



C305 – Eastern Running Tunnels

I&M Close out report for Electrolevels at Limehouse Link Tunnel (Drive Y)

CRL Document Number: C305-DSJ-C2-RGN-CR144_WS155-50023

Supplier Document Number: N/A

Contract MDL reference C08.079

1. Contractor Document Submittal History:

Revision:	Date:	Prepared by:	Checked by:	Approved by:	Reason for Issue:
2.0	25-11-2015	[Redacted]	[Redacted]	[Redacted]	For approval

2a. Stakeholder Review Required? YES NO

Stakeholder submission required: LU NR DLR RfL LO Other: _____

Purpose of submission: For no objection For information

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: _____ Role: _____ Name: _____ Date: _____

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2b. Review by Stakeholder (if required):

Stakeholder Organisation	Job Title	Name	Signature	Date	Acceptance
					<input type="checkbox"/>
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Position: PFE				
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I&M Close out report for Electrolevels at Limehouse Link Tunnel (Drive Y)				
C305 Crossrail Eastern Running Tunnels				
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2.0	25-11-2015	[REDACTED]	[REDACTED]	[REDACTED]
		[REDACTED]	[REDACTED]	[REDACTED]
Document History :				
Revision:	Date:	Prepared by:	Checked by:	Engineering Approved by:
1.0	03-11-2015	[REDACTED]	[REDACTED]	[REDACTED]

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1. CLOSE OUT REPORT PURPOSE

As stated in the specification: C122-OVE-Z4-RSP-CR001-00007 Rev 7.0, the purpose of this close-out report is to summarise the data from the instrumentation included in this document and to relate the recorded movements to the construction activities which produce any observed changes. For construction activities it is intended excavation of the C305 twin bored tunnels and dewatering of cross passages; impacts from cross passage excavation or from other CRL contracts are not included in this report.

The long term readings have been used to demonstrate that the subsequent movement has reached an acceptably stable rate within the accuracy of the system in order to decommission and/or that C305 works are no longer impacting the area concerned.

As stated in the specifications the settlement rate of 2 mm/yr has been defined. Where this is not achieved this report seeks agreement from all parties that the rate is acceptably low enough to cease monitoring and decommission.

2. LOCATION OF THE WORKS

The instrumentation included in this report is situated within Area 6, Canary Wharf Station to Stepney Green Shaft, at project chainage 82250. Instruments were installed in the Limehouse Link Tunnel, arranged in a 28 sensor array per bound, corresponding to 29 monitoring points per array.

See Appendix A for the instrument location.

3. DOCUMENTATION SUMMARY

CROSSRAIL NUMBER	DOCUMENT NAME	REASON FOR ISSUE	TYPE AND NUMBER OF INSTRUMENTATION INSTALLED
C305-DSJ-C2-GMS-CRG03-50027	MS Topographical Set Out Limehouse Link Electrolevels	Main Method statement	56 Electrolevels sensor
C305-DSJ-C2-GMS-CRG03-50030	MS I&M Limehouse Link Tunnel (Electrolevels installation)	Main Method statement	56 Electrolevels sensor
C305-DSJ-C2-RGN-CR144_WS155-50011	I&M Installation report for Electrolevels at Limehouse Link Tunnel (Drive Y)	Installation report	56 Electrolevels sensor

4. SUMMARY OF INSTALLED INSTRUMENTATION ON SITE

The total number of instruments installed, as per method statements listed in section above was:

- Limehouse Link Tunnel 56 Electrolevels:
 - ✓ C305-EL060101-S--C305-EL060128-S
 - ✓ C305-EL060201-S--C305-EL060228-S

Detailed information of the installed instrumentation is reported in Appendix B.

5. CONSTRUCTION ACTIVITY

TBM PASSAGE

DRIVE Y	RINGS	PROJECT CHAINAGE	DATES
Eastbound	1454-1481	82269.4 - 82223.5	06/09/2013 to 08/09/2013
Westbound	1469-1497	82262.6 - 82215	01/11/2013 to 03/11/2013

Stoppage period

Eastbound Drive-Y No stoppage
 Westbound Drive-Y No stoppage

The periods of TBM passage and stoppage are related to the rings located close to the instrumentation included in this close out report.

DEWATERING

Cross passage 12 12th March 2014 to 29th July 2014
 Cross passage 11 8th July 2014 to 16th January 2015
 Canary Wharf It is understood that Canary Wharf dewatering systems were switched on throughout the monitoring period
 Limmo 4th November 2013 (still on)

6. METHODOLOGY

To determine the settlement rate the following methodology has been used. A Linear Regression has been applied for a defined period using long term readings after TBM construction. This uses the following formula to calculate the gradient or slope of the line:

$$b = \frac{\sum_{i=1}^n (X_i - \bar{X}_i) \cdot (Y_i - \bar{Y}_i)}{\sum_{i=1}^n (X_i - \bar{X}_i)^2}$$

Where:

B =gradient or slope

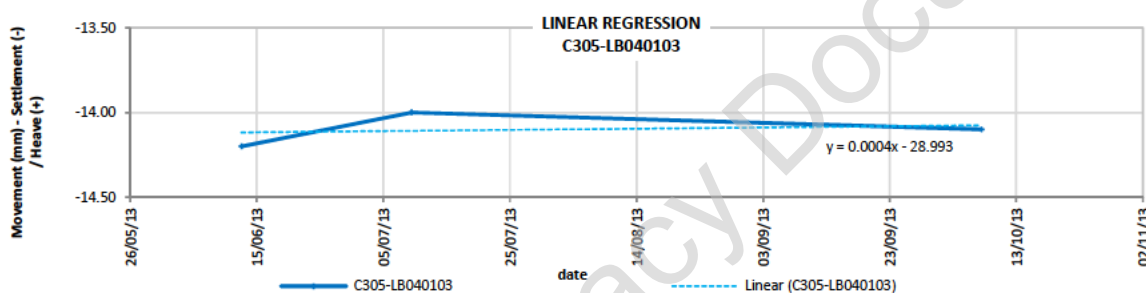
X (independent variable) = date

Y (dependent variable) = vertical movement

From this, the settlement rate per day can be calculated and rate per year determined (negative values is for settlement, positive is for heave). For these values, the percentage at or below 2 mm/yr will be used to determine the trend of the section/area being considered. Also for comparison, values at or below 3 mm/year are presented to highlight that the rate is close to achieving the 2 mm/yr. Note the percentages of settlement rate presented in the sections below refer to values rounded to the nearest integer.

One example of this calculation can be seen below

	Registered movement (mm)			RATE mm/year
	12/06/2013	09/07/2013	07/10/2013	
C305-LB040103	-14.20	-14.00	-14.10	0.146



CALCULATION - C305-LB040103

X_i	Y_i	$X_i - \bar{X}_i$	$Y_i - \bar{Y}_i$	$(X_i - \bar{X}_i)^2$	$(X_i - \bar{X}_i) \cdot (Y_i - \bar{Y}_i)$
12/06/2013	-14.2	-47.94	-0.10	2298.67	4.794
09/07/2013	-14	-21.03	0.10	442.17	-2.103
07/10/2013	-14.1	68.97	0.00	4757.17	0.000

\bar{X}_i	41485.53	
\bar{Y}_i	-14.10	
$\sum_{i=1}^n (X_i - \bar{X}_i)^2$	7498.00	(2)
$\sum_{i=1}^n (X_i - \bar{X}_i) \cdot (Y_i - \bar{Y}_i)$	2.692	(1)
m (SLOPE)	(1)/(2)	0.0004
Rate (mm/year)	m * 365	0.146

7. SUMMARY OF THE DATA

The methodology explained in section 6 is applied here for the electrolevel monitoring points (C305-EL060101-29 and C305-EL060201-29).

