



## C510 – Whitechapel and Liverpool Street Station Tunnels

### Instrumentation and Monitoring Close Out Report Block 13 Liverpool Street

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#### 2a. Stakeholder Review Required?

YES  NO

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: \_\_\_\_\_ Role: \_\_\_\_\_ Name: \_\_\_\_\_ Date: \_\_\_\_\_

Sign: \_\_\_\_\_ Role: \_\_\_\_\_ Name: \_\_\_\_\_ 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:

		<b>Crossrail Review and Acceptance Decal</b>	
This decal is to be used for submitted documents requiring acceptance by Crossrail.			
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Crossrail approval of design, details, calculations, analysis, test methods or materials developed or selected by the designer/supplier.			

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1.0	22/12/2016	For approval

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## 1 Purpose of Close out Report

Materials and Workmanship Specification - Instrumentation and Monitoring (C122-OVE-Z4-RSP-CR001-00007), section KX10.2114 specifies the requirement for a close out report prior to the decommissioning of monitoring sensors and instruments. It is therefore, the purpose of this close out report to gain acceptance to decommission identified monitoring sensors in Block 13 of Crossrails's C510 Liverpool St. Acceptance to decommission sensors will result in ceasing measurements, stopping the reporting and removing sensors.

To gain approval to decommission instrumentation and monitoring, the monitoring data will be analysed to demonstrate settlement does not breach specified rates after the minimum monitoring period is complete.

**N.B.** Monitoring sensors refers to all monitoring points; which includes BREs, road studs, extensometers, inclinometers, tilt meters, crack meters, retros (survey stickers) and prisms. Please note this is not an exhaustive list and does not include monitoring systems/equipment, such as communication boxes.

## 2 Scope of Monitoring Assessment for Close Out

Specification KX10.4103 of document C122-OVE-Z4-RSP-CR001-00007 states that to establish approval for decommissioning, the contractor is to produce a close out report which summarises the observations in correlation with the construction activities. The report is to demonstrate monitoring has reached acceptable settlement rates; whether to the specified rate, or where no rate is specified trigger values are evaluated against potential residual risks. I&M schedule C122-OVE-C2-DDJ-CR001-Z-31511 specifies the acceptable settlement rates with the requirements to monitor at different construction phases, and duration for completion. To summarise the I&M schedule states that the manual monitoring decommissioning specified rate is 2mm per year, following 16 months post construction monitoring (4 months step down and quarterly measurements for a minimum of 12 months long term monitoring). The I&M schedule does not identify the need for long term automated monitoring or specify a settlement rate requirement, it only states that monitoring must continue for 6 months post construction. At the 6 month juncture, agreement must be sought from the project manager to decommission automated monitoring programmes through a close out report or agreeing to cease the works with the project manager. In most cases decommissioning will be possible, as the residual risk will be captured through the remaining long term manual monitoring.

Contrary to the Specification for Instrumentation and Monitoring (C122-OVE-Z4-RSP-CR001-00007), the Project Managers Instruction (PMI) C510-PMI-01102 replaces long term monitoring with satellite interferometry (InSAR) for the areas agreed by the project manager. If long term monitoring responsibilities are removed from BBMV and covered by satellite interferometry, the specified settlement criteria may not be met by BBMV. If this occurs, reference to the agreement will be provided to state BBMV are no longer responsible for the sensors and consequently decommissioning acceptance will be proposed.

In some cases it may be agreed with the project manager to cease monitoring prior to meeting the specified rates. The close out report will be revised to incorporate these agreements prior to decommissioning. Due to multiple influencers and large construction monitoring zones, it may be prudent to submit successive document revisions for close out reports, where the specification is not met or the minimum post construction monitoring has not been achieved.

### 3 Close Out Report Block Description and Location Plan

#### 3.1 Block 13 Location

Figure 1 shows the Liverpool St general location plan, C510 tunnel construction and where Block 13 is situated. Detailed location plans can be found within the installation reports and photomontages as listed in Section 3.2. Each monitoring sensor’s location is shown within the assessment plans (Section 5.4).

Critical assets in Block 13 include Thames Water 10 & 12 inch cast iron water mains on London Wall and Coleman St. Goswell Street Sewer (north branch) runs from Fore Street, across London Wall and heads down Coleman Street and London Wall sewer is also Critical Assets. Other utilities include cast iron and plastic gas mains on London Wall and Coleman St. The location and details of these assets can be found in Instrumentation and Monitoring Plan: Liverpool Street Station Ground Movement and Asset Protection C122-OVE-C2-RGN-C101-50013 or the relevant C122 prepared Damage Assessment Reports.

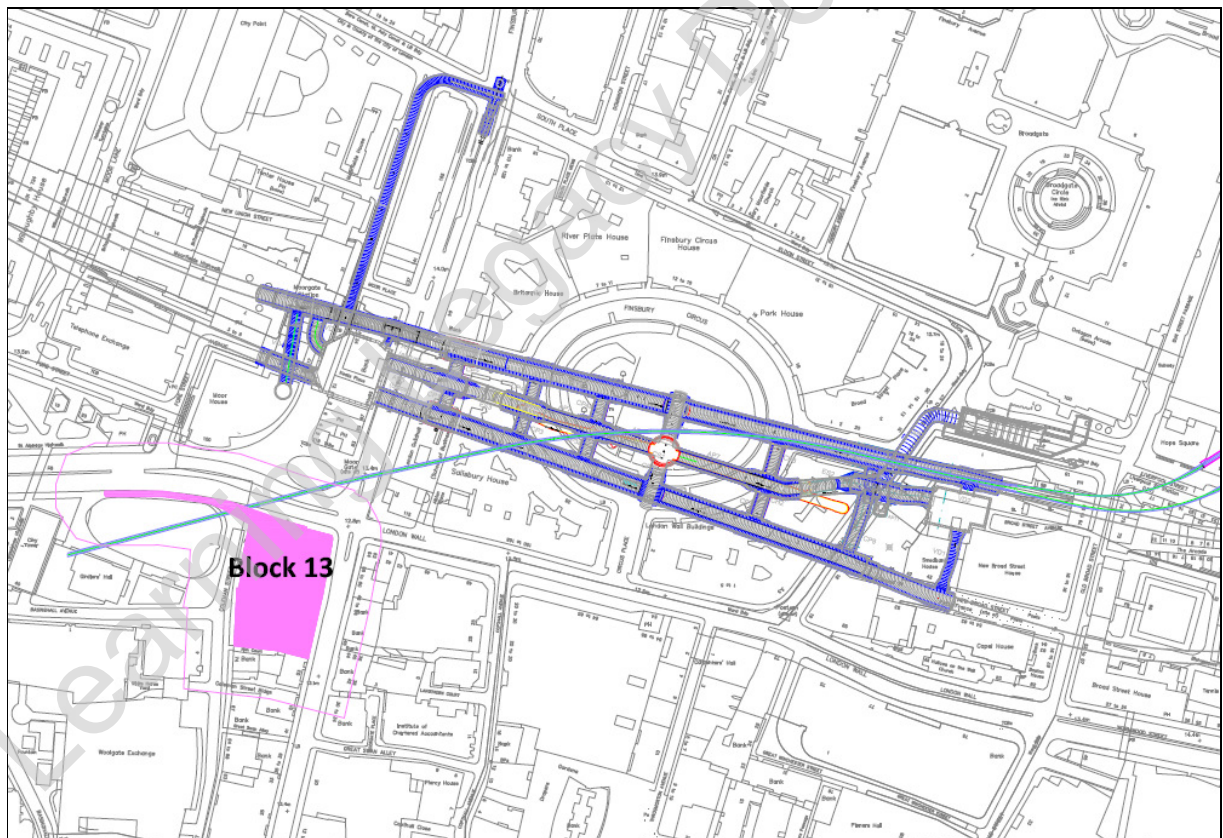


Figure 1 - Liverpool St General Location Plan - including Block 13 monitoring area

