



# C510 – Whitechapel and Liverpool Street Station Tunnels

## Instrumentation and Monitoring Close Out Report Post Office Tunnel Liverpool Street

CRL Document Number: C510-BBM-C2-RGN-C101-50230

Supplier Document Number: N/A

Contract MDL reference: C13.014.476

### 1. Contractor Document Submittal History:

Revision:	Date:	Prepared by:	Checked by:	Approved by:	Reason for Issue:
1.0	14/07/2017	[Redacted]	[Redacted]	[Redacted]	For Acceptance

### 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:

Crossrail Review and Acceptance Decal	
This decal is to be used for submitted documents requiring acceptance by Crossrail.	
<input checked="" type="checkbox"/>	Code 1. Accepted. Work May Proceed
<input type="checkbox"/>	Code 2. Not Accepted. Revise and resubmit. Work may proceed subject to incorporation of changes indicated
<input type="checkbox"/>	Code 3. Not Accepted. Revise and resubmit. Work may not proceed
<input type="checkbox"/>	Code 4. Received for information only. Receipt is confirmed
[Redacted]	Date: 20/11/17
Crossrail approval of design, details, calculations, analyses, test methods or materials developed or selected by the designer/supplier.	

Document Revision History		
Revision	Date	Purpose
1.0	14/07/2017	For approval

## TABLE OF CONTENTS

<b>1</b>	<b>Purpose of Close out Report .....</b>	<b>3</b>
<b>2</b>	<b>Scope of Monitoring Assessment for Close Out .....</b>	<b>4</b>
<b>3</b>	<b>Description and Location Plan.....</b>	<b>5</b>
3.1	<b>Post office tunnel Location .....</b>	<b>5</b>
3.2	<b>Post office Tunnel Description .....</b>	<b>6</b>
<b>4</b>	<b>Construction Programme Influencing Post office tunnel.....</b>	<b>7</b>
4.1.1	<b>Tunnel Advances Affecting Post office tunnel .....</b>	<b>9</b>
<b>5</b>	<b>Monitoring Assessment of Post office tunnel .....</b>	<b>11</b>
5.1	<b>Time Graphs Monitoring Full History and Construction Durations .....</b>	<b>11</b>
5.2	<b>Post office tunnel Decommissioning Status Tracker .....</b>	<b>14</b>
5.3	<b>Supplementary Evidence for Decommissioning.....</b>	<b>19</b>
5.4	<b>Monitoring sensor Location Plan and Decommissioning Status .....</b>	<b>22</b>
<b>6</b>	<b>Decommissioning Recommendations .....</b>	<b>27</b>

## Figures and Tables

Figure 1 - Liverpool St General Location Plan.....	5
Figure 2 - Post office tunnel and C510 Construction.....	8
Figure 3- The position of post office tunnel in relation to ES3 sectional Plan .....	19
Figure 4 - The Post Office tunnel X, Y and Z movement within the area of ES3 .....	20
Figure 5a - RP Monitoring Sensor Settlement Status and Location Plan .....	23
Figure 5b - RP Monitoring Sensor Settlement Status and Location Plan .....	24
Figure 6a - LP Monitoring Sensor Settlement Status and Location Plan.....	25
Figure 6b - LP Monitoring Sensor Settlement Status and Location Plan.....	26

Graph 1- All Post office tunnel Geodetic Prisms (RP) Automated Monitoring History in Relation to Construction .....	12
---	----

Graph 2 - All Post office tunnel (LP) Manual Monitoring History in Relation to Construction .....	13
---	----

Table 1 - Tunnel Advances Affecting Post office tunnel.....	9
---	---

Table 2 (RP) - Post office tunnel Decommissioning Status Tracker.....	16
---	----

Table 3 (LP) - Post office tunnel Decommissioning Status Tracker .....	18
--	----

## 1 Purpose of Close out Report

KX10.2114 in C122-OVE-Z4-RSP-CR001-00007 Materials and Workmanship Specification I&M 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 Post Office Tunnel 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.

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 Description and Location Plan

#### 3.1 Post office tunnel Location

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

Post Office running tunnels are located within the vicinity of London Liverpool Street and Moorgate underground station and the tunnels are highlighted in red. The location and details of these assets can be found in Instrumentation and Monitoring Plan: C122-OVE-C2-RAN-C101-00024 or the relevant C122 prepared Damage Assessment Reports.

