



C305 – Eastern Running Tunnels

I&M Close out report for UKPN Cable Tunnel Instrumentation
(Drive Y)

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 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: _____ Role: _____ Name: _____ Date: _____

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2b. Review by Stakeholder (if required):

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

3. Acceptance by Crossrail:

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Reviewed/Accepted by: (signature)	Print Name:	Position:	Date:
[Redacted]	[Redacted]	[Redacted]	17/3/16
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C305 Crossrail Eastern Running Tunnels					
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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 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 UKPN Cable Tunnel is located beneath the East India Dock Basin, within Area 4 of the C305 Drive Y running tunnels (Limmo Shaft to Canary Wharf Station), at approximately chainage 84430. The tunnel contains electrical cables that run between the West Ham Shaft and North Greenwich Shaft with access from Brunswick Wharf Shaft which is located in Switchouse in East India. This tunnel contains among others the electrical cables feeding the O2 Arena.

The array of electrolevels was installed within the UKPN Cable Tunnel in order to continuously monitor any movement which could potentially arise in the UKPN tunnel due to its location inside the area of influence of the Crossrail tunnelling works. 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-C4-GMS-CRG03-50008	Method Statement Millennium Dome Cable Tunnel Instrumentation	Main Method statement	22 Electrolevels sensor
C305-DSJ-C2-RGN-CRG03-50021	IR for I&M installed as per "UKPN Cable Tunnel Instrumentation" MS	Installation Report	22 Electrolevels sensor

4. SUMMARY OF INSTALLED INSTRUMENTATION ON SITE

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

- UKPN Cable Tunnel 22 Electrolevels:
 - ✓ C305-EL040101-S--C305-EL040122-S

Instruments were fitted on the western wall of the tunnel, just below spring line (see picture below), and arranged in a 22 sensor array, corresponding to 23 monitoring points.



Straight after the installation, commissioning readings were taken to verify that the instruments installed were working as per design parameters.

Once the above verification was confirmed, the baseline readings started. The objective of taking readings during the baseline period is to understand the UKPN tunnel behaviour prior to any source movement that may affect the tunnel to occur. Over a certain period of time (from January 2013 to March 2013) readings were taken in such a way. Fluctuations of +/-2mm were recorder due to the environment's changes. See bottom chart at page 8.

Detailed information of the installed instrumentation, including coordinates and commissioning readings, is reported in Appendix B.

5. CONSTRUCTION ACTIVITY

TBM PASSAGE

DRIVE Y	RING	PROJECT CHAINAGE	DATE
Eastbound	266-268	84430	25/03/2013
Westbound	262-264	84434	09/04/2013

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.

CONSTRUCTION

Cross passage 14 26th May 2015 to 14th July 2015

DEWATERING

Cross passage 13 26th November 2013 to 3rd August 2015

Cross passage 14 16th December 2013 to 17th January 2014

28th July 2014 to 28th July 2015

Limmo 4th November 2013 (still on)

Canary Wharf It is understood that Canary Wharf dewatering systems were switched on throughout the monitoring period