(From General Document Template ref: BBMV-0)

### 3.2 Block 13 Description

Block 13 is located on the South side of London Wall to the west of Moorgate. The Block is approximately 60 metres south and parallel to the Platform Tunnel West (PTW), further detail of the construction programmes can be found in Section 4. Block 13 contains the following types of monitoring sensors:

- Building (BREs) - manual monitoring
- Road Studs (LP)- manual monitoring

Each monitoring assets details are listed within the Decommissioning Status Tracker (*Table 2*) and further relevant information can be sourced from the installation reports.

Block 13 Installation Report References:

- Monitoring Installation Report LIV-LB-13-Liverpool Street  
CRL Document Number: C510-BBM-C2-RGN-C101-50135
- Monitoring Installation Report LIV-LP-33 (13)-Liverpool Street  
CRL Document Number: C510-BBM-C2-RGN-C101-50167

The Settlement Contour Drawing (C122-OVE-C2-DDA-CR001\_Z-21313) predicts the Block 13 area to experience approximately 1-5mm of settlement.

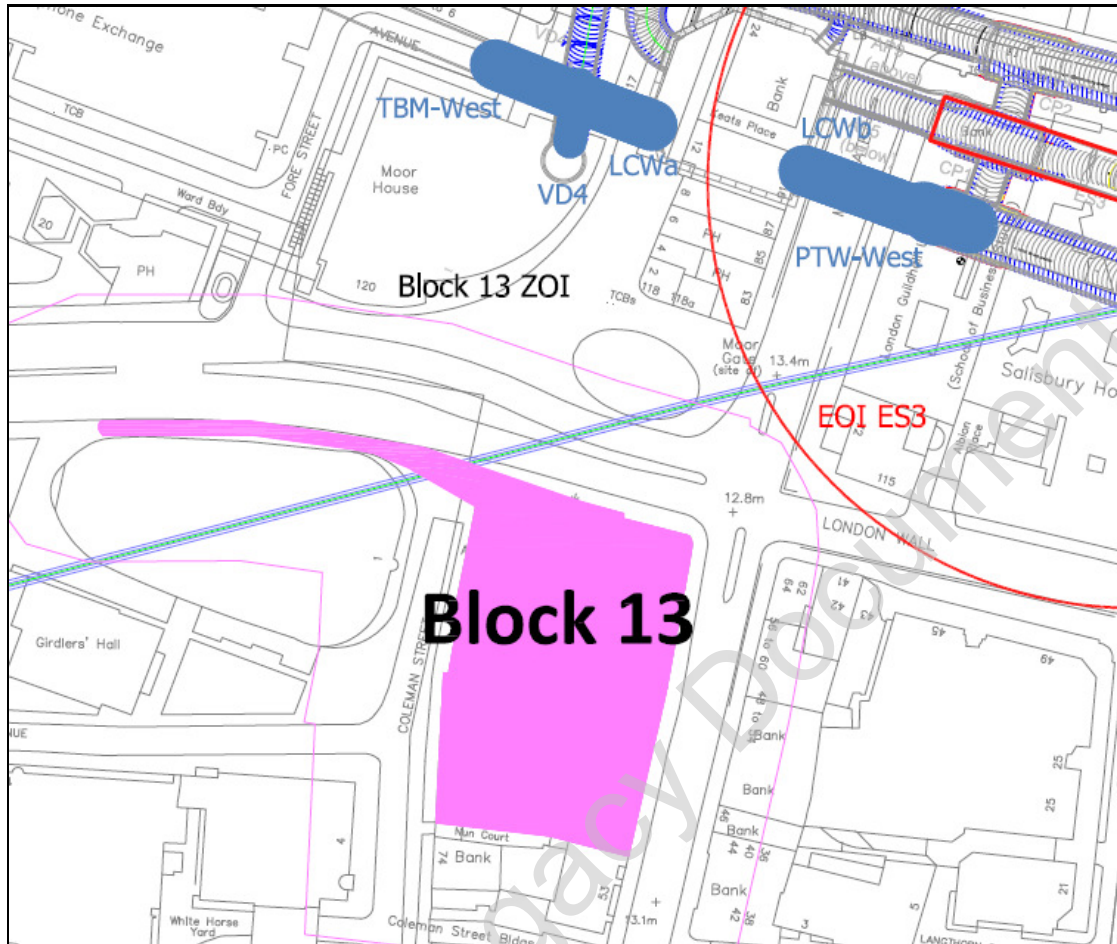
## 4 Construction Programme Influencing Block 13

Extent of Influence (EOI) monitoring areas were established to record ground movements in relation to C510 construction. The EOI purpose is to ensure all assets and areas are adequately monitored for movement during construction, this is achieved by controlling when and how often monitoring occurs. The Asset Protection Instrument and Monitoring (I&M) Schedules (C122 –OVE-C2-DDJ-CR001\_Z-31511) states the extent of influence (EOI) of an active tunnel is 2 x depth from the active tunnel face. The EOI is used to determine when monitoring sensors are no longer influenced by construction and can be considered for decommissioning.

The original specification received amendments to manual monitoring frequency within the EOI through several PMIs, with the latest PMI (C510-PMI-01103) establishing an Active ZOI (Zone of Influence) as 2 x tunnel diameter from the active tunnel face projected to the surface. The Active ZOI changed the rates of monitoring frequency, it did not replace EOI. The EOI is used to determine when a monitoring sensor is eligible for decommissioning. Whereas, active ZOI is used to analyse manual monitoring movement against construction.

To identify the tunnels that had the potential to significantly affect Block 13, a ZOI area was established by giving each monitoring sensor a radius of 2.0 x tunnel diameter. This area was then used to determine all the mining advances that occurred within its boundary, *Figure 2* shows this area (pink outline) and the tunnels. The tunnel advances start and finish dates will be used in assessment of the monitoring data.

**N.B.** ES3 EOI is represented in *Figure 2* to display that no Block 13 monitoring sensors are within the EOI of remaining C510 construction.