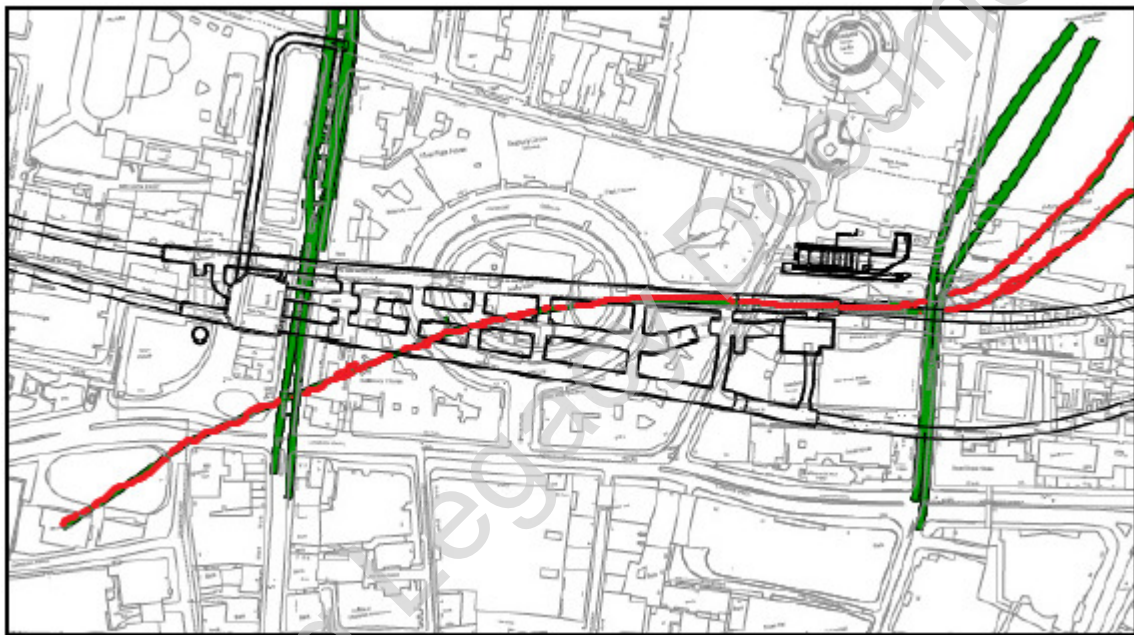


Figure 1 - Liverpool St General Location Plan

### 3.2 Post office Tunnel Description

The Post Office tunnel is located CRL Liverpool Street underground station and is adjacent C510 tunnel construction work. Approximately 400m of Office tunnel overlaps C510 tunnel construction work as the tunnels generally head in an east-west direction. Further detail of the construction programmes can be found in Section 4. Post Office tunnel contains the following types of monitoring sensors:

- Prisms (RP) - automated monitoring
- Road Studs (LP) – manual monitoring

Monitoring asset details are listed within the Decommissioning Status Tracker (Table 2) and further relevant information can be sourced from the installation reports.

Post Office tunnel Installation Report References:

- Assessment of ground movement effects on post office tunnel at Liverpool street station  
CRL Document Number: C122-OVE-C2-RAN-C101-00016
- Instrumentation and Monitoring Plan Post Office Tunnel at Liverpool Street  
CRL Document Number: C122-OVE-C2-RAN-C101-50024
- Procedure for Numbering of Instrumentation and Transfer of Monitoring Data  
CRL Document Number: CRL1-XRL-Z-GPD-CR001-00002
- Monitoring Installation of ATS system in the Post Office Tunnels, Liverpool Street  
CRL Document Number: C510-BBM-C-GMS-C101-50004.
- Monitoring Installation Report - Post Office Tunnels (POT), Liverpool Street  
CRL Document Number: C510-BBM-C2-RGN-C101-50070.