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

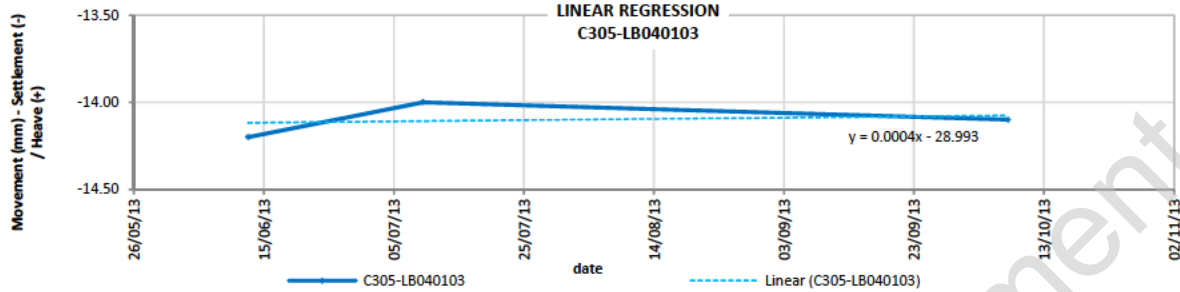
X (independent variable) = date

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

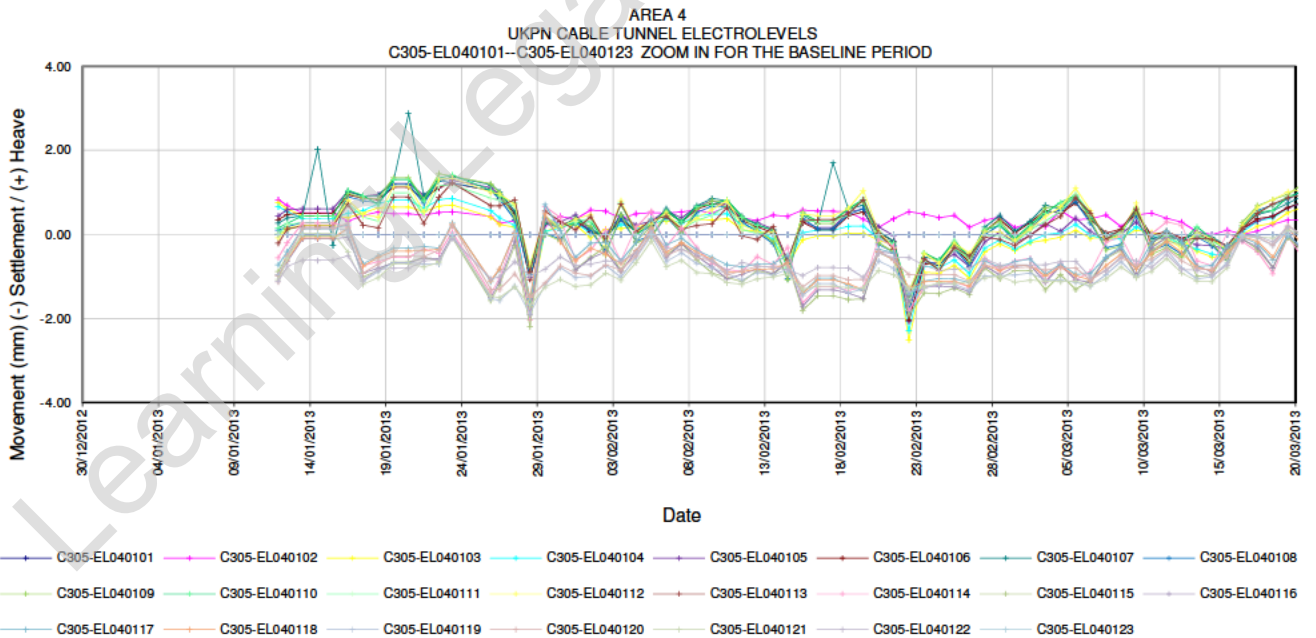
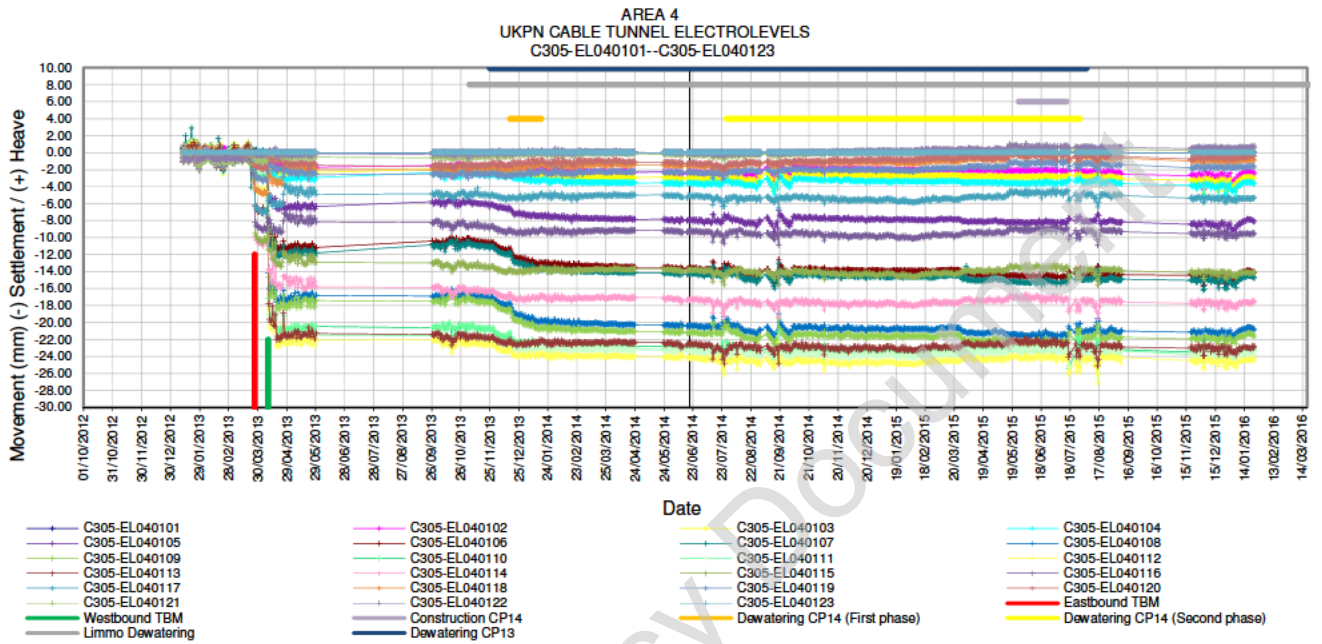
7. SUMMARY OF THE DATA