**Figure 2 - Block 13 Active ZOI Construction**

Figure 2 shows that no C510 works are within 2 x tunnel diameter of Block 13 (active ZOI). Therefore, to assist the monitoring analysis of Block 13, the EOI will be referenced against settlement. The construction advances EOI that have the potential to affect Block 13 are listed and summarised in Table 1.

The last completed C510 construction which had the potential to affect Block 13 within its EOI, is the LCWa Enlargement, which was completed on the 9<sup>th</sup> of February 2015. As there is no further C510 construction that has the potential to affect Block 13 and the last construction advance within the EOI has surpassed 16 months of post construction monitoring, the entire Block 13 can be assessed for decommissioning.

C305's Westbound TBM construction had the potential to influence Block 13, and is included within the table and the graph to assess the monitoring data. Further evidence for construction dates can be seen in Table 2, which lists the latest tunnel advances for each point.



#### 4.1.1 Tunnel Advances Affecting Block 13

The information presented in *Table 1* is used in the monitoring graph (Section 5.1), to show the ground movements in relation to construction. As no construction's active ZOI affects Block 13, construction's EOI has been used.

TUNNEL ADVANCES STARTS & ENDS FOR GRAPHS							
Tunnel Code	Tunnel Reference	Primary Layer Type	Start Date	End Date	Start Advance	End Advance	Zone
TBM-West-LC-Pilot	TBM-West-LC	Pilot	11/04/2015	14/04/2015	4014	4016	C305
LCWa-Enlargement	LCWa	Enlargement	29/01/2015	09/02/2015	3	41	EOI
LCWa-Pilot	LCWa	Pilot	17/01/2015	24/01/2015	1	24	EOI
VD4-Enlargement	VD4	Enlargement	13/08/2014	11/09/2014	32	43	EOI
LCWb-Enlargement	LCWb	Enlargement	25/02/2014	05/03/2014	1	36	EOI
PTW-West-Enlargement	PTW-West	Enlargement	17/02/2014	24/02/2014	161	182	EOI
LCWb-Pilot	LCWb	Pilot	20/10/2013	24/10/2013	1	19	EOI
PTW-West-Pilot	PTW-West	Pilot	16/10/2013	20/10/2013	117	130	EOI

**Table 1 - Tunnel Advances Affecting Block 13**

N.B. The advance number for TBM headings, is the advance ring number.

#### Heading Index:

AP – Access Passage

CH - Chamber

CP - Cross Passage

ES – Escalator

GAD – Grout Adit

LCE - Launch Chamber East

LCW – Launch Chamber West

PTE – Platform Tunnel East

PTW – Platform Tunnel West

RCE – Reception Chamber East

RCW – Reception Chamber West

TBM – Tunnel Boring Machine

VD – Ventilation Drive

## 5 Monitoring Assessment of Block 13

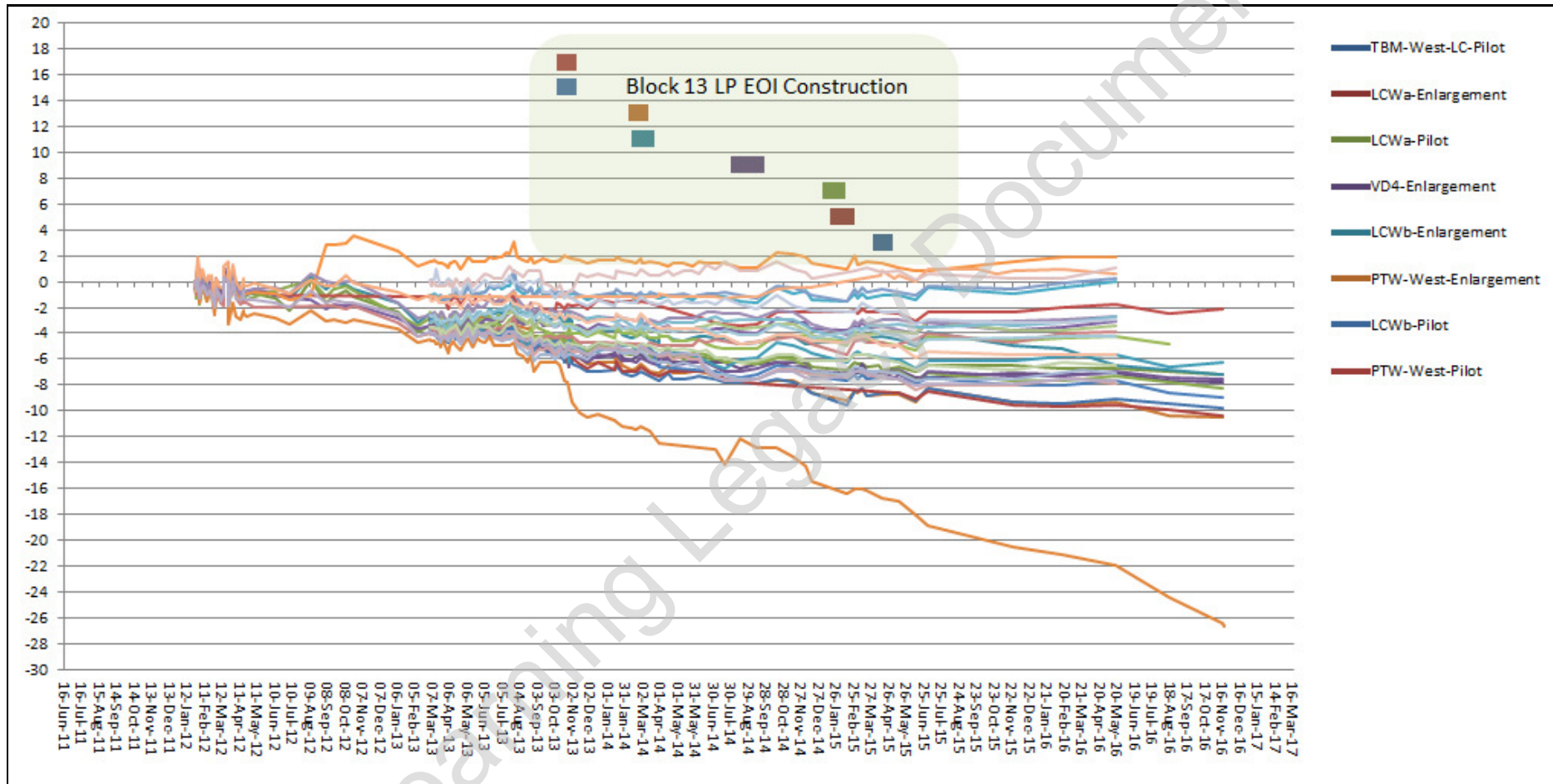
Evidence for decommissioning each monitored sensor is shown through graphs, tables (*Table 2*) and plans. Each element of assessment compliments the other and is used together to determine acceptance of decommissioning. *Table 2 - Decommissioning Tracker* highlights the monitoring sensors to be considered for decommissioning and provides the supporting evidence for the decision. In some cases supplementary evidence is required to prove stability or provide reasoning for decommissioning.