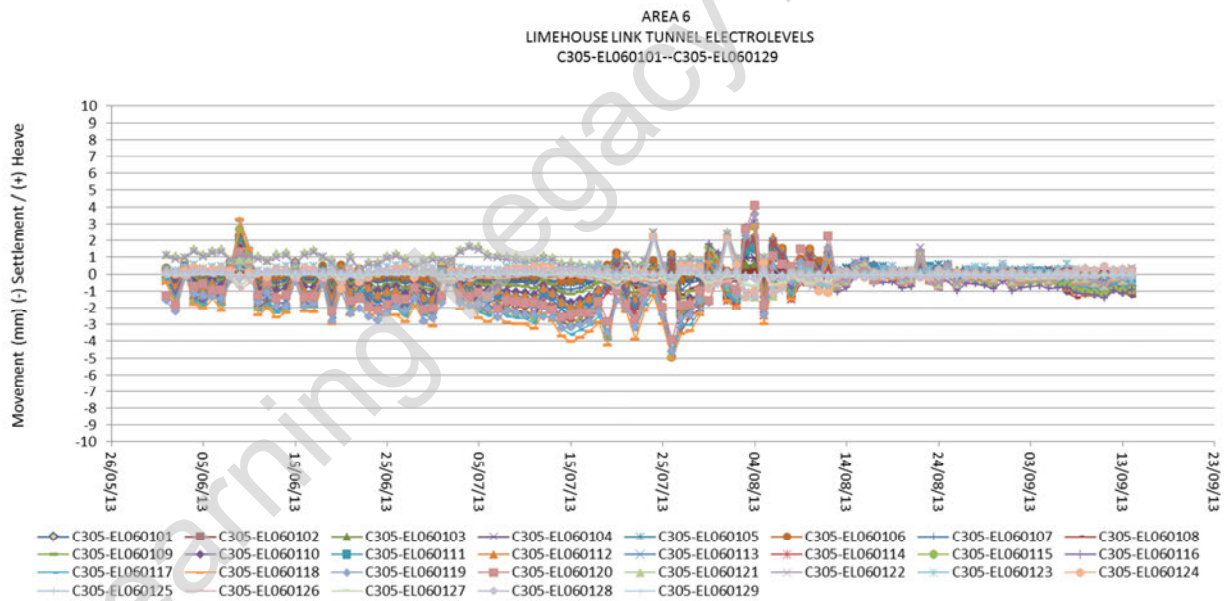
Note: For the following data plots #N/A refers to instances where readings were not taken for that sensor (e.g. damaged sensor, no access, etc).

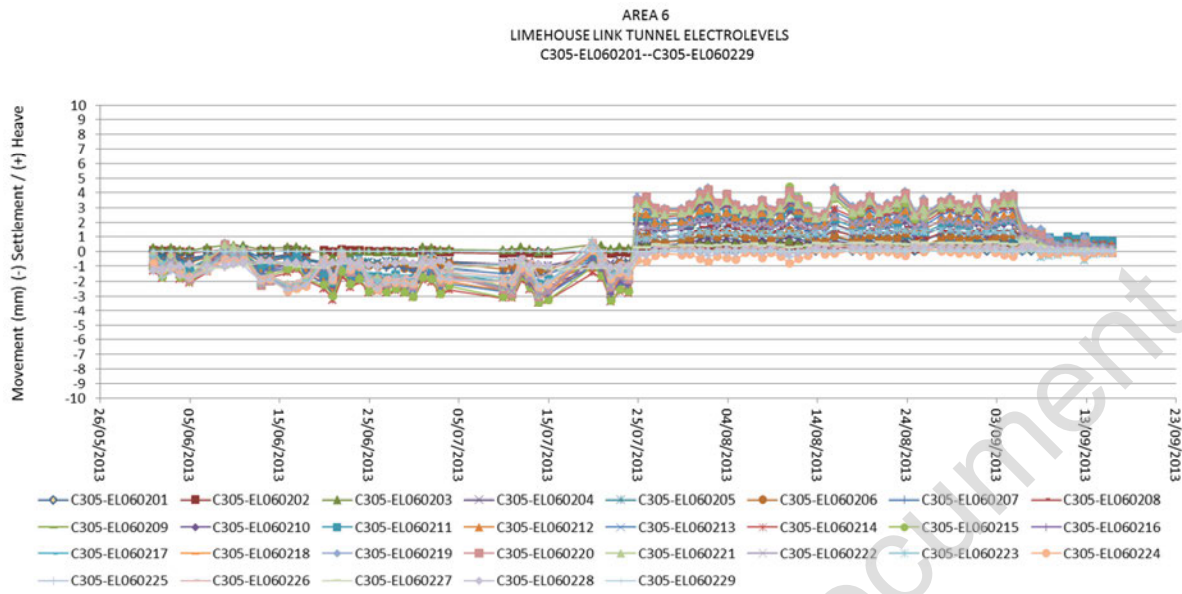
ELECTROLEVELS (MONITORING POINTS) LIMEHOUSE LINK TUNNEL

BASELINE

This paragraph is intended to show the variability of readings before the EB TBM transited underneath the Limehouse Link Tunnel (06/09/2013) and what was done to set a baseline.

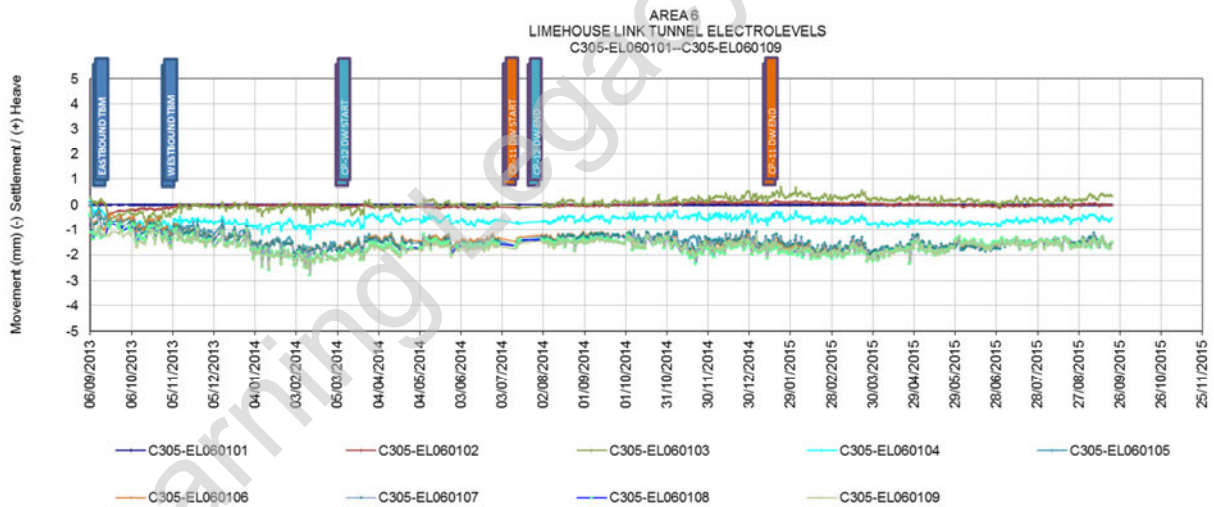
As shown in the charts below, monitoring of both arrays was affected by noise. Initially the electrolevel readings were slightly noisy, this was difficult to resolve due to the location of the equipment and access issues. However more stable readings were achieved prior to the first TBM entering the zone of influence.