The methodology explained in section 6 is applied here for the electrolevel monitoring points (C305-EL040101-23).

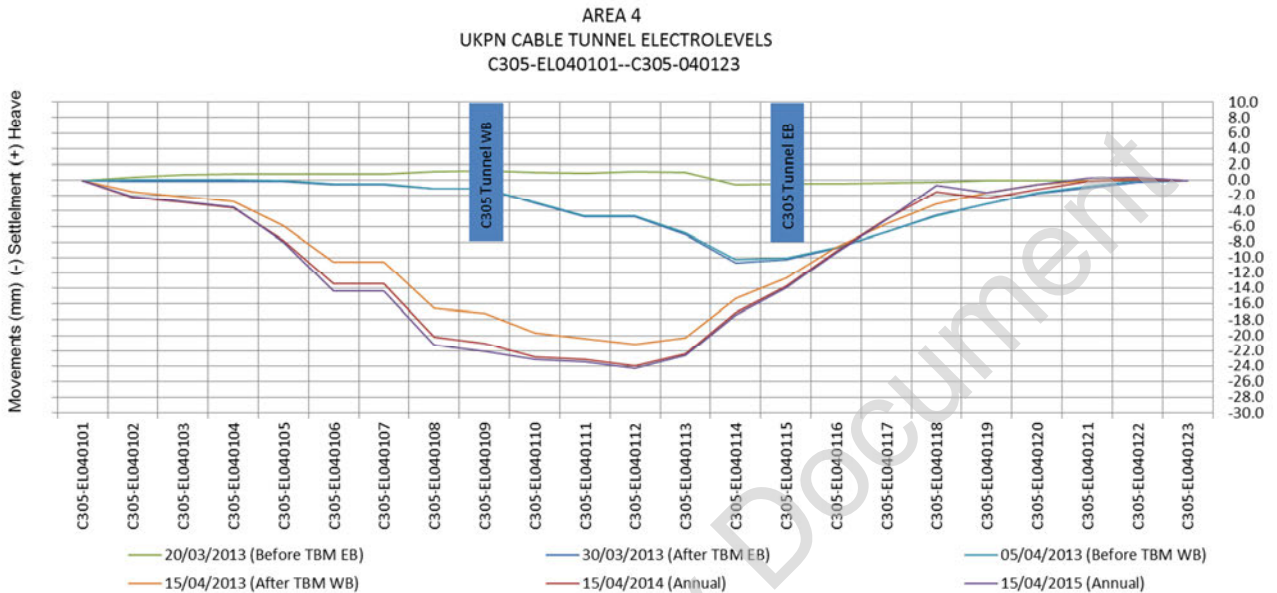
Note: For the following data plots #N/A refers to instances where readings were not taken for that sensor (e.g. damaged sensor, no access, etc).

C305-EL040101 - C305-EL040123

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



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



Electrolevel monitoring points C305-EL040101--C305-EL040123 recorded a maximum settlement of approximately 22 mm due to the Eastbound TBM & Westbound TBM transit.