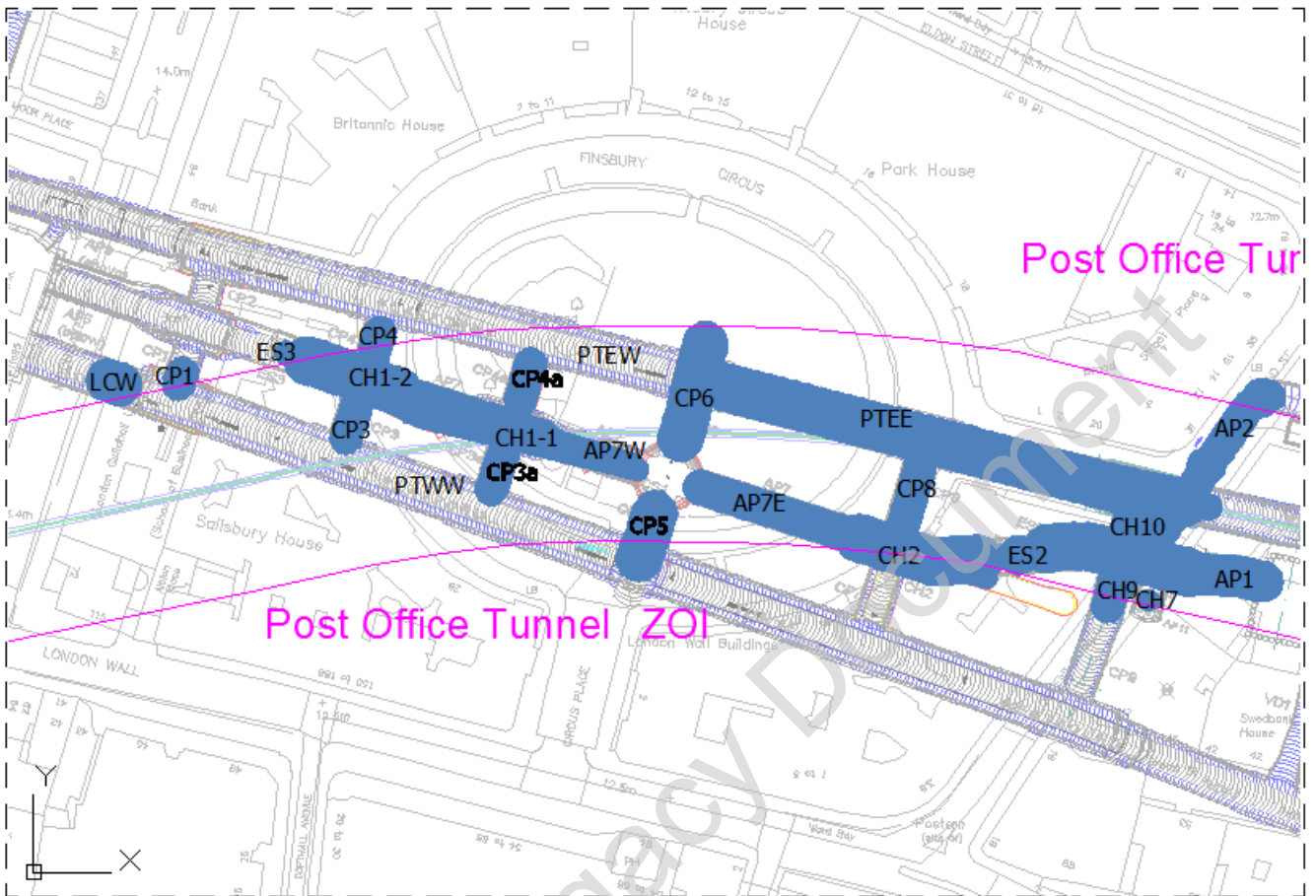
The Settlement Contour Drawing (C122-OVE-C2-DDA-CR001\_Z-21313) predicts the post office tunnel area to experience approximately 0 - 130mm of settlement.

#### 4 Construction Programme Influencing Post office tunnel

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 Post office tunnel, 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 the ZOI area (purple outline) and the tunnels. Start and finish dates of tunnel constructions will be used in the assessment of the monitoring data.



(From General Document Template ref: BBMV-Form-S9-04 rev 5.0)

**Figure 2 - Post office tunnel and C510 Construction**

Post Office tunnel Active ZOI Construction shows C510 construction works that are within 2 x tunnel diameter of Post Office tunnel (active ZOI) and these construction works are shown in Figure 2. Therefore, to assist the monitoring analysis of the Post office tunnel, the ZOI construction work will be referenced against sensor settlement. The construction advances ZOI that have the potential to affect Post Office tunnel are listed and summarised in Table 1.

The last completed SCL advance, which had the potential to affect the Post Office tunnel through its ZOI, is ES3 Enlargement top heading uphill advance 1 and invert downhill advance 38, which was completed on 20/02/2017. Even though the post office tunnel is in the EOI of ES3, the construction work of ES3 had no discernible effect on the post office tunnel within the influence zone; further evidence for this can be found in section 5.2 supplementary evidence.

The entire Post Office tunnel can be assessed for decommissioning. Further evidence for construction dates can be seen in the decommissioning tracker Table 2 , which lists the last tunnel advances within a 25m radius for each point.



#### 4.1.1 Tunnel Advances Affecting Post office tunnel

The information presented in Table 1 is used in the monitoring graph (Section 5.1) to show ground movement in relation to construction.