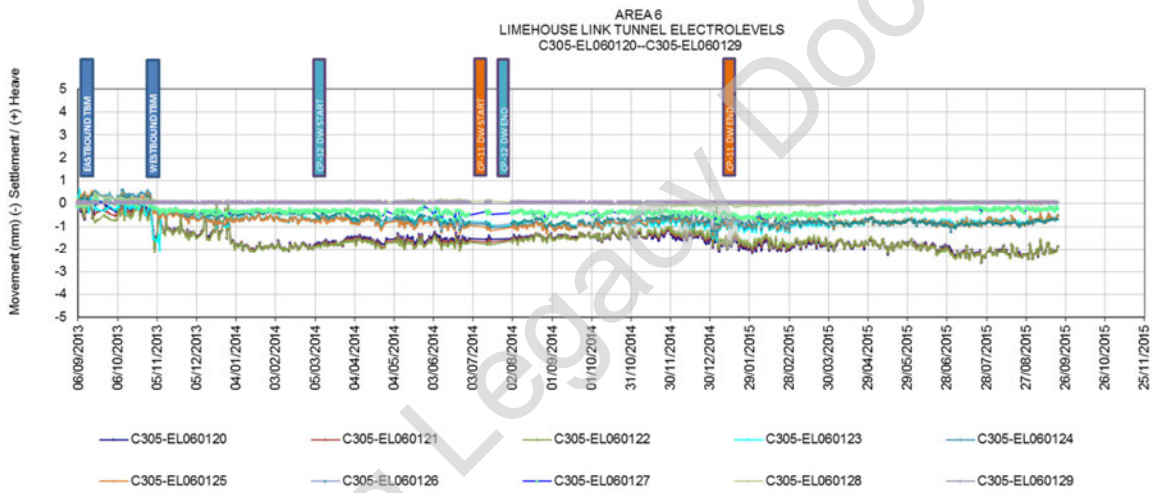
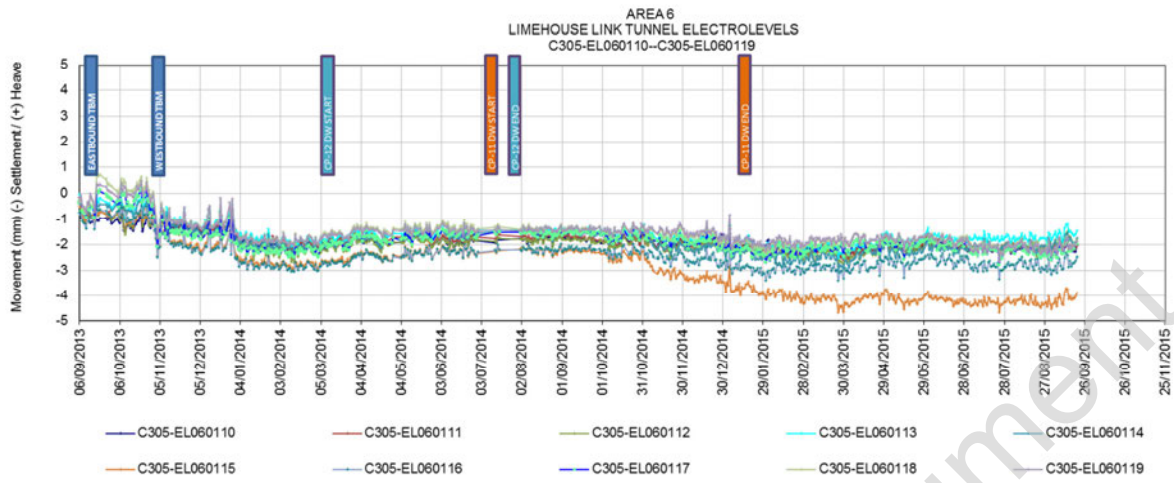




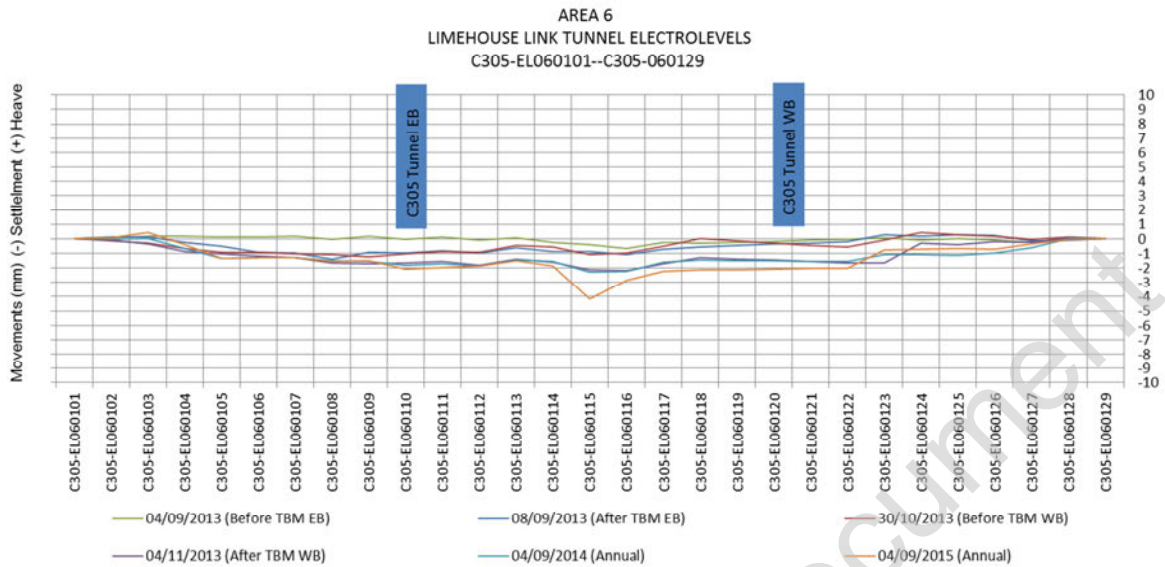
C305-EL060101 - C305-EL060129 (WB Tunnel)

Data are presented below in a “movement vs. time” chart:





Data are presented below in a “longitudinal profile” chart:



Electrolevel monitoring points C305-EL060101--C305-EL060129 recorded a maximum settlement of -3.0 mm during the Eastbound TBM & Westbound TBM transit.