There is evidence that the effect of CP13, CP14 and Limmo dewatering on the UKPN Cable Tunnel is minimal, as shown in the graphs above.

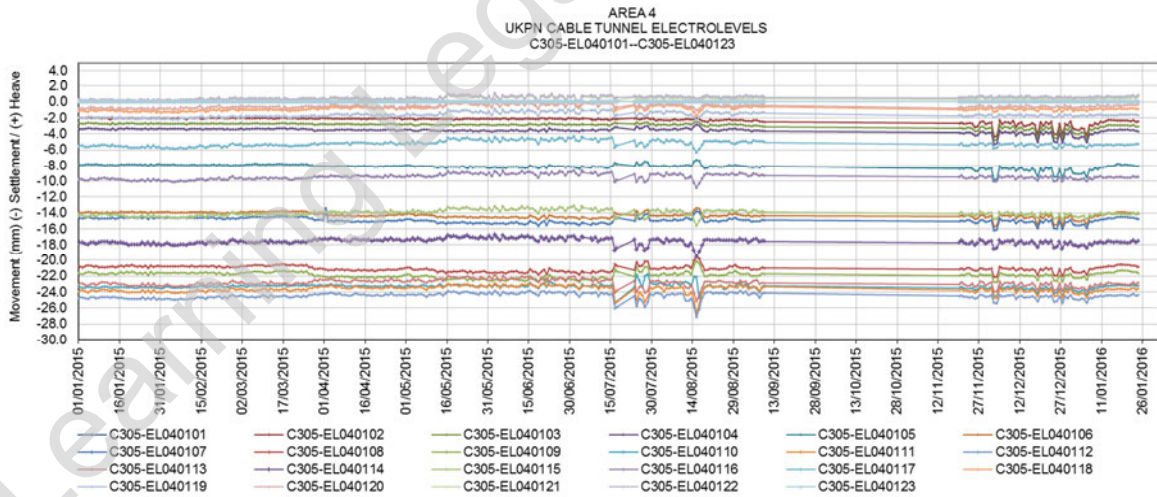
In order to verify the electrolevel reference points has not moved altogether, and confirm minimal movement of the UKPN tunnel due to dewatering activities, manual verification readings on both end points of the electrolevel array were taken 6 months after CP14 works and compared to baseline readings taken 1 year before. As illustrated in the table below, the result (ΔL_t) is that these points did not move, confirming then they are located outside the settlement trough and verifying the assumption above.

Point ID	From reference point ΔL (m)		ΔL_t (m)
	09/11/2012	14/01/2016	
C305-EL040101-LEVELLING POINT (ELP01)	-0.2731	-0.2735	-0.0004
C305-EL040123-LEVELLING POINT (ELP23)	-0.0797	-0.0799	-0.0002

Readings since January 2015 were used to calculate the annual projection of the settlement rate.

	Registered movement (mm)		Rate (mm/year)
C305-EL040101			0.000
C305-EL040102			-0.891
C305-EL040103			-0.748
C305-EL040104			-0.603
C305-EL040105			-0.619
C305-EL040106			-0.557
C305-EL040107			-0.421
C305-EL040108			-0.267
C305-EL040109			-0.123
C305-EL040110			-0.220
C305-EL040111			-0.153
C305-EL040112			-0.007
C305-EL040113			-0.277
C305-EL040114			-0.131
C305-EL040115			0.055
C305-EL040116			0.196
C305-EL040117			0.145
C305-EL040118			0.153
C305-EL040119			0.298
C305-EL040120			0.183
C305-EL040121			0.225
C305-EL040122			0.370
C305-EL040123			0.000
	READINGS FROM 01/01/2015 TO 24/01/2016		
	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-EL040101 to C305-EL040123 since 01/01/2015.