### 5.1 Time Graphs Monitoring Full History and Construction Durations

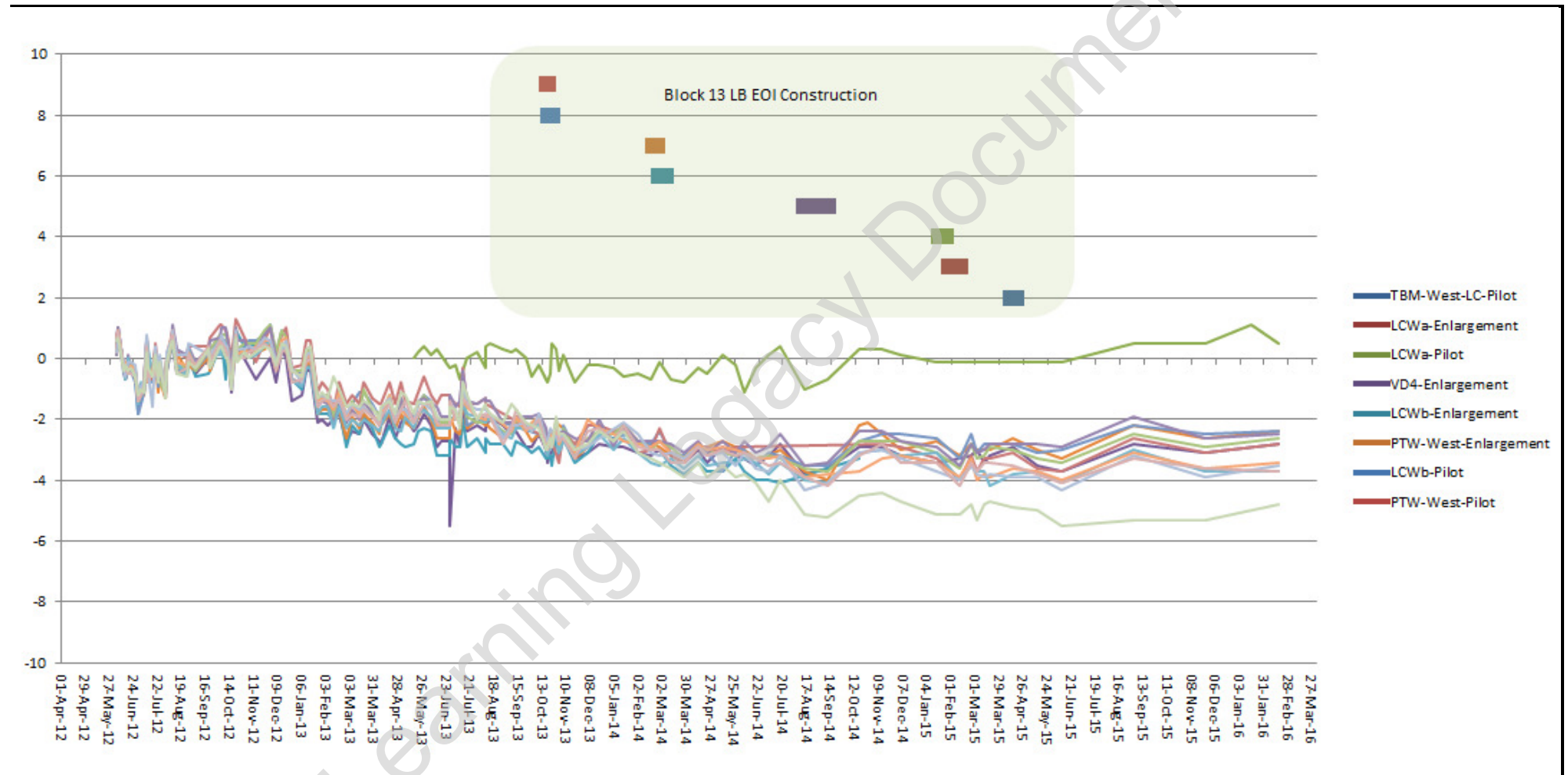
To assess the movement of Block 13 monitoring sensors; each monitoring sensor data type is displayed in a line graph, with a gantt chart (bar) representing the construction identified in Section 4:

- *Graph 1* - All Block 13 Road Studs (LP) Manual Monitoring History in Relation to Construction
- *Graph 2* - All Block 13 Building (BRE) Manual Monitoring History in Relation to Construction

**Graph 1 - All Block 13 Road Studs (LP) Manual Monitoring History in Relation to Construction**



**Graph 2 - Block 13 Building (BRE) Manual Monitoring History in Relation to Construction**



## 5.2 Block 13 Decommissioning Status Tracker

The decommissioning tracker identifies (*Table 2*) each monitoring sensor and provides the critical information to enable decommissioning assessment for each sensor. The initial fields shown in the tracker are descriptors of the monitoring sensor, whilst the remaining fields are the assessment for decommissioning. The purpose of the tracker is to provide Crossrail reviewers with sufficient information in conjunction with construction movement graphs and plots, to accept BBMV's proposal to decommission sensors on an individual basis.

Detailed explanation of the tracker column headers:

### Tracker Column Header – Last Construction Date and Traffic Lights

For each sensor the EOI parameter is used to determine the latest completed construction advance that had the potential to cause settlement. All construction tunnel advances that had the potential to affect a sensor through its EOI are listed for each sensor, from the list the latest advance is used as a construction completion indicator. A traffic light system is used to highlight when a sensor has surpassed defined monitoring time frames 4 months (120 days), 6 months (180 days) and 16 months (480 days)

**N.B.** Each monitoring sensor's last affecting primary construction heading and advance number's completion date has been listed within the Decommissioning Status Tracker. The last construction heading listed, is not the closest to the monitoring sensor, but the last completed within the EOI radius (2 x depth).

If any Block 13 sensors are not within a distance of 2 x depth of any tunnel advance location, the last completed construction's EOI that had the potential to affect Block 13 is used as a reference.

### Tracker Column Header – 120, 180 & 365 Days Average Settlement Trend

There are three average settlement trends, which tie into the defined monitoring time frames; 120, 180 and 365 days. The calculation used to determine the trend is the same for all three periods. It is a slope calculation (explained below) of the defined period, multiplied over one year. The trend is calculated from the latest reading and includes all readings within the defined period, which is averaged and then multiplied over 1 year. If there is no initial reading for the time frame date, the calculation will continue back to include the next available date. This is an important consideration when assessing the trend and to assist the reviewers, the time frame used within the calculation is included within the decommissioning tracker status table. Defined monitoring time frames:

- The 120 day average rate is used to show the completion of manual monitoring step down period, this is the minimum period of monitoring prior to InSAR taking monitoring responsibility.
- The 180 day average rate is the minimum monitoring period after construction for automated sensors.
- The 365 day average trend is a calculation to determine annual settlement rates using measurements taken across a full year. This measurement period is therefore the desired duration to be used to assess whether long term settlement meets the 2mm per annum specification.

### Slope calculation Settlement Trend:

**Description** – The settlement trend calculates the slope of the linear regression line through data points in known\_y's and known\_x's. The slope is the vertical distance divided by the horizontal distance between any two points on the line, which is the rate of change along the regression line.