Please note, the monitoring point C305-EL060115 (between sensors C305-EL060114-S and C305-EL060115-S) shows a 1 mm settlement increase between November 2014 and January 2015, with no remarkable movement since then. This movement may be due to the anchor point being hit or knocked.

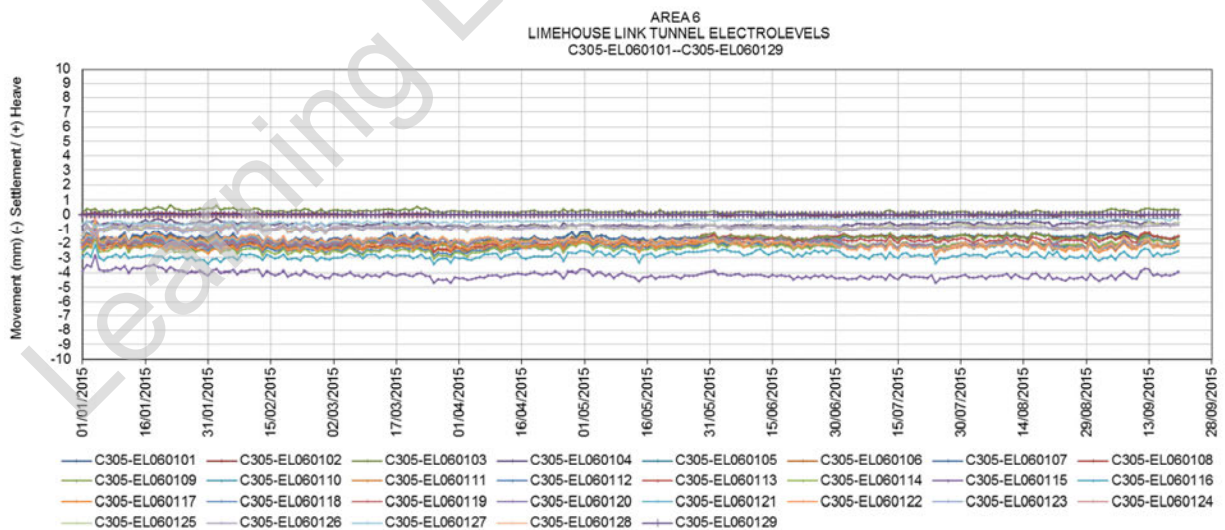
There is no evidence of dewatering at CP-11 and CP-12 affecting settlements in the Limehouse Link Tunnel, as shown in the graphic above. Readings since January 2015 were used to calculate the annual projection.

	Registered movement (mm)	Rate (mm/year)	
C305-EL060101		0.000	
C305-EL060102		-0.190	
C305-EL060103		-0.252	
C305-EL060104		-0.025	
C305-EL060105		0.474	
C305-EL060106		0.286	
C305-EL060107		0.089	
C305-EL060108		0.685	
C305-EL060109		0.493	
C305-EL060110		-0.137	
C305-EL060111		0.244	
C305-EL060112		0.580	
C305-EL060113		0.700	
C305-EL060114		0.828	
C305-EL060115		-0.595	
C305-EL060116		0.309	
C305-EL060117		0.050	
C305-EL060118		-0.224	
C305-EL060119		-0.419	
C305-EL060120		-0.611	
C305-EL060121		-0.805	
C305-EL060122		-0.996	
C305-EL060123		0.524	
C305-EL060124		0.326	
C305-EL060125		0.129	
C305-EL060126		-0.064	
C305-EL060127		0.580	
C305-EL060128		0.191	
C305-EL060129		0.000	
	Rate less than -2.5 mm/year	% less 2 mm/year	100.00%
	Rate greater than -3.5 mm/year	% less 3 mm/year	100.00%

READINGS FROM
01/01/2015 TO 01/09/2015

The table above shows the annual rate for the electrolevel monitoring points in this array.

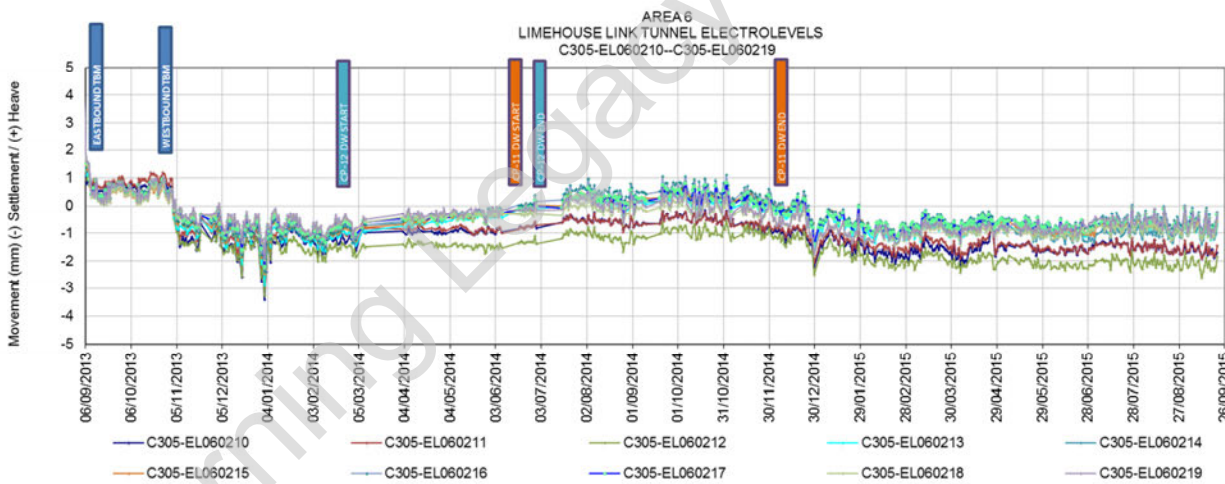
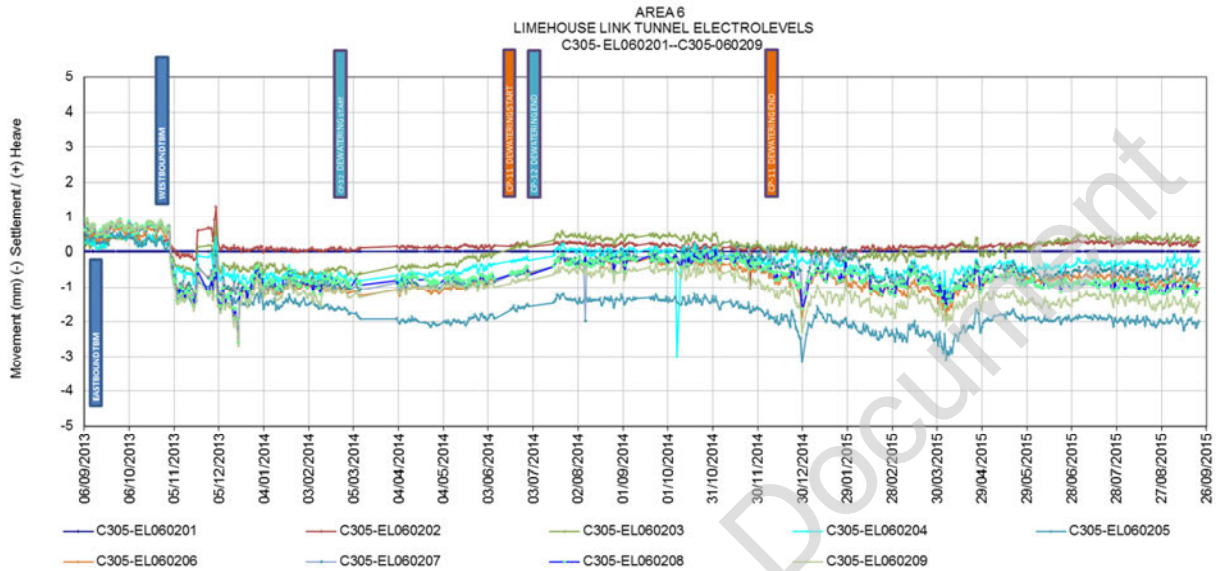
The percentage of sensors with a settlement rate less than 2 mm/year is 100%.