8. SUMMARY STATEMENT

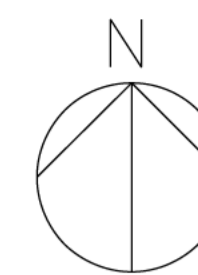
It has been agreed between the Project Manager, the Designer, the Contractor and the Sub Contractor that the instrumentation covered herein, for monitoring ground movement effects of Crossrail works, including long term effects, can be closed out for decommissioning a trends of the monitoring points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

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**APPENDIX A:
INSTRUMENT LOCATION**

LEAMOUTH ROAD



LOWER LEA CROSSING

84500

Switch House

EI Sub Sta

4

- ◆ C305-EL040123
- ◆ C305-EL040122
- ◆ C305-EL040121
- ◆ C305-EL040120
- ◆ C305-EL040119
- ◆ C305-EL040118
- ◆ C305-EL040117
- ◆ C305-EL040116
- ◆ C305-EL040115
- ◆ C305-EL040114
- ◆ C305-EL040113
- ◆ C305-EL040112
- ◆ C305-EL040111
- ◆ C305-EL040110
- ◆ C305-EL040109
- ◆ C305-EL040108
- ◆ C305-EL040107
- ◆ C305-EL040106
- ◆ C305-EL040105
- ◆ C305-EL040104
- ◆ C305-EL040103
- ◆ C305-EL040102
- ◆ C305-EL040101

84400

15300

15100

15200

2

9

17
14
11
8
5
2
1 to 7

PILGRIMS WEMMS

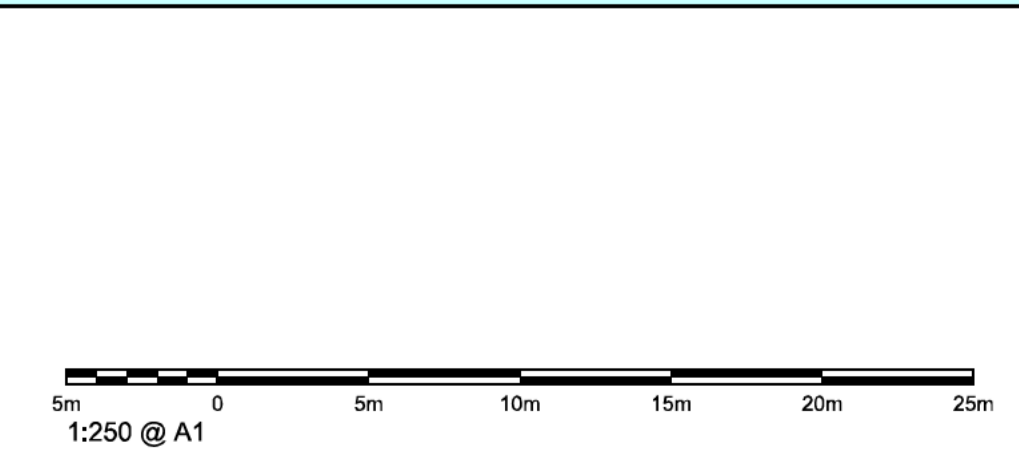
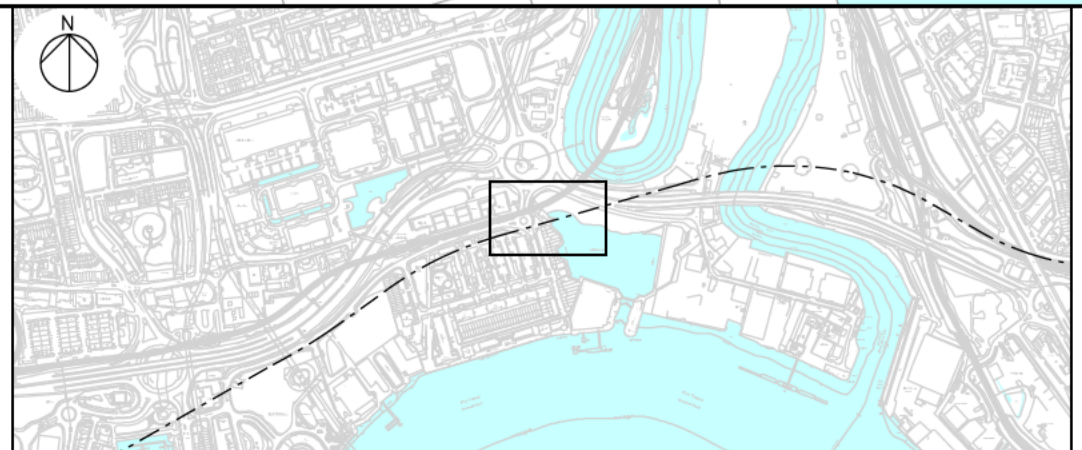
West Quay