### Calculation

$$b = \frac{\sum (x - \bar{x})(y - \bar{y})}{\sum (x - \bar{x})^2}$$

Example - If the calculated trend for a 6 month period is 1.5mm, it is multiplied into 365 days, to equal a projected settlement trend of 3mm over 1 year.

### Tracker Column Header – ERP Ceased date

ERP and CTC meetings have identified project efficiencies, by ceasing manual monitoring programmes early, or prior to reaching 2mm/yr. InSAR may have taken responsibility of monitoring or the perceived risk may be low enough to warrant ceasing the monitoring. In these situations the cease date is provided, along with a comment explaining the reasoning. Monitoring that has been ceased still requires approval to decommission and will be identified within the decommissioning status tracker as proposed to decommission.

### Tracker Column Header – Decommissioning Status

The status is the decommissioning situation for each sensor within Block 13. The different statuses are as follows:

- Outstanding - Monitoring sensor has not met the close out requirements and approval to decommission will be sought in subsequent revisions of this close out report.
- Proposed - the sensor is proposed to be decommissioned. Crossrail to accept the sensor can be decommissioned.
- Agreed – Agreed to decommission through previous revision of the close out report. No further reporting or monitoring has taken place.
- Complete - Monitoring sensor has been removed and evidence gathered during decommissioning.

**N.B.** When monitoring sensors have not met the requirements, it may still be appropriate to decommission. In this scenario supplementary evidence will be provided to explain the reasoning for decommissioning.