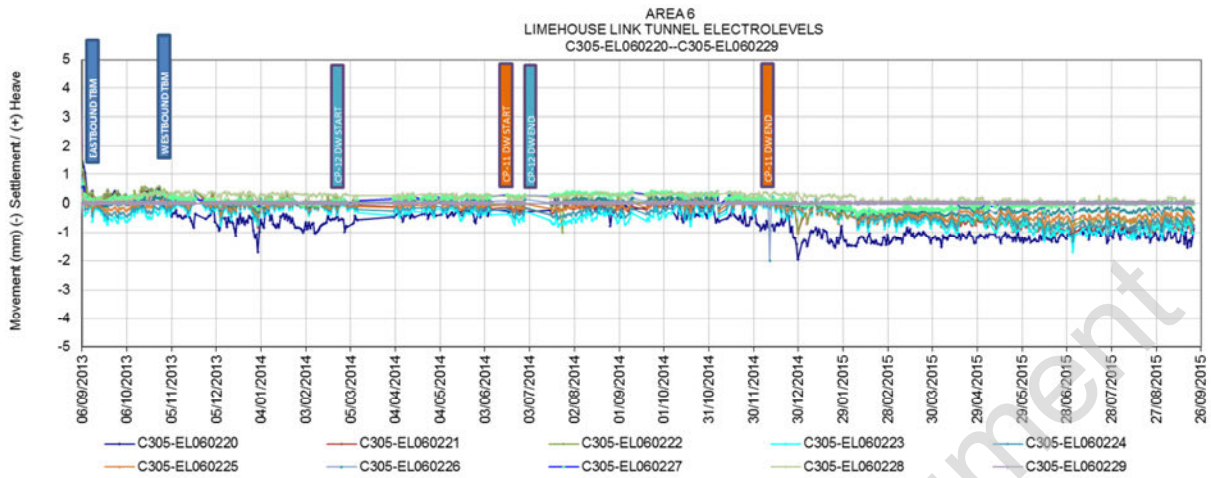


Above: settlement data plot C305-EL060101 to C305-EL060129 since 01/01/2015.

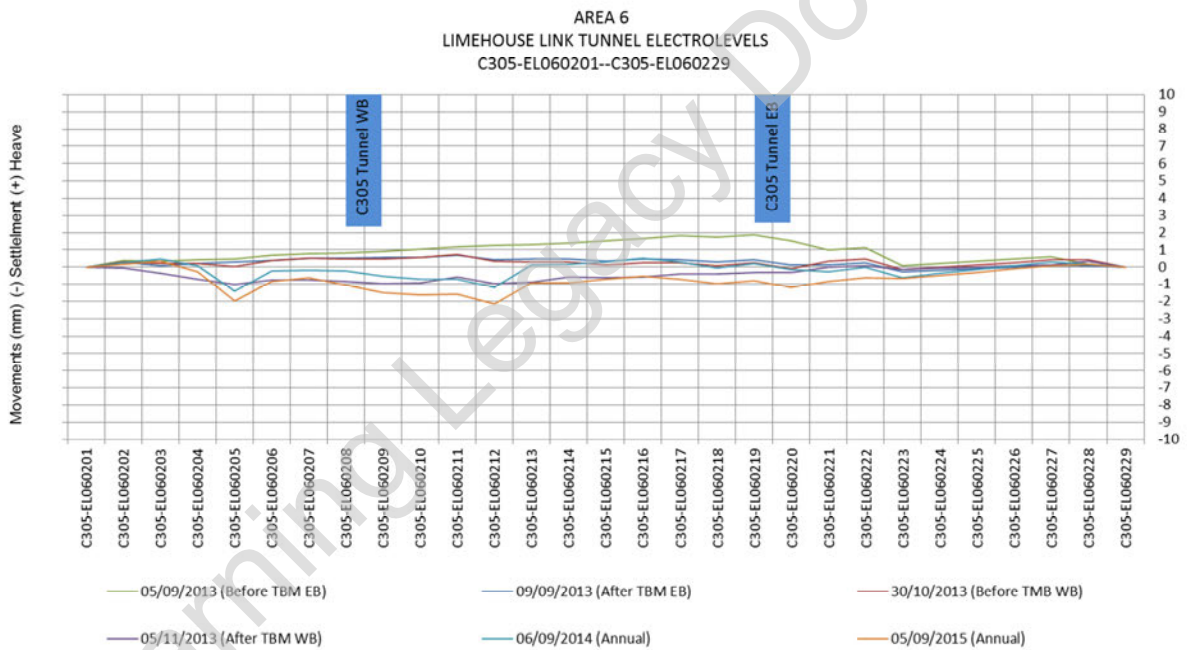
C305-EL060201 - C305-EL060229 (EB Tunnel)

Data are presented below in a “movement vs. time” chart:





Data are presented below in a “longitudinal profile” chart:



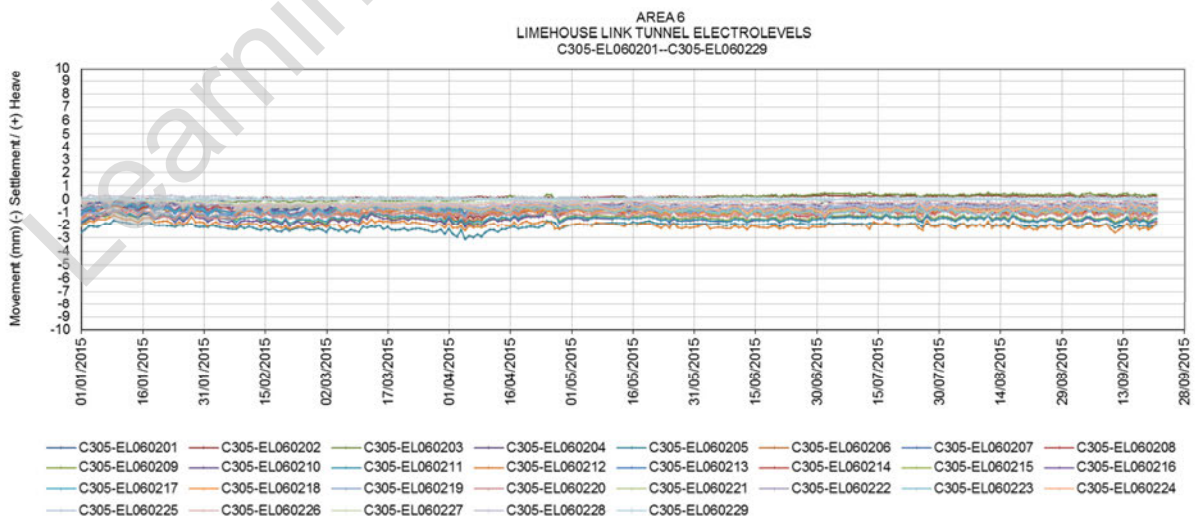
Electrolevel monitoring points C305-EL060201--C305-EL060229 recorded a maximum settlement of -3.5 mm during the Eastbound TBM & Westbound TBM transit.