TUNNEL ADVANCE START & END FOR GRAPHS							
Tunnel Code	Tunnel Reference	Primary Layer Type	Start Date	End Date	Start Advance	End Advance	Zone
ES3-Enlargement	ES3	Enlargement	15/02/2017	20/02/2017	1	38	ZOI
ES2-Enlargement	ES2	Enlargement	28/10/2016	20/11/2016	7	45	ZOI
CH3-Enlargement	CH3	Enlargement	21/08/2016	28/08/2016	1	11	ZOI
AP11-Enlargement	AP11	Enlargement	06/08/2016	11/08/2016	7	18	ZOI
AP12-Enlargement	AP12	Enlargement	04/08/2016	04/08/2016	2	2	ZOI
AP2-Enlargement	AP2	Enlargement	21/06/2016	28/06/2016	1	37/2	ZOI
ES3-Pilot	ES3	Pilot	24/06/2016	09/08/2016	1	9	ZOI
AP2-Pilot	AP2	Pilot	25/04/2016	25/05/2016	1	57	ZOI
ES2-Pilot	ES2	Pilot	31/10/2015	24/04/2016	6	45	ZOI
PRM Lift-Enlargement	PRM Lift	Enlargement	09/08/2015	09/10/2015	1	100	ZOI
AP10b-Enlargement	AP10b	Enlargement	21/07/2015	31/07/2015	1	19	ZOI
AP10a-Enlargement	AP10a	Enlargement	14/07/2015	20/07/2015	1	10	ZOI
TBM-East-RC-Pilot	TBM-East-RC	Pilot	23/01/2015	31/01/2015	3830	3909	ZOI
CP4-Enlargement	CP4	Enlargement	27/09/2014	03/10/2014	3	9	ZOI
CP10-Enlargement	CP10	Enlargement	15/08/2014	17/08/2014	3	7	ZOI
CP9-Enlargement	CP9	Enlargement	08/08/2014	11/08/2014	3	10	ZOI
CP9-Pilot	CP9	Pilot	17/07/2014	18/07/2014	3	8	ZOI
CP10-Pilot	CP10	Pilot	15/07/2014	16/07/2014	3	6	ZOI
AP6-1-Enlargement	AP6-1	Enlargement	12/07/2014	18/05/2015	129	172	ZOI
CP1-Enlargement	CP1	Enlargement	26/06/2014	28/06/2014	8	13	ZOI
VD1-Enlargement	VD1	Enlargement	08/06/2014	08/06/2014	41	41	ZOI
CP1-Pilot	CP1	Pilot	07/06/2014	07/06/2014	9	9	ZOI
CP3a-Enlargement	CP3a	Enlargement	24/05/2014	31/05/2014	3	end face	ZOI
VD2-Enlargement	VD2	Enlargement	17/05/2014	17/05/2014	2	3	ZOI
CP4-Pilot	CP4	Pilot	07/05/2014	09/05/2014	2	7	ZOI
CP3-Enlargement	CP3	Enlargement	01/05/2014	06/05/2014	3	15	ZOI
CP3-Pilot	CP3	Pilot	29/04/2014	01/05/2014	3	10	ZOI
CP8-Enlargement	CP8	Enlargement	14/04/2014	26/04/2014	3	END FACE	ZOI
CP4a-Enlargement	CP4a	Enlargement	13/04/2014	16/09/2014	3	13	ZOI
CP8-Pilot	CP8	Pilot	07/04/2014	12/04/2014	2	END FACE	ZOI
LCWb-Enlargement	LCWb	Enlargement	25/02/2014	26/02/2014	1	5	ZOI
RCE-Enlargement	RCE	Enlargement	31/01/2014	05/03/2014	1	86	ZOI
CP4a-Pilot	CP4a	Pilot	14/01/2014	19/01/2014	2	12	ZOI
CP3a-Pilot	CP3a	Pilot	10/01/2014	14/01/2014	2	end face	ZOI
PTE-East-Enlargement	PTE-East	Enlargement	22/10/2013	30/01/2014	4	168	ZOI
PTE-West-Enlargement	PTE-West	Enlargement	07/10/2013	01/12/2013	4	83	ZOI
RCE-Pilot	RCE	Pilot	09/09/2013	26/09/2013	1	51	ZOI
PTW-West-Enlargement	PTW-West	Enlargement	18/08/2013	24/02/2014	4	182	ZOI
AP1a-Enlargement	AP1a	Enlargement	04/08/2013	14/08/2013	53	80	ZOI
AP1b-Enlargement	AP1b	Enlargement	13/07/2013	04/08/2013	1	52	ZOI
PTE-East-Pilot	PTE-East	Pilot	23/06/2013	09/09/2013	1	121	ZOI
PTE-West-Pilot	PTE-West	Pilot	05/06/2013	16/06/2013	2	52	ZOI
PTW-West-Pilot	PTW-West	Pilot	04/06/2013	19/10/2013	9	125	ZOI
AP1a-Pilot	AP1a	Pilot	19/05/2013	07/06/2013	125	142	ZOI
CH1-Enlargement	CH1	Enlargement	16/05/2013	26/05/2013	49	83	ZOI
ES3/CH5-Pilot	ES3/CH5	Pilot	23/04/2013	24/04/2013	84	89	ZOI
CH2-Enlargement	CH2	Enlargement	11/04/2013	01/05/2013	3	49	ZOI
AP1b-Pilot	AP1b	Pilot	27/03/2013	18/05/2013	89	124	ZOI
ES2-Initial-Pilot	ES2-Initial	Pilot	19/03/2013	26/03/2013	74	88	ZOI
CH1-Pilot	CH1	Pilot	09/03/2013	22/04/2013	61	83	ZOI
AP7 East-Enlargement	AP7 East	Enlargement	02/03/2013	10/04/2013	1	41	ZOI
AP7 West-Enlargement	AP7 West	Enlargement	16/02/2013	26/05/2013	1	83	ZOI
CH2-Pilot	CH2	Pilot	14/02/2013	18/03/2013	43	73	ZOI
CP6-Enlargement	CP6	Enlargement	19/01/2013	31/01/2013	1	37	ZOI
CP5-Enlargement	CP5	Enlargement	08/12/2012	08/01/2013	1	20	ZOI
CP6-Pilot	CP6	Pilot	16/11/2012	08/12/2012	1	28	ZOI
CP5-Pilot	CP5	Pilot	10/11/2012	12/11/2012	1	14	ZOI
AP7 West-Pilot	AP7 West	Pilot	03/11/2012	09/03/2013	2	60	ZOI
AP7 East-Pilot	AP7 East	Pilot	21/10/2012	14/02/2013	2	42	ZOI
GAD2-Pilot	GAD2	Pilot	10/02/2012	04/03/2012	1	73	ZOI
GAD1-Pilot	GAD1	Pilot	19/01/2012	07/02/2012	1	75	ZOI