East India Dock Basin

Rev.	Date	Description	By	Chkd	App	Auth
P01	28/01/2016	First Issue	MD	MD	MD	-

Notes

- ◆ Electrolevel



<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: M.DAVIS</p> <p>App: M.DAVIS</p> <p>Auth: -</p>	
	<p>Title: Installation & Monitoring Report for I&M Installed as per UKPN Cable Tunnel Instrumentation MS.</p>	<p>Scale: 1:250 @ A1</p>	<p>Rev: P01</p>
	<p>Drawing and CAD No: C305-DSJ-C2-RGN-CRG03-50021</p>	<p>Subsidiary: S4</p>	<p>Rev: P01</p>
	<p>www.crossrail.co.uk</p>	<p>1:250 @ A1</p>	<p>Rev: P01</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	Location MONR	Location MONR	Comm. Readings (mm)	Comm. Readings (mm)	Comm. Readings (mm)
						Easting X	Northings Y	Elevation Z	08/01/2013	09/01/2013	10/01/2013
Electrolevels	C305-EL040101-S	4768	05/11/2012	INSTALLED	C305-EL040101	89336.771	35390.572	87.324	0.00	0.00	0.00
					C305-EL040102	89335.537	35393.296	87.333	0.77	0.75	0.85
Electrolevels	C305-EL040102-S	3924	05/11/2012	INSTALLED	C305-EL040103	89334.006	35395.876	87.341	0.71	0.68	0.78
					C305-EL040104	89332.512	35398.476	87.350	0.64	0.60	0.71
Electrolevels	C305-EL040104-S	3296	05/11/2012	INSTALLED	C305-EL040105	89331.095	35401.119	87.359	0.53	0.43	0.52
					C305-EL040106	89329.697	35403.773	87.368	0.36	0.35	0.42
Electrolevels	C305-EL040106-S	1548	05/11/2012	INSTALLED	C305-EL040107	89328.265	35406.409	87.376	0.20	0.12	0.16
					C305-EL040108	89326.832	35409.045	87.385	0.07	0.06	0.19
Electrolevels	C305-EL040108-S	3908	05/11/2012	INSTALLED	C305-EL040109	89325.432	35411.698	87.394	0.01	-0.02	0.12
					C305-EL040110	89324.069	35414.371	87.403	0.15	0.27	0.15
Electrolevels	C305-EL040110-S	4486	05/11/2012	INSTALLED	C305-EL040111	89322.734	35417.057	87.411	0.03	0.04	0.17
					C305-EL040112	89321.443	35419.764	87.420	-0.03	-0.04	0.10
Electrolevels	C305-EL040112-S	4514	05/11/2012	INSTALLED	C305-EL040113	89320.221	35422.503	87.429	-0.15	-0.16	-0.02
					C305-EL040114	89319.043	35425.262	87.438	-0.45	-0.49	-0.59
Electrolevels	C305-EL040114-S	3277	05/11/2012	INSTALLED	C305-EL040115	89317.875	35428.025	87.446	-0.78	-0.82	-0.90
					C305-EL040116	89316.724	35430.796	87.455	-0.85	-0.90	-1.08
Electrolevels	C305-EL040116-S	5184	05/11/2012	INSTALLED	C305-EL040117	89315.642	35433.593	87.464	-0.66	-0.64	-0.81
					C305-EL040118	89314.631	35436.417	87.473	-0.91	-0.85	-1.00
Electrolevels	C305-EL040118-S	3878	05/11/2012	INSTALLED	C305-EL040119	89313.634	35439.246	87.481	-1.01	-0.95	-1.11
					C305-EL040120	89312.656	35442.082	87.490	-1.01	-0.97	-1.04
Electrolevels	C305-EL040120-S	4525	05/11/2012	INSTALLED	C305-EL040121	89311.727	35444.924	87.499	-1.12	-1.10	-1.20
					C305-EL040122	89310.854	35447.772	87.508	-1.03	-1.02	-1.03
Electrolevels	C305-EL040122-S	5188	05/11/2012	INSTALLED	C305-EL040123	89309.620	35450.496	87.516	0.00	0.00	0.00