There is no evidence of dewatering at CP-11 and CP-12 affecting settlements in the Limehouse Link Tunnel, as shown in the graphic above. Readings since January 2015 were used to calculate the annual projection.

	Registered movement (mm)		Rate (mm/year)
C305-EL060201			0.0000
C305-EL060202			0.3368
C305-EL060203			0.8917
C305-EL060204			0.2958
C305-EL060205			0.4481
C305-EL060206			0.3568
C305-EL060207			-0.2186
C305-EL060208			-0.4001
C305-EL060209			-0.0070
C305-EL060210			-0.0556
C305-EL060211			-0.3711
C305-EL060212			-0.5034
C305-EL060213			-0.0355
C305-EL060214			-0.5487
C305-EL060215	READINGS FROM 01/01/2015 TO 01/09/2015		-0.2268
C305-EL060216			0.1112
C305-EL060217			0.0287
C305-EL060218			0.2883
C305-EL060219			0.6289
C305-EL060220			0.2683
C305-EL060221			-0.8143
C305-EL060222			-0.4734
C305-EL060223			-0.9754
C305-EL060224			-0.6361
C305-EL060225			-0.2965
C305-EL060226			0.0401
C305-EL060227			0.3799
C305-EL060228			-0.1368
C305-EL060229			0.0000
	Rate less than -2.5 mm/year	% less 2 mm/year	100.00%
	Rate greater than 3.5 mm/year	% less 3 mm/year	100.00%

The table above shows the annual rate for the electrolevel monitoring points in this array.

The percentage of sensors with a settlement rate less than 2 mm/year is 100%.



Above: settlement data plot C305-EL060201 to C305-EL060229 since 01/01/2015.

8. SUMMARY STATEMENT

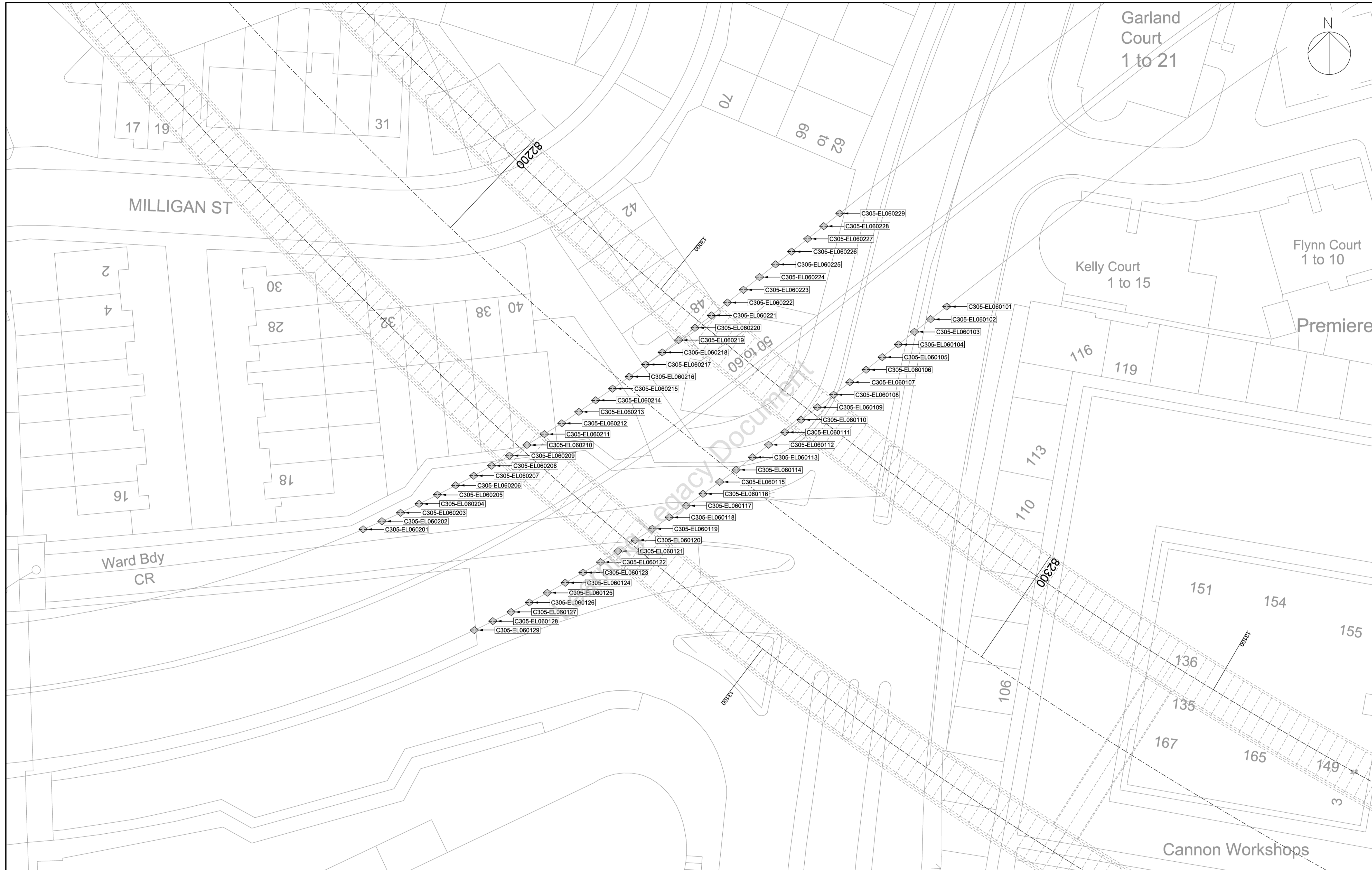
It has been agreed between the Project Manager, the Designer, the Contractor and the Sub Contractor that the instrumentation covered herein, for monitoring ground movement effects of Crossrail works, including long term effects, can be closed out for decommissioning a trends of the monitoring points were approaching or had achieved the specified 2 mm/year settlement rate.

Minutes of the Close Out meeting(s) are attached as Appendix C.