Table 2 - Block 13 Decommissioning Status Tracker

22/12/2016

< 2.0 mm GREEN < 3.5 mm AMBER > 3.5 mm RED

22/12/2016

C510 Sensor Name	Block	Section	Int / Ext	Measurement Type	Sensor Type	Sensor Description	Asset/Location	EOI Last Primary Layer Construction	Last Construction Date	Latest Surveyed Date	AVERAGE SETTLEMENT TREND				Ceased Date	General Comment	Decommissioning Status		
											120 Day Trends	120 Day Calculation Period	180 Day Trends	180 Day Calculation Period				365 Day Trends	365 Day Calculation Period
C510-LB11300	Block 113	S11301	External	Manual	LB	BRE	63-73 Moorgate	LIV_LCWa_Enlargement_Adv-36	05/03/2014	16/02/2016	0.54	168	1.14	252	0.95	398	10/03/2016	Ceased - ERP 10/03/2016 (Benchmark - do not remove)	Proposed
C510-LB11301	Block 113	S11301	External	Manual	LB	BRE	63-73 Moorgate	LIV_LCWa_Enlargement_Adv-36	05/03/2014	16/02/2016	0.00	168	1.04	252	0.37	370	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LB11302	Block 113	S11301	External	Manual	LB	BRE	63-73 Moorgate	LIV_LCWa_Enlargement_Adv-36	05/03/2014	16/10/2014	2.36	120	0.04	187	-0.99	373	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LB11303	Block 113	S11301	External	Manual	LB	BRE	63-73 Moorgate	LIV_LCWa_Enlargement_Adv-36	05/03/2014	16/02/2016	-0.43	168	1.00	252	0.67	370	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LB11304	Block 113	S11301	External	Manual	LB	BRE	63-73 Moorgate	LIV_LCWa_Enlargement_Adv-36	05/03/2014	16/02/2016	-0.43	168	0.65	252	0.65	370	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LB11305	Block 113	S11301	External	Manual	LB	BRE	63-73 Moorgate	LIV_LCWa_Enlargement_Adv-8	05/03/2014	16/02/2016	-0.43	168	0.96	252	0.78	370	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LB11306	Block 113	S11301	External	Manual	LB	BRE	63-73 Moorgate	LIV_LCWa_Enlargement_Adv-9	05/03/2014	16/02/2016	-0.22	168	0.87	252	0.61	370	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LB11307	Block 113	S11301	External	Manual	LB	BRE	63-73 Moorgate	LIV_LCWa_Enlargement_Adv-18	05/03/2014	16/02/2016	-1.30	168	0.22	252	0.76	370	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LB11308	Block 113	S11301	External	Manual	LB	BRE	63-73 Moorgate	LIV_LCWa_Enlargement_Adv-30	05/03/2014	16/02/2016	-1.52	168	0.22	252	0.28	370	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LB11309	Block 113	S11301	External	Manual	LB	BRE	63-73 Moorgate	LIV_TBM-West-LC_Pilot_Adv-4014	30/01/2015	16/02/2016	-0.65	168	0.57	252	0.42	370	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LB11310	Block 113	S11301	External	Manual	LB	BRE	63-73 Moorgate	LIV_TBM-West-LC_Pilot_Adv-4016	31/01/2015	16/02/2016	-0.65	168	0.74	252	0.29	370	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LB11311	Block 113	S11301	External	Manual	LB	BRE	34 London Wall	LIV_TBM-West-LC_Pilot_Adv-4016	01/02/2015	16/02/2016	-0.87	168	0.39	252	0.05	370	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LB11312	Block 113	S11301	External	Manual	LB	BRE	63-73 Moorgate	LIV_TBM-West-LC_Pilot_Adv-4022	04/02/2015	16/02/2016	-1.09	168	0.91	252	-0.14	370	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LP13301	Block 113	S11301	External	Manual	LP	Road Stud	London Wall	LIV_LCWa_Enlargement_Adv-17	02/02/2015	15/11/2016	-0.95	182	-0.95	182	-0.50	503		Below 2mm/yr. 15/11/2016	Proposed
C510-LP13302	Block 113	S11301	External	Manual	LP	Road Stud	London Wall	LIV_LCWa_Enlargement_Adv-18	03/02/2015	15/11/2016	-1.38	182	-1.38	182	-0.33	503		Below 2mm/yr. 15/11/2016	Proposed
C510-LP13303	Block 113	S11301	External	Manual	LP	Road Stud	London Wall	LIV_LCWa_Enlargement_Adv-30	06/02/2015	15/11/2016	-1.49	182	-1.49	182	-2.55	503		180 Day Trend met specification- all adjacent road studs stable	Proposed
C510-LP13304	Block 113	S11301	External	Manual	LP	Road Stud	London Wall	LIV_TBM-West-LC_Pilot_Adv-4014	11/04/2015	15/11/2016	-2.43	182	-2.43	182	-1.64	503		Below 2mm/yr. 15/11/2016	Proposed
C510-LP13305	Block 113	S11301	External	Manual	LP	Road Stud	London Wall	LIV_TBM-West-LC_Pilot_Adv-4016	14/04/2015	15/11/2016	-1.40	182	-1.40	182	-0.92	503		Below 2mm/yr. 15/11/2017	Proposed
C510-LP13306	Block 113	S11301	External	Manual	LP	Road Stud	London Wall	LIV_TBM-West-LC_Pilot_Adv-4018	14/04/2015	15/11/2016	-1.87	182	-1.87	182	-1.14	503		Below 2mm/yr. 15/11/2018	Proposed
C510-LP13307	Block 113	S11301	External	Manual	LP	Road Stud	London Wall	LIV_TBM-West-LC_Pilot_Adv-4020	16/04/2015	15/11/2016	-1.81	182	-1.81	182	-0.60	503		Below 2mm/yr. 15/11/2019	Proposed
C510-LP13308	Block 113	S11301	External	Manual	LP	Road Stud	London Wall	LIV_TBM-West-LC_Pilot_Adv-4022	18/04/2015	15/11/2016	-1.32	182	-1.32	182	-0.35	503		Below 2mm/yr. 15/11/2020	Proposed
C510-LP13309	Block 113	S11301	External	Manual	LP	Road Stud	London Wall	LIV_TBM-West-LC_Pilot_Adv-4026	20/04/2015	15/11/2016	-1.21	182	-1.21	182	-0.17	503		Below 2mm/yr. 15/11/2021	Proposed
C510-LP13310	Block 113	S11301	External	Manual	LP	Road Stud	London Wall	LIV_TBM-West-LC_Pilot_Adv-4028	20/04/2015	18/11/2016	-9.25	185	-9.25	185	-5.71	506		Not met 2mm/yr. Supplementary evidence provided.	Proposed
C510-LP13311	Block 113	S11301	External	Manual	LP	Road Stud	London Wall	LIV_TBM-West-LC_Pilot_Adv-4032	20/04/2015	15/11/2016	-2.64	182	-2.64	182	-1.01	503		Below 2mm/yr. 15/11/2016	Proposed
C510-LP13312	Block 113	S11301;S11302	External	Manual	LP	Road Stud	London Wall	LIV_TBM-West-LC_Pilot_Adv-4034	20/04/2015	15/11/2016	-0.61	182	-0.61	182	0.10	503		Below 2mm/yr. 15/11/2017	Proposed
C510-LP13313	Block 113	S11302	External	Manual	LP	Road Stud	London Wall	LIV_TBM-West-LC_Pilot_Adv-4034	20/04/2015	16/08/2016	-0.93	182	-0.93	182	-0.31	412	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LP13314	Block 113	S11302	External	Manual	LP	Road Stud	London Wall	LIV_TBM-West-LC_Pilot_Adv-4036	21/04/2015	17/05/2016	1.46	175	0.10	321	0.48	371	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LP13315	Block 113	S11302	External	Manual	LP	Road Stud	London Wall	LIV_TBM-West-LC_Pilot_Adv-4036	21/04/2015	17/05/2016	1.88	175	0.55	321	0.94	371	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LP13316	Block 113	S11302	External	Manual	LP	Road Stud	London Wall	LIV_LCWa_Enlargement_Adv-53	12/02/2015	17/05/2016	0.62	175	1.31	321	1.15	371	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LP13317	Block 113	S11302	External	Manual	LP	Road Stud	London Wall	LIV_TBM-West-LC_Pilot_Adv-4034	20/04/2015	17/05/2016	1.87	175	0.70	321	0.98	371	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LP13318	Block 113	S11302	External	Manual	LP	Road Stud	London Wall	LIV_TBM-West-LC_Pilot_Adv-4034	20/04/2015	17/05/2016	1.65	175	0.23	321	0.57	371	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LP13319	Block 113	S11302	External	Manual	LP	Road Stud	London Wall	LIV_TBM-West-LC_Pilot_Adv-4034	20/04/2015	17/05/2016	0.85	175	-0.41	321	0.17	371	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LP13320	Block 113	S11302	External	Manual	LP	Road Stud	London Wall	LIV_TBM-West-LC_Pilot_Adv-4034	20/04/2015	17/05/2016	0.84	175	0.53	321	0.34	371	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LP13321	Block 113	S11302	External	Manual	LP	Road Stud	London Wall	LIV_TBM-West-LC_Pilot_Adv-4034	20/04/2015	17/05/2016	1.47	175	1.13	205	0.58	371	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LP13322	Block 113	S11302	External	Manual	LP	Road Stud	London Wall	LIV_TBM-West-LC_Pilot_Adv-4034	20/04/2015	17/05/2016	-0.43	175	-0.01	205	0.48	371	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LP13323	Block 113	S11303	External	Manual	LP	Road Stud	Coleman St	LIV_TBM-West-LC_Pilot_Adv-4020	16/04/2015	17/05/2016	1.25	175	0.70	321	0.44	371	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LP13324	Block 113	S11303	External	Manual	LP	Road Stud	Coleman St	LIV_LCWa_Enlargement_Adv-29	06/02/2015	17/05/2016	0.33	175	0.40	321	0.34	371	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LP13325	Block 113	S11303	External	Manual	LP	Road Stud	Coleman St	LIV_VD4_Enlargement_Adv-43	11/09/2014	17/05/2016	0.61	175	0.13	321	0.01	371	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LP13326	Block 113	S11303	External	Manual	LP	Road Stud	Coleman St	LIV_VD4_Enlargement_Adv-43	11/09/2014	17/05/2016	0.41	175	0.30	321	0.10	371	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LP13327	Block 113	S11303	External	Manual	LP	Road Stud	Coleman St	LIV_VD4_Enlargement_Adv-43	11/09/2014	17/05/2016	0.41	175	0.38	321	0.26	371	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LP13328	Block 113	S11303	External	Manual	LP	Road Stud	Coleman St	LIV_VD4_Enlargement_Adv-43	11/09/2014	17/05/2016	-0.21	175	-0.36	321	-0.40	371	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LP13329	Block 113	S11303	External	Manual	LP	Road Stud	Coleman St	LIV_VD4_Enlargement_Adv-43	11/09/2014	17/05/2016	0.42	175	-0.04	321	-0.28	371	10/03/2016	Ceased - ERP 10/03/2016	Proposed
C510-LP13330	Block 113	S11303	External	Manual	LP	Road Stud	Coleman St	LIV_VD4_Enlargement_Adv-43	11/09/2014	17/05/2016	1.69	175	0.43	321	0.29	371	10/03/2016	Ceased - ERP 10/03/2016	Proposed

### 5.3 Supplementary Evidence for Decommissioning

If the decommissioning specifications for the monitoring sensors have not been met and they are proposed for decommissioning, evidence /reasoning is provided.

