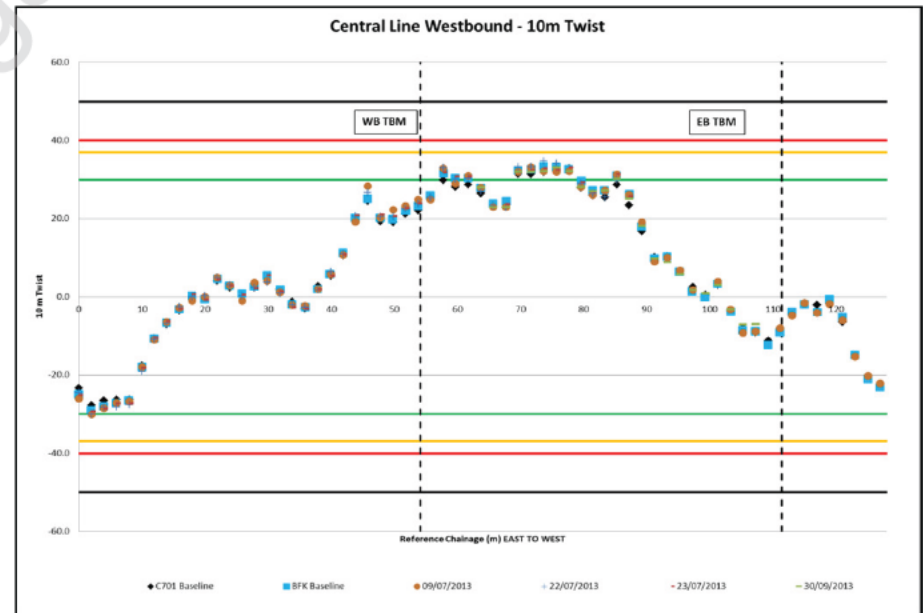
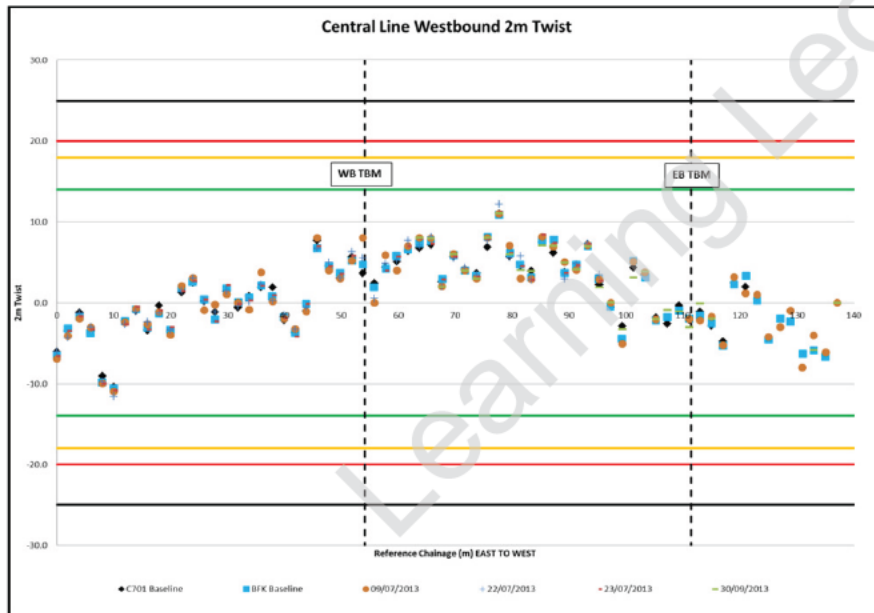
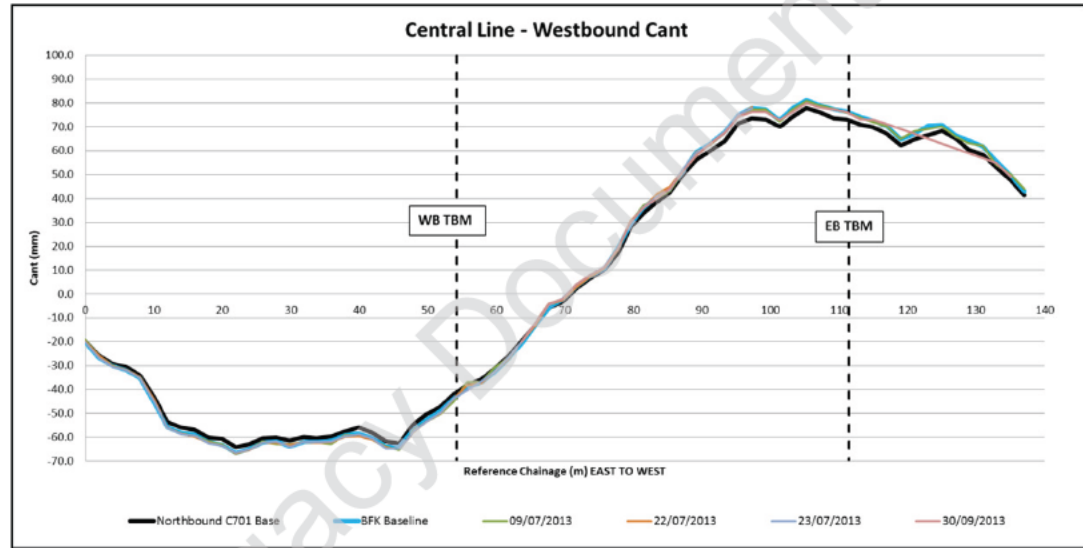
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