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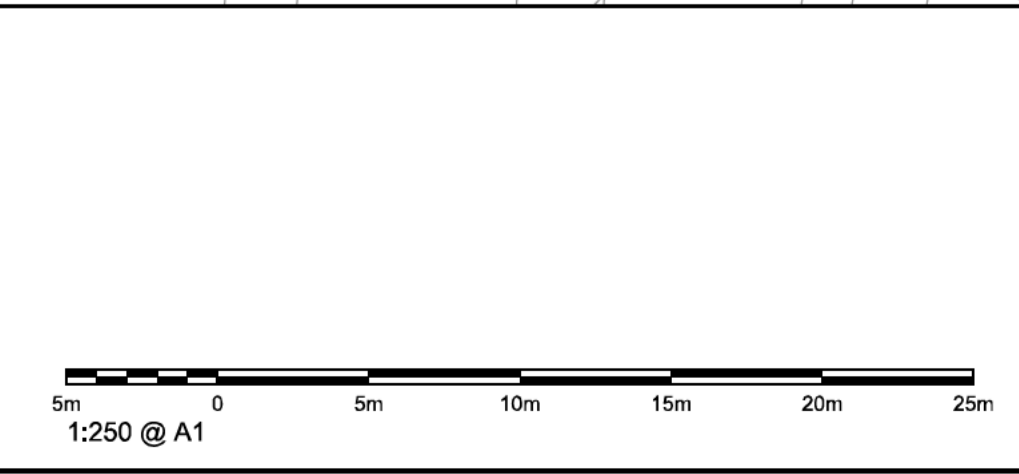
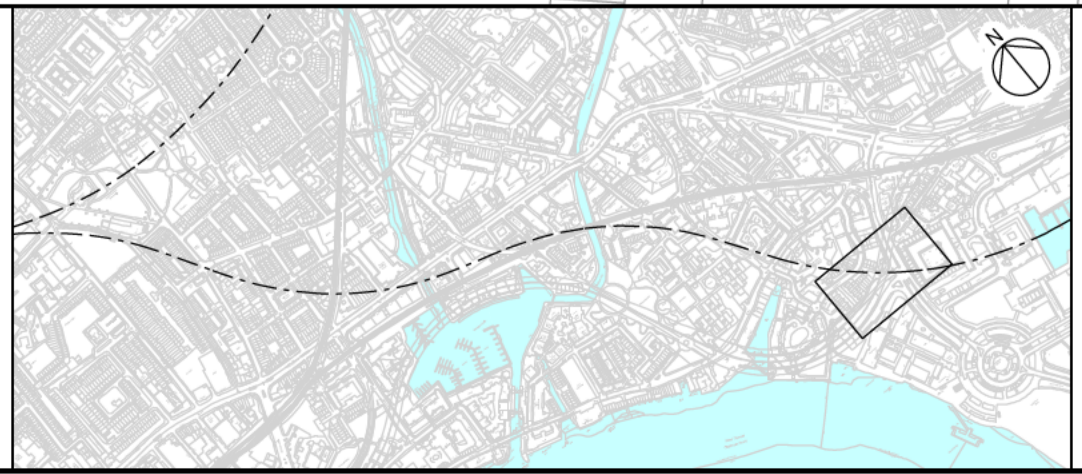
APPENDIX A: INSTRUMENT LOCATION



Rev.	Date	Description	By	Chkd	App	Auth
P01	02/10/2015	First Issue	MD	RC	RC	-
P02	20/11/2015		MD	SD	SD	-

Notes

- ◆ Electrolevel Beam (Monitoring Point)



<p>Crossrail Limited 25 Canada Square Canary Wharf London E14 6LQ</p> <p>© Crossrail www.crossrail.co.uk</p>	<p>Contract: Tunnels East - Drive Y LIM to FAR & Drive Z SGJ to PML & Drive G</p> <p>Originator: Dragados Sisk Joint Venture</p> <p>Location: Crossrail Tunnels - Drive Y (Limmo Peninsula to Farringdon Stn)</p>	<p>By: M.DAVIS</p> <p>CHK: S.DIRKWE</p> <p>APP: S.DIRKWE</p> <p>Auth: -</p>
	<p>Title: Instrumentation & Monitoring Installation Report for Electrolevels at Limehouse Link Tunnel (Drive Y)</p> <p>C305-DSJ-C2-RGN-CRG03-50011</p>	<p>Scale: 1:250 @ A1</p> <p>Drawing and CAD No: C305-DSJ-C2-DDA-CRT00_ST006_1-08154</p> <p>Rev: P02</p> <p>Suitability: S4</p>

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APPENDIX B: SUMMARY OF INSTRUMENTATION INSTALLED ON SITE

Summary Installed Instrumentation - Electrolevels											
Sensor Type	Sensor ID	Sensor Serial Number	Date Installation	Status	Monitoring ID	Location MONR			Comm. Readings (mm)		
						Eastings X	Northings Y	Elevation Z	01/06/2013	02/06/2013	03/06/2013
Electrolevels	C305-EL060101-S	1565	24/05/2013	INSTALLED	C305-EL060101	87334.585	35233.942	860.123	0.00	0.00	0.00
					C305-EL060102	87332.220	35232.095	860.148	-0.05	0.01	-0.14
Electrolevels	C305-EL060102-S	3117	24/05/2013	INSTALLED	C305-EL060103	87329.856	35230.248	860.173	0.00	0.08	-0.16
					C305-EL060104	87327.492	35228.401	860.198	0.16	0.29	-0.15
Electrolevels	C305-EL060104-S	3292	24/05/2013	INSTALLED	C305-EL060105	87325.137	35226.543	860.223	0.23	0.39	-0.24
					C305-EL060106	87322.774	35224.695	860.248	0.30	0.49	-0.30
Electrolevels	C305-EL060105-S	3295	24/05/2013	INSTALLED	C305-EL060107	87320.395	35222.868	860.273	0.17	0.40	-0.49
					C305-EL060108	87318.020	35221.035	860.298	0.08	0.38	-0.68
Electrolevels	C305-EL060107-S	3484	24/05/2013	INSTALLED	C305-EL060109	87315.641	35219.207	860.323	0.27	0.60	-0.70
					C305-EL060110	87313.264	35217.376	860.348	0.14	0.48	-0.92
Electrolevels	C305-EL060110-S	3564	24/05/2013	INSTALLED	C305-EL060111	87310.888	35215.545	860.373	-0.29	0.11	-1.38
					C305-EL060112	87308.511	35213.714	860.398	-0.14	0.29	-1.33
Electrolevels	C305-EL060112-S	3632	24/05/2013	INSTALLED	C305-EL060113	87306.135	35211.883	860.423	-0.43	0.09	-1.66
					C305-EL060114	87303.759	35210.052	860.448	-0.56	-0.03	-1.93
Electrolevels	C305-EL060114-S	3641	24/05/2013	INSTALLED	C305-EL060115	87301.339	35208.279	860.473	-0.59	-0.04	-1.99
					C305-EL060116	87298.899	35206.534	860.498	-0.49	0.11	-1.93
Electrolevels	C305-EL060115-S	3643	24/05/2013	INSTALLED	C305-EL060117	87296.450	35204.800	860.523	-0.65	-0.03	-2.18
					C305-EL060118	87293.976	35203.103	860.548	-0.83	-0.15	-2.42
Electrolevels	C305-EL060116-S	3646	24/05/2013	INSTALLED	C305-EL060119	87291.502	35201.406	860.573	-0.74	-0.53	-1.76
					C305-EL060120	87288.989	35199.768	860.598	-0.13	-0.24	-1.34
Electrolevels	C305-EL060117-S	3873	24/05/2013	INSTALLED	C305-EL060121	87286.461	35198.153	860.623	0.99	0.34	0.68
					C305-EL060122	87283.925	35196.550	860.648	0.95	0.33	0.51
Electrolevels	C305-EL060118-S	3896	24/05/2013	INSTALLED	C305-EL060123	87281.345	35195.020	860.673	0.25	-0.15	0.01
					C305-EL060124	87278.743	35193.527	860.698	0.17	-0.28	-0.01
Electrolevels	C305-EL060119-S	3920	24/05/2013	INSTALLED	C305-EL060125	87276.125	35192.062	860.723	0.13	-0.19	0.09
					C305-EL060126	87273.485	35190.637	860.748	-0.07	-0.24	0.14
Electrolevels	C305-EL060120-S	3923	24/05/2013	INSTALLED	C305-EL060127	87270.826	35189.247	860.773	0.00	-0.14	0.15
					C305-EL060128	87268.144	35187.902	860.798	0.05	-0.01	0.14
Electrolevels	C305-EL060121-S	4463	24/05/2013	INSTALLED	C305-EL060129	87265.445	35186.593	860.822	0.00	0.00	0.00