Table 1 - Tunnel Advances Affecting Post office tunnel

**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

Learning Legacy Document

(From General Document Template ref: BBMV-Form-S9-04 rev 5.0)

## 5 Monitoring Assessment of Post office tunnel

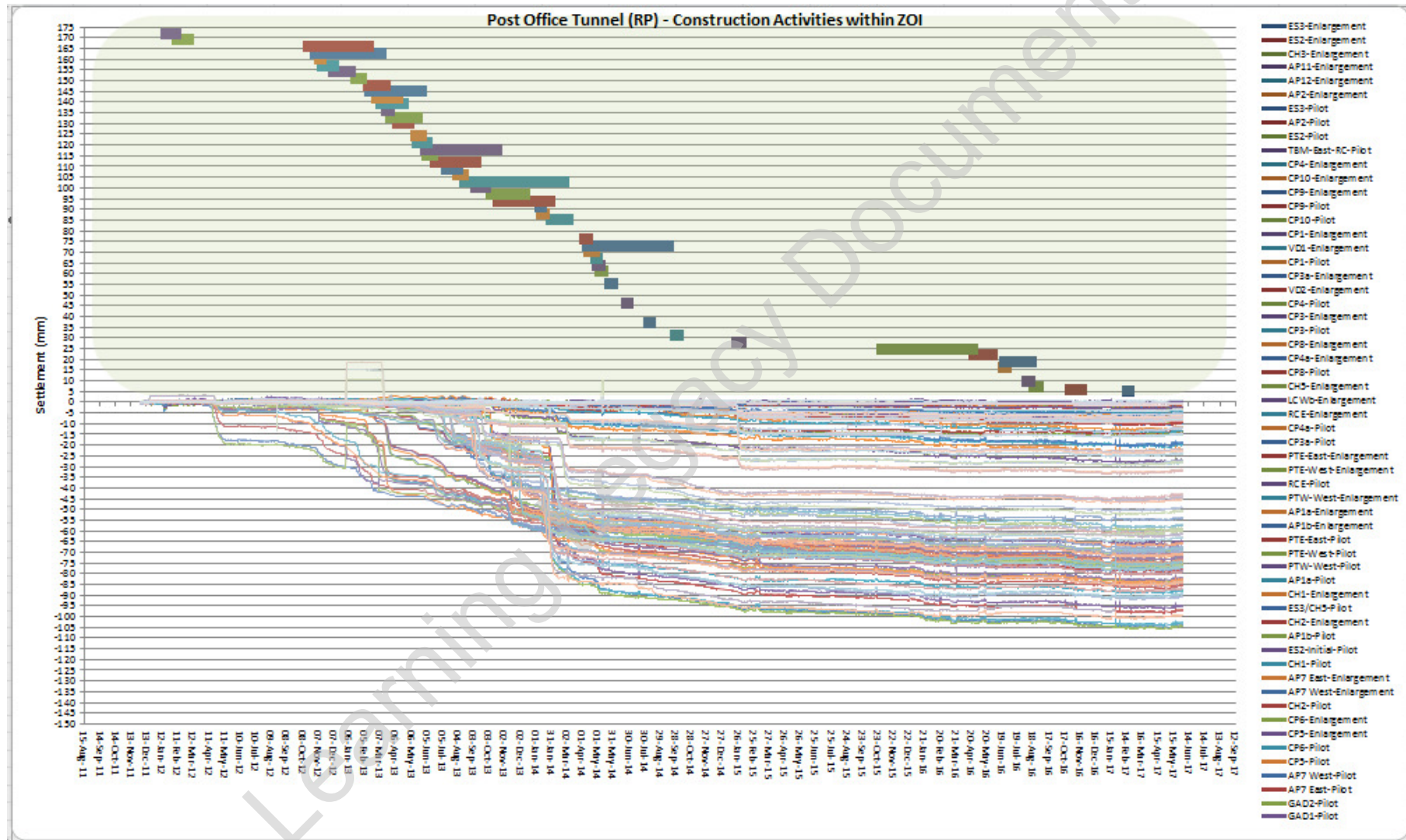
Evidence for decommissioning each monitoring sensor is shown through graphs, tables (Table 2 & 3) and plans. Each element of assessment compliments the other and is used together to determine acceptance of decommissioning. Table 2 representing (RP) and Table 3 representing (LP) - Post office tunnel Decommissioning Status 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