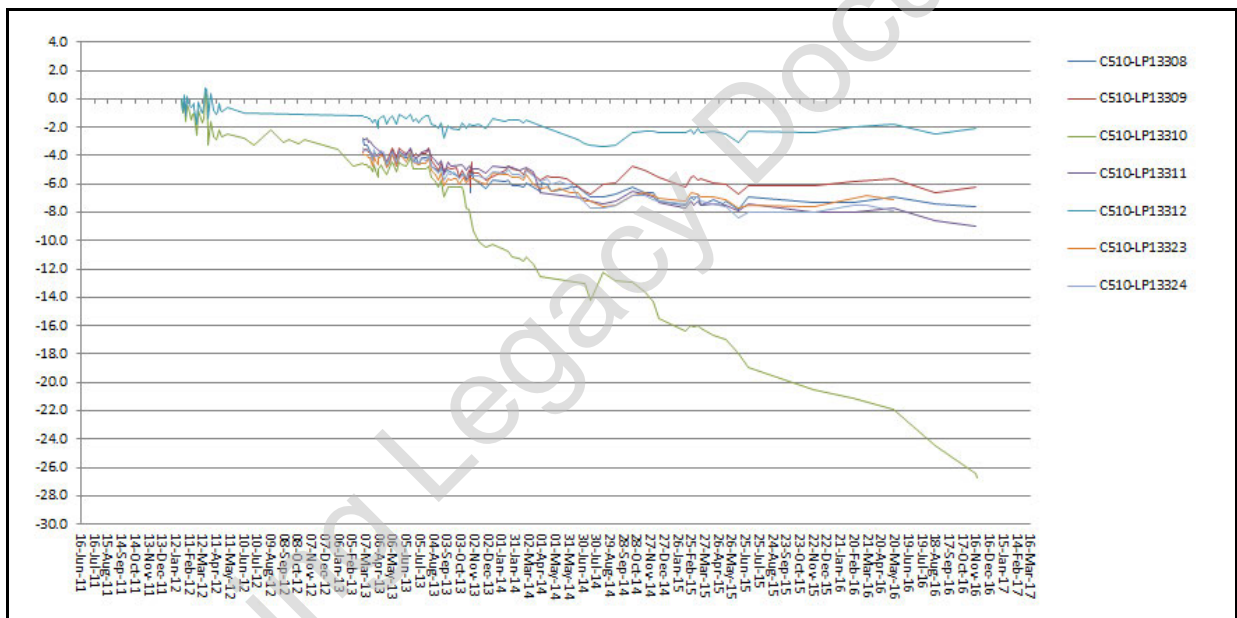
#### Road Studs (LP) Manual Monitoring

Includes: C510-LP13310

#### Reasons to propose decommissioning

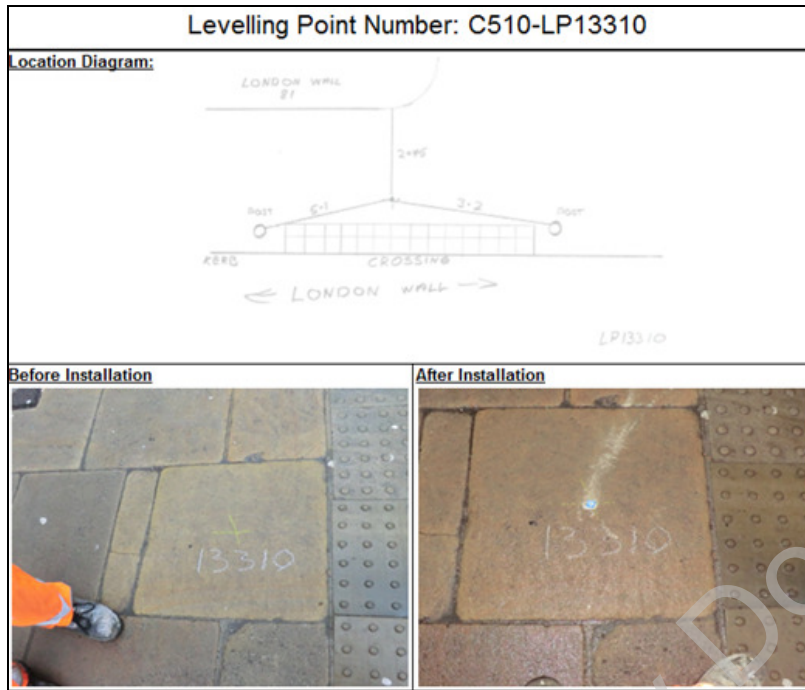
C510-LP13310 has not met the 2mm per annum specification identified in Section 2. The LP13310 results are anomalous when investigating the trend against the rest of the block. Investigations show that adjacent monitoring sensors have met the 2mm per annum specification. *Graph 3* displays surrounding surface road studs.

**Graph 3 - Movement of C510-LP13310 and adjacent monitoring**





**Figure 3- C510-LP13310 Road Stud Installation Report (2012)**



**Figure 4- C510-LP13310 Road Stud (2016)**



It is evident that the original pavement slabs no longer exist. Road works were undertaken between March and July 2014 to replace the old pavement and C510-LP13310 was reinstalled close to its original location (3<sup>rd</sup> time requiring reinstallation). It is apparent that the pavement slab is experiencing settlement rather than actual ground movement as *Graph 3* shows that the adjacent road studs have all met specification.

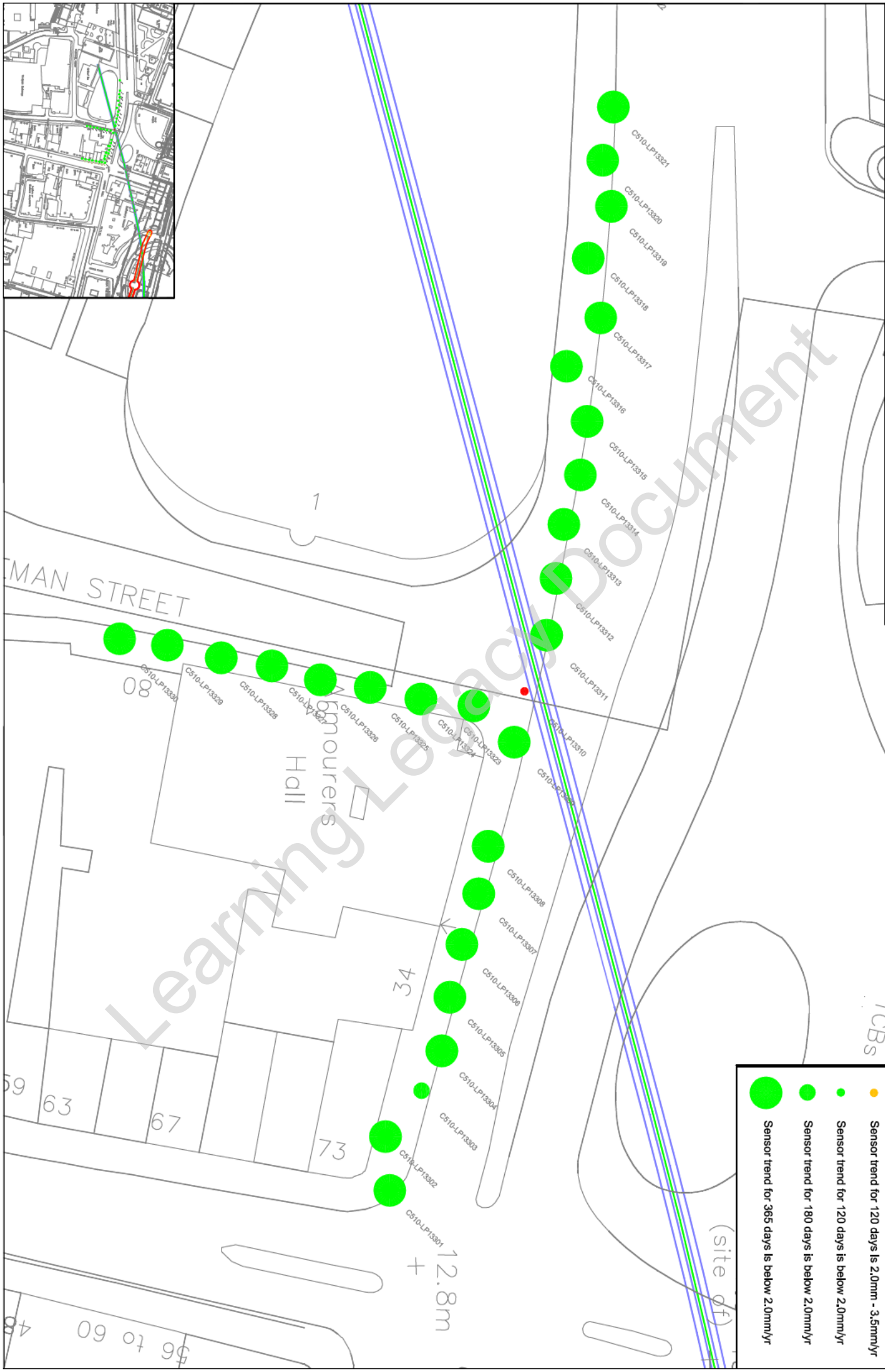
#### 5.4 Monitoring sensor Location Plan and Decommissioning Status