Summary Installed Instrumentation - Electrolevels											
Sensor Type	Sensor ID	Sensor Serial Number	Date Installation	Status	Monitoring ID	Location MONR			Comm. Readings (mm)		
						Eastings X	Northings Y	Elevation Z	01/06/2013	01/06/2013	01/06/2013
Electrolevels	C305-EL060201-S	2452	24/05/2013	INSTALLED	C305-EL060201	87249.162	35201.339	860.798	0.00	0.00	0.00
					C305-EL060202	87251.919	35202.523	860.773	0.18	0.12	0.04
Electrolevels	C305-EL060202-S	3275	24/05/2013	INSTALLED	C305-EL060203	87254.648	35203.768	860.748	0.47	0.45	0.23
					C305-EL060204	87257.350	35205.073	860.723	0.18	0.13	-0.08
Electrolevels	C305-EL060203-S	3276	24/05/2013	INSTALLED	C305-EL060205	87260.040	35206.400	860.698	0.24	0.24	-0.09
					C305-EL060206	87262.705	35207.777	860.673	0.11	0.11	-0.29
Electrolevels	C305-EL060204-S	3286	24/05/2013	INSTALLED	C305-EL060207	87265.353	35209.188	860.648	0.26	0.31	-0.26
					C305-EL060208	87267.970	35210.655	860.623	-0.21	-0.19	-0.77
Electrolevels	C305-EL060205-S	3374	24/05/2013	INSTALLED	C305-EL060209	87270.584	35212.126	860.598	-0.03	0.06	-0.65
					C305-EL060210	87273.147	35213.686	860.573	-0.23	-0.18	-0.93
Electrolevels	C305-EL060206-S	3376	24/05/2013	INSTALLED	C305-EL060211	87275.692	35215.275	860.548	0.13	0.23	-0.69
					C305-EL060212	87278.236	35216.864	860.523	-0.19	-0.03	-1.06
Electrolevels	C305-EL060207-S	3398	24/05/2013	INSTALLED	C305-EL060213	87280.729	35218.534	860.498	-0.07	0.13	-0.91
					C305-EL060214	87283.202	35220.231	860.473	-0.33	-0.09	-1.25
Electrolevels	C305-EL060208-S	3455	24/05/2013	INSTALLED	C305-EL060215	87285.675	35221.929	860.448	-0.19	0.15	-1.08
					C305-EL060216	87288.107	35223.687	860.423	0.84	1.20	-0.16
Electrolevels	C305-EL060209-S	3472	24/05/2013	INSTALLED	C305-EL060217	87290.524	35225.464	860.398	1.08	1.44	-0.04
					C305-EL060218	87292.941	35227.241	860.373	1.05	1.42	-0.13
Electrolevels	C305-EL060210-S	3540	24/05/2013	INSTALLED	C305-EL060219	87295.344	35229.036	860.348	1.19	1.56	-0.10
					C305-EL060220	87297.743	35230.838	860.323	1.06	1.53	-0.19
Electrolevels	C305-EL060211-S	3554	24/05/2013	INSTALLED	C305-EL060221	87300.126	35232.660	860.298	1.18	1.61	0.04
					C305-EL060222	87302.476	35234.525	860.273	0.79	1.45	-0.09
Electrolevels	C305-EL060212-S	3562	24/05/2013	INSTALLED	C305-EL060223	87304.826	35236.390	860.248	0.63	1.35	0.00
					C305-EL060224	87307.176	35238.255	860.223	0.30	0.72	-0.39
Electrolevels	C305-EL060213-S	3572	24/05/2013	INSTALLED	C305-EL060225	87309.526	35240.120	860.198	0.08	0.40	-0.44
					C305-EL060226	87311.875	35241.985	860.173	0.02	0.42	-0.14
Electrolevels	C305-EL060214-S	3578	24/05/2013	INSTALLED	C305-EL060227	87314.225	35243.850	860.148	-1.48	-1.36	-1.01
					C305-EL060228	87316.575	35245.715	860.123	-1.35	-1.28	-1.01
Electrolevels	C305-EL060215-S	3633	24/05/2013	INSTALLED	C305-EL060229	87318.925	35247.580	860.098	0.00	0.00	0.00
					C305-EL060228-S	5378	24/05/2013	INSTALLED			

Learning Legacy Document

APPENDIX C: MINUTES OF THE CLOSE OUT MEETING



I&M Close Out Meeting

Date & Time		25/09/2015 10:00	
Meeting No.		7	
<p>The purpose of this document is to record agreement to cease monitoring long term monitoring and decommission based on review of the data against the requirements. Agreement from this meeting is then considered acceptance from all parties that the Close Out Report can then be produced based on the data shown and this will be acceptable to the Project Manager.</p>			
Attendees:			
[Redacted]		[Redacted]	
Data Reviewed			
Monitoring References	Location	Settlement rate	Agreement to decommission
Area 6 - Limehouse Link Tunnel			
EL060101-EL060128	Westbound	N/A	2mm max, stable since TBM Yes. Annotate
EL060201-EL060228	Eastbound	N/A	4mm max, stable since TBM Yes.
Area 10 - BT Deep Level Tunnels and Shaft			
EL101001-EL101096	Commercial Street and Brushfield Street Tunnel	N/A	Annotate graphs for loss of data / knocked beam. Manual readings need to be reviewed.
EL101101-EL101111	Brushfield Street Adit	N/A	Annotate graphs as above and review with manual readings.
TU106101 - TU106105	Brushfield Street Shaft	N/A	Yes - convert degrees to mm/m
LC101001-LC101003	Brushfield Street Shaft	N/A	Yes -
EL102001-EL102061	Bishopsgate Tunnel	N/A	Review with manual readings.
Area 10 - Post Office Tunnel			
EL104001-EL104051	Widgate Street/ Middlesex Street	N/A	Yes - electrolevels, data / crown box already removed. Last 2 manual readings < 1mm change.
Notes			
<p>- Annotate graphs to highlight knocks, loss of readings - For BT tunnels set of manual readings needed to confirm long term stability.</p>			
Sign off			
DSJV	Geocise	Crosstail	C122
[Redacted]	[Redacted]	[Redacted]	[Redacted]