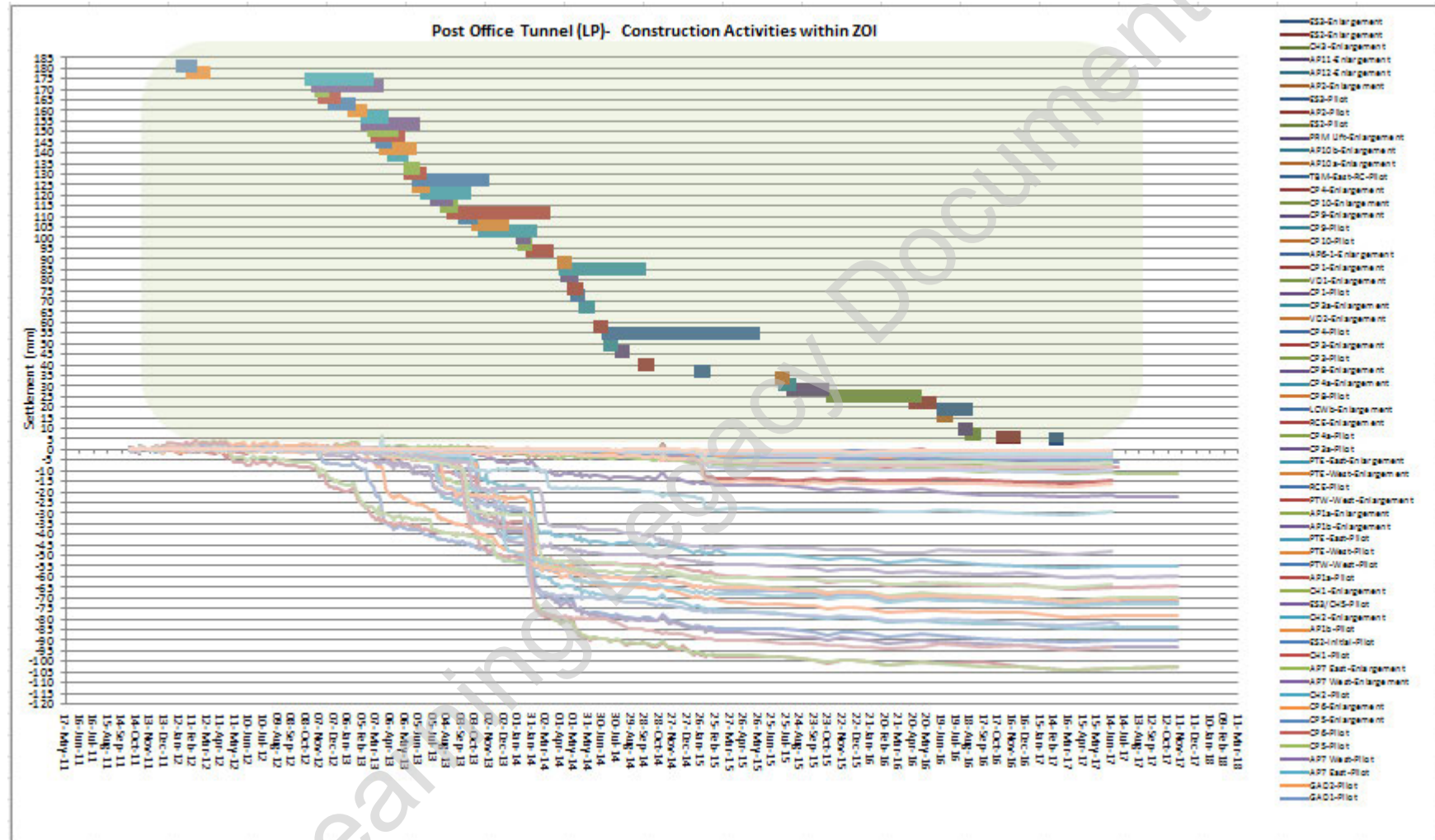
To assess the movement of Post office tunnel monitoring sensors; each monitoring sensor data type is displayed in a line graph, with a Gantt chart (bar) representing the construction identified in Section 4:

- Graph 1- All Post office tunnel Geodetic Prisms (RP) Automated Monitoring History in Relation to Construction
- Graph 2 - All Post office tunnel (LP) Manual Monitoring History in Relation to Construction

Graph 1- All Post office tunnel Geodetic Prisms (RP) Automated Monitoring History in Relation to Construction



Graph 2 - All Post office tunnel (LP) Manual Monitoring History in Relation to Construction



## 5.2 Post office tunnel 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 a 50m radius.

If any Post office tunnel sensors are not within a distance of 2 x depth of any tunnel advance location, the last completed construction within a 50m radius that had the potential to affect Post office tunnel is used as a reference.

### Tracker Column Header – 120, 180, 270 & 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 270 day average rate is the minimum monitoring period after construction for automated sensors.
- The 365 day average trend is the desired period to be used if the long term monitoring has been completed for decommissioning evidence. The specification states that if the trend is below 2mm/yr, then the sensor is eligible for decommissioning.