The following plots provide a visual representation of all Block 13 monitoring sensors with a colour circle that defines its settlement status. A green circle represents when a trend is below 2mm/yr and the larger the circle the greater the trend period. When a trend has not been met, a small red circle will represent the monitoring sensor. There is one plan for Block 13 BRE monitoring sensors.

- *Figure 5 - LP Monitoring Sensor Settlement Status and Location Plan*
- *Figure 6 - LB Monitoring Sensor Settlement Status and Location Plan*

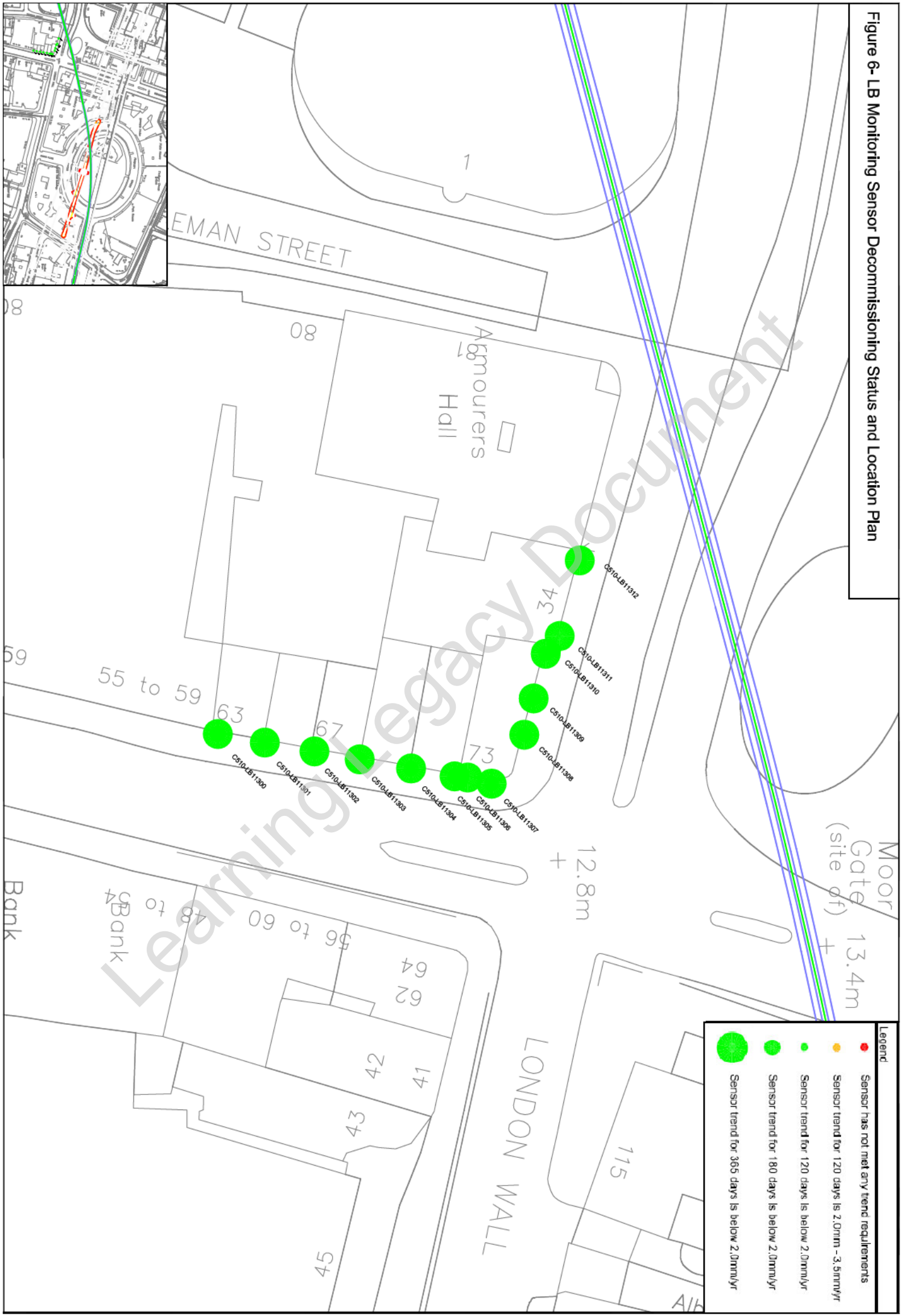
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Figure 5 - LP Monitoring Sensors Proposed to Decommission Location Plan



Legend	
<span style="color: red;">●</span>	Sensor has not met any trend requirements
<span style="color: orange;">●</span>	Sensor trend for 120 days is 2.0mm - 3.5mm/yr
<span style="color: green;">●</span>	Sensor trend for 120 days is below 2.0mm/yr
<span style="color: green;">●</span>	Sensor trend for 180 days is below 2.0mm/yr
<span style="color: green;">●</span>	Sensor trend for 365 days is below 2.0mm/yr

Figure 6- LB Monitoring Sensor Decommissioning Status and Location Plan



## 6 Decommissioning Recommendations

Through the monitoring assessment process in Section 5, it is proposed that all Block 13 sensors are to be decommissioned. *Table 2* lists all Block 13 monitoring sensor's decommissioning status and the supporting evidence. Road Stud C510-LP13310 is the only sensor to have not met the specification identified in Section 2. The additional movement is unrelated to Crossrail works (refer to Section 5.3 Supplementary Evidence).

**N.B.** When required, decommissioning and re-instatement evidence will be collected during the removal of monitoring sensors, which will be included within the final report.

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