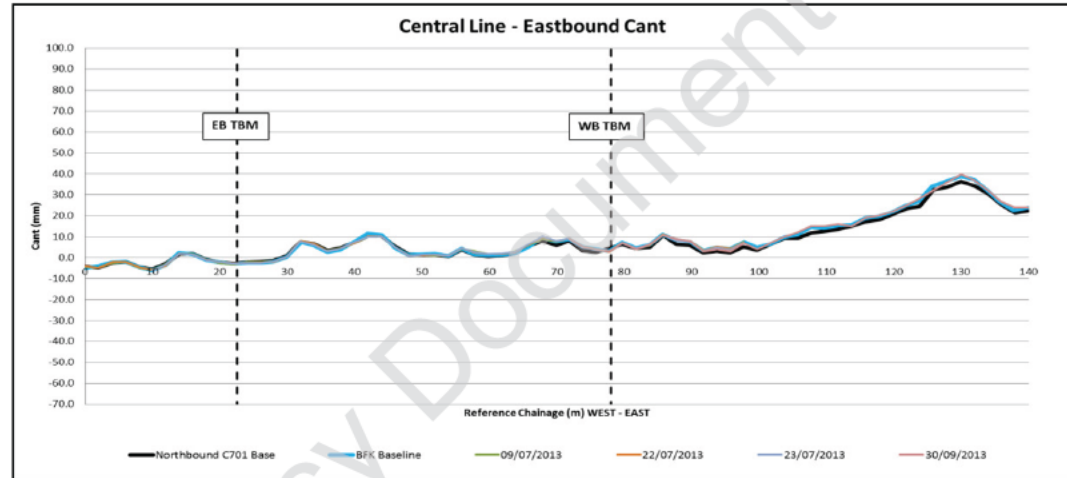
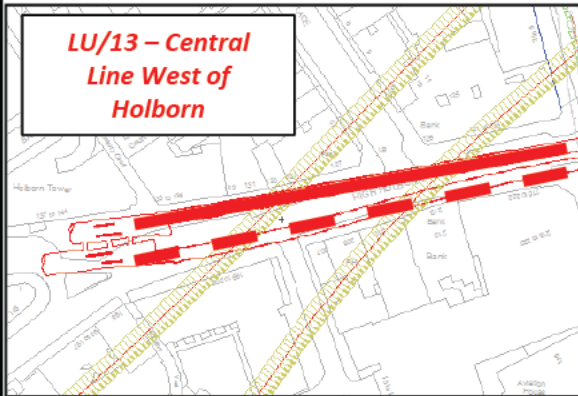
LU-TBMs Interfaces Manual Track Readings decommissioning