### 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 Post office tunnel. 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 3 - Post Office Tunnel Decommissioning Status Tracker LP

10/11/2017

< 2.0 mm GREEN < 3.5 mm AMBER > 3.5 mm RED  
AVERAGE SETTLEMENT TREND

10/11/2017  
MATCH No:

C510 Sensor Name	Block	Section	Int / Ext	Measurement Type	Sensor Type	Sensor Description	Asset/Location	ZOI Last Primary Layer Construction	Last Construction Date	Latest Surveyed Date	180 Day	180 Days	180 Day Calculation Period	270 Day	270Days	270 Day Calculation Period	365 Days	365 Day Calculation Period	General Comment	Decommissioning Status
C510-LP84709	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10a_Enlargement_Adv-1	26/01/2015	15/06/2017	1.13	1.13	188	0.05	0.05	273	-0.75	366	2mm/year Specification met	Proposed
C510-LP84909	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10a_Enlargement_Adv-10	26/01/2015	15/06/2017	0.72	0.72	188	-0.17	-0.17	273	-0.73	366	2mm/year Specification met	Proposed
C510-LP85109	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10a_Enlargement_Adv-2	26/01/2015	15/06/2017	-0.51	-0.51	188	-0.31	-0.31	273	-0.76	366	2mm/year Specification met	Proposed
C510-LP85309	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10a_Enlargement_Adv-3	26/01/2015	15/06/2017	0.30	0.30	188	-0.04	-0.04	273	-0.59	366	2mm/year Specification met	Proposed
C510-LP85509	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10a_Enlargement_Adv-5	27/01/2015	15/06/2017	0.61	0.61	188	0.22	0.22	273	-0.38	366	2mm/year Specification met	Proposed
C510-LP85709	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10a_Enlargement_Adv-6	31/01/2015	15/06/2017	0.46	0.46	188	0.13	0.13	273	0.51	366	2mm/year Specification met	Proposed
C510-LP90109	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10a_Enlargement_Adv-7	31/01/2015	15/06/2017	2.06	2.06	188	1.80	1.80	273	0.98	366	2mm/year Specification met	Proposed
C510-LP90309	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10a_Enlargement_Adv-8	31/01/2015	15/06/2017	-1.88	-1.88	188	0.68	0.68	273	0.21	366	2mm/year Specification met	Proposed
C510-LP90509	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10a_Enlargement_Adv-9	31/01/2015	15/06/2017	1.68	1.68	188	1.56	1.56	273	0.50	366	2mm/year Specification met	Proposed
C510-LP90709	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10a_Enlargement_Adv-1	31/01/2015	15/06/2017	-1.94	-1.94	188	0.68	0.68	273	0.31	366	2mm/year Specification met	Proposed
C510-LP90909	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10b_Enlargement_Adv-10	31/01/2015	15/06/2017	1.57	1.57	188	1.29	1.29	273	0.10	366	2mm/year Specification met	Proposed
C510-LP91109	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10b_Enlargement_Adv-11	31/01/2015	27/06/2017	-2.04	-2.04	200	-0.37	-0.37	285	-0.60	378	2mm/year Specification met	Proposed
C510-LP91309	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10b_Enlargement_Adv-12	09/10/2015	27/06/2017	0.52	0.52	200	-0.12	-0.12	285	-0.99	378	2mm/year Specification met	Proposed
C510-LP91509	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10b_Enlargement_Adv-13	09/10/2015	31/10/2017	0.41	0.41	228	-1.55	-1.55	326	-0.83	411	2mm/year Specification met	Proposed
C510-LP91709	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10b_Enlargement_Adv-14	09/10/2015	31/10/2017	0.55	0.55	228	-0.40	-0.40	326	-0.71	411	2mm/year Specification met	Proposed
C510-LP91859	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10b_Enlargement_Adv-15	26/02/2014	31/10/2017	1.35	1.35	228	0.09	0.09	326	-0.71	411	2mm/year Specification met	Proposed
C510-LP91909	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10b_Enlargement_Adv-16	28/06/2014	31/10/2017	0.25	0.25	228	-1.86	-1.86	326	-1.47	411	2mm/year Specification met	Proposed
C510-LP91959	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10b_Enlargement_Adv-17	18/03/2017	31/10/2017	1.79	1.79	228	0.46	0.46	326	-0.48	411	2mm/year Specification met	Proposed
C510-LP92009	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10b_Enlargement_Adv-18	18/03/2017	31/10/2017	2.13	2.13	228	0.50	0.50	326	-1.75	411	2mm/year Specification met	Proposed
C510-LP92059	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10b_Enlargement_Adv-19	18/03/2017	31/10/2017	1.83	1.83	228	0.35	0.35	326	-0.47	411	2mm/year Specification met	Proposed
C510-LP92109	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10b_Enlargement_Adv-2	18/03/2017	31/10/2017	1.32	1.32	228	-0.17	-0.17	326	-0.85	411	2mm/year Specification met	Proposed
C510-LP92159	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10b_Enlargement_Adv-3	15/03/2017	31/10/2017	1.70	1.70	228	-0.61	-0.61	326	-1.08	411	2mm/year Specification met	Proposed
C510-LP92309	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10b_Enlargement_Adv-5	03/10/2014	31/10/2017	0.69	0.69	228	-1.52	-1.52	326	-1.52	411	2mm/year Specification met	Proposed