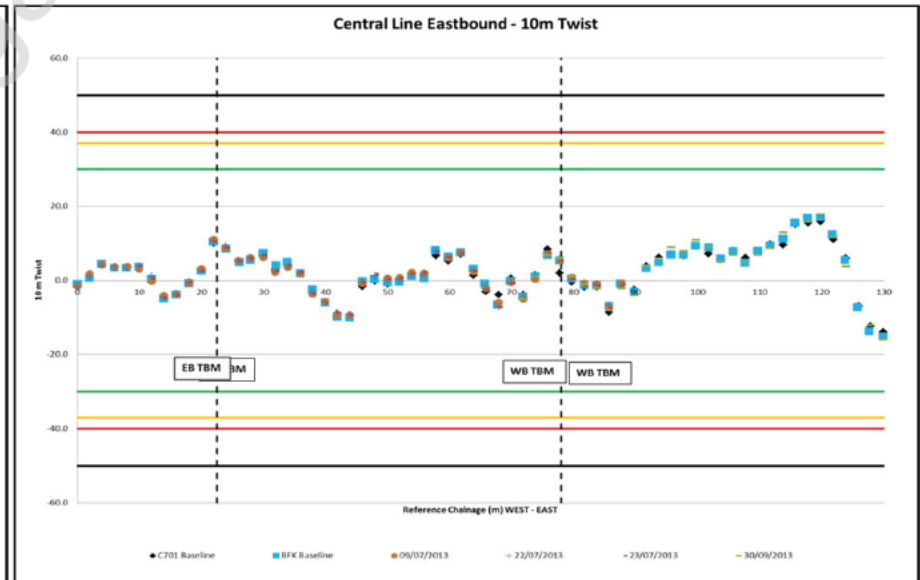
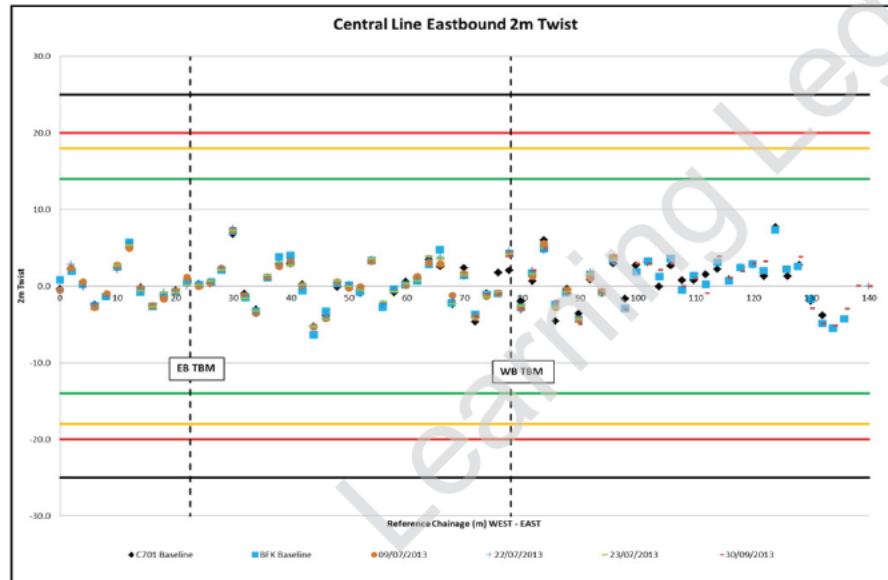
2. Manual Survey results - Westbound



LU-TBMs Interfaces Manual Track Readings decommissioning



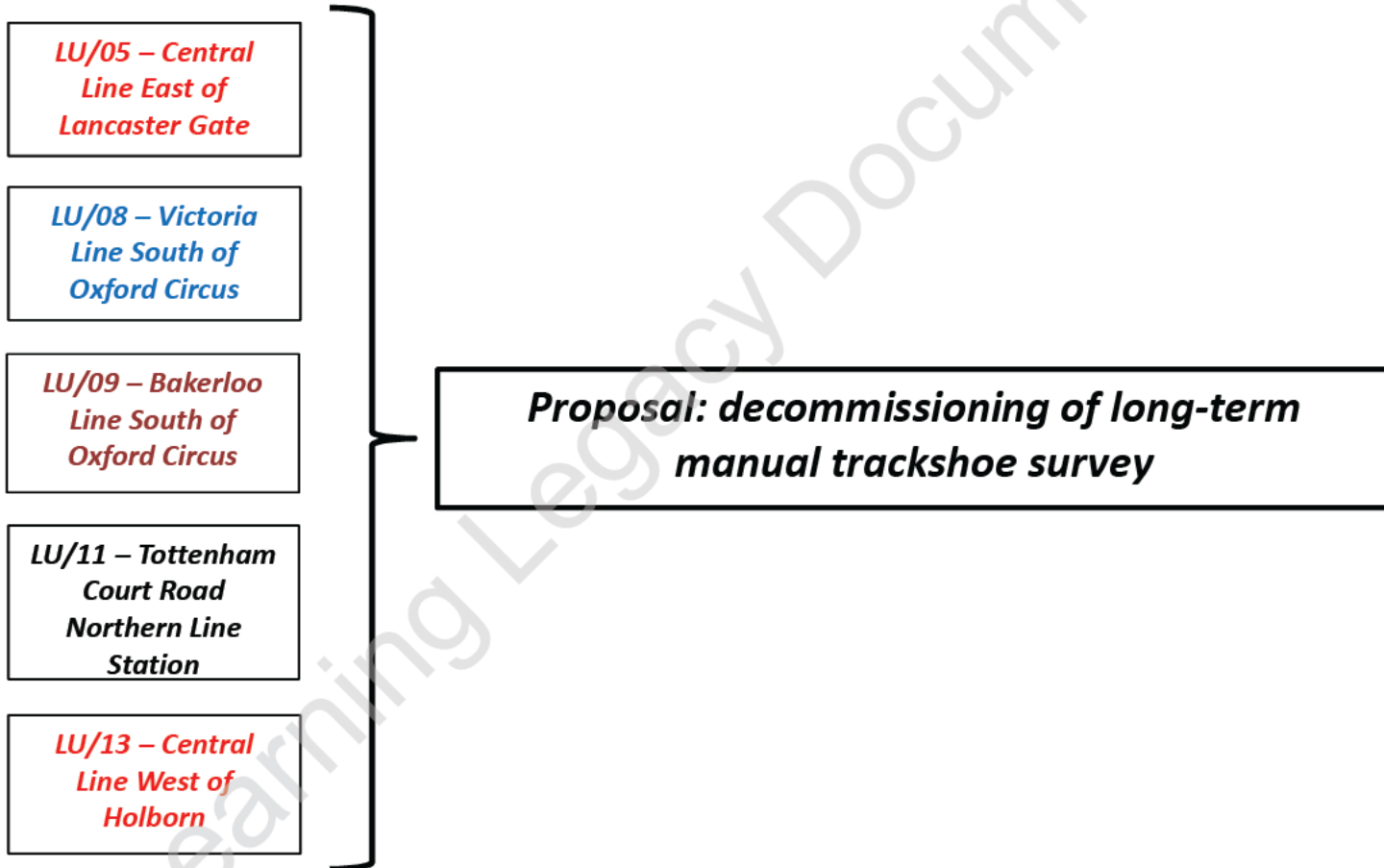
2. Manual Survey results - Eastbound



LU-TBMs Interfaces Manual Track Readings decommissioning

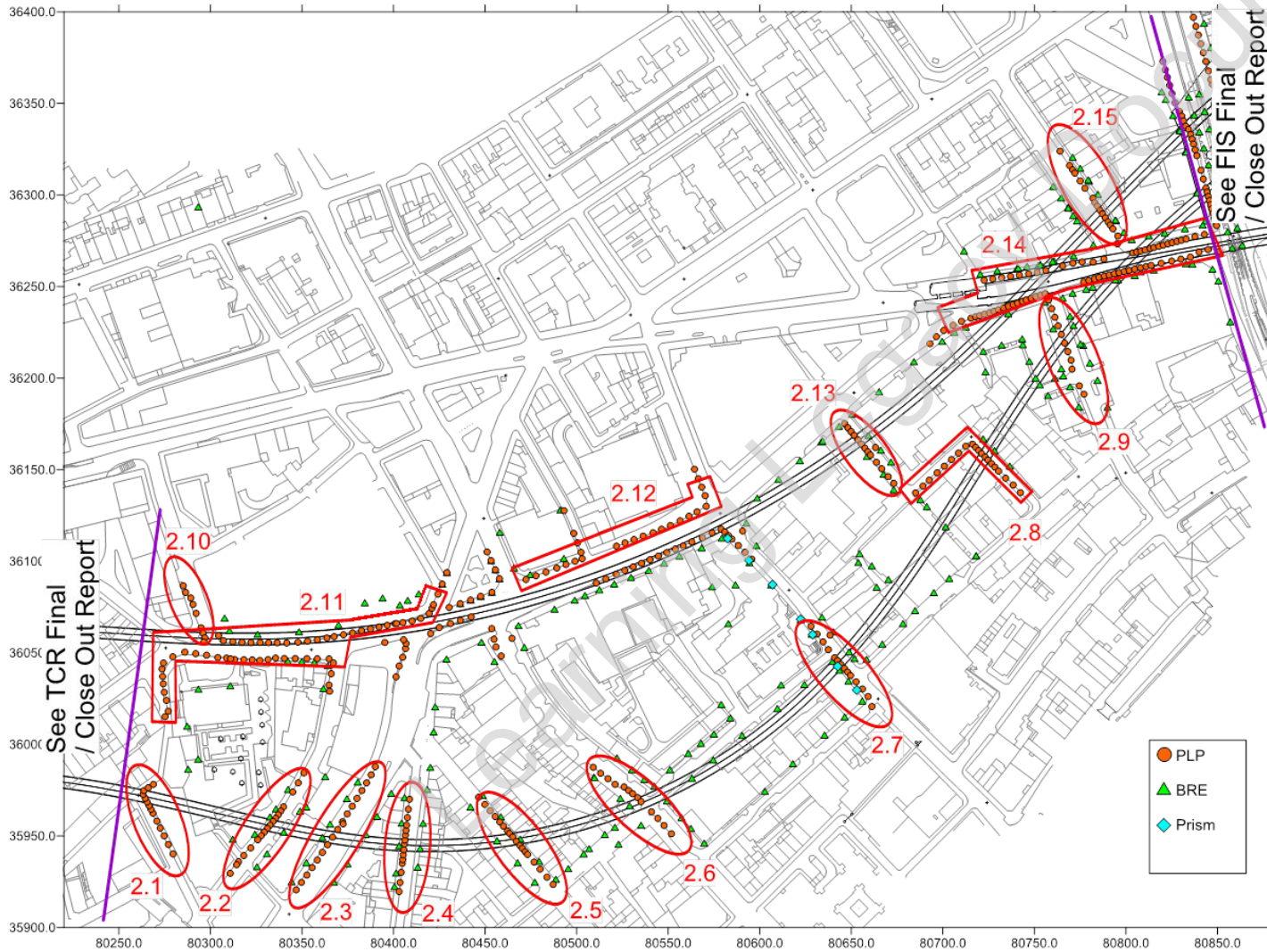
LU/05 – Central Line East of Lancaster Gate	EB Electrolevels: stabilized, max. settlement = approx. 20mm WB Electrolevels: quite stable, max. settlement = approx. 20mm	Almost no effect on LU assets rails geometry (cant, 2m base twist, 10m base twist)
LU/08 – Victoria Line South of Oxford Circus	NB Electrolevels: stabilized, max. settlement = approx. 15-20mm (drifting) SB Electrolevels: stabilized, max. settlement = approx. 10mm	
LU/09 – Bakerloo Line South of Oxford Circus	NB Electrolevels: quite stable (after drifting?) max. settlement = approx. 10mm SB Electrolevels: quite stable, max. settlement = approx. 10mm	
LU/11 – Tottenham Court Road Northern Line Station	NB Electrolevels: quite stable (drifting?), max. heave = approx. 3mm SB Electrolevels: quite stable, max. heave = approx. 4mm	
LU/13 – Central Line West of Holborn	EB Electrolevels: Drifting?, max. heave = approx. 4mm WB Electrolevels: quite stable (drifting?), max. heave = approx. 3mm	

LU-TBMs Interfaces Manual Track Readings decommissioning



Appendix 7. Summary Plots

Location and Section Numbers for data presented



Summary of final recorded settlement