C510-LP92509	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10b_Enlargement_Adv-6	03/10/2014	31/10/2017	1.04	1.04	228	-0.19	-0.19	326	-0.94	411	2mm/year Specification met	Proposed
C510-LP92709	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10b_Enlargement_Adv-7	16/09/2014	31/10/2017	1.83	1.83	228	-0.70	-0.70	326	-0.80	411	2mm/year Specification met	Proposed
C510-LP92909	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10b_Enlargement_Adv-8	16/09/2014	31/10/2017	1.98	1.98	228	0.26	0.26	326	-0.47	411	2mm/year Specification met	Proposed
C510-LP93109	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP10b_Enlargement_Adv-9	22/11/2013	31/10/2017	1.30	1.30	228	-1.19	-1.19	326	-1.27	411	2mm/year Specification met	Proposed
C510-LP93309	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP11_Enlargement_Adv-18	17/11/2013	31/10/2017	1.25	1.25	228	-0.08	-0.08	326	-0.87	411	2mm/year Specification met	Proposed
C510-LP93509	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP11_Enlargement_Adv-7	26/04/2014	27/06/2017	-1.75	-1.75	200	-2.00	-2.00	285	-2.44	378	2mm Specification met over 9 months	Proposed
C510-LP93709	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP12_Enlargement_Adv-2	24/11/2016	27/06/2017	0.57	0.57	200	-1.02	-1.02	285	-1.96	378	2mm/year Specification met	Proposed
C510-LP93909	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP1a_Enlargement_Adv-53	24/11/2016	15/06/2017	-0.48	-0.48	188	-0.52	-0.52	273	-1.29	366	2mm/year Specification met	Proposed
C510-LP94109	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP1a_Enlargement_Adv-55	07/11/2016	15/06/2017	1.26	1.26	188	-0.30	-0.30	273	-1.37	366	2mm/year Specification met	Proposed
C510-LP94309	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP1a_Enlargement_Adv-56	07/11/2016	15/06/2017	-0.12	-0.12	188	-0.41	-0.41	273	-0.95	366	2mm/year Specification met	Proposed
C510-LP94509	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP1a_Enlargement_Adv-58	06/08/2016	15/06/2017	1.30	1.30	188	-0.04	-0.04	273	-0.80	366	2mm/year Specification met	Proposed
C510-LP94709	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP1a_Enlargement_Adv-59	31/01/2015	15/06/2017	1.24	1.24	188	0.27	0.27	273	-0.47	366	2mm/year Specification met	Proposed
C510-LP94909	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP1a_Enlargement_Adv-61	31/01/2015	15/06/2017	1.12	1.12	188	0.08	0.08	273	-0.48	366	2mm/year Specification met	Proposed
C510-LP95109	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP1a_Enlargement_Adv-62	31/01/2015	15/06/2017	1.02	1.02	188	0.21	0.21	273	-0.25	366	2mm/year Specification met	Proposed
C510-LP95309	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP1a_Enlargement_Adv-64	27/01/2015	15/06/2017	0.59	0.59	188	0.02	0.02	273	-0.27	366	2mm/year Specification met	Proposed
C510-LP95509	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP1a_Enlargement_Adv-65	26/01/2015	15/06/2017	0.57	0.57	188	-0.08	-0.08	273	-0.28	366	2mm/year Specification met	Proposed
C510-LP95709	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP1a_Enlargement_Adv-67	26/01/2015	15/06/2017	0.00	0.00	188	-0.12	-0.12	273	0.04	366	2mm/year Specification met	Proposed
C510-LP95909	POT	SPOT01	Internal	Manual	LP	Road Stud	Post Office Tunnel	LIV_AP1a_Enlargement_Adv-68	25/01/2015	15/06/2017	0.41	0.41	188	0.18	0.18	273	0.00	366	2mm/year Specification met	Proposed

### 5.3 Supplementary Evidence for Decommissioning

In some cases supplementary evidence will be provided to support the decommissioning evidence.

#### Geodetic Prisms (RP) Automated Monitoring

In General - There are no long term monitoring requirements for the automated monitoring, as detailed in I&M Schedule. Therefore, provided there are no particular discrepancies between the automated and manual monitoring, agreement to decommission the manual monitoring will generally apply to the automated monitoring.

Figure 3- shows the position of post office tunnel in relation to ES3, section 1 illustrates where post office tunnel is within the EOI of ES3 at the bottom of the tunnel while section 2 illustrates where post office tunnel is outside EOI at the top of tunnel of ES3.

Despite the fact that section 1 Post Office tunnels are within the EOI of ES3, there are no discernible effects of movement from ES3 to the post office tunnel. Because, The X, Y & Z Movement shows stability around ES3 before the starting of construction in mid-February 2017, during and after finishing of the construction in 20 of February 2017. These trends can be seen in Figure 4.

Note that, in Figure 4 on X, Y & Z Movement between 29/04/2017 and 10/05/2017 the system was down, there were no data recorded. The step in the data was not due to physical movement of the tunnel, it was an offset applied after the system was re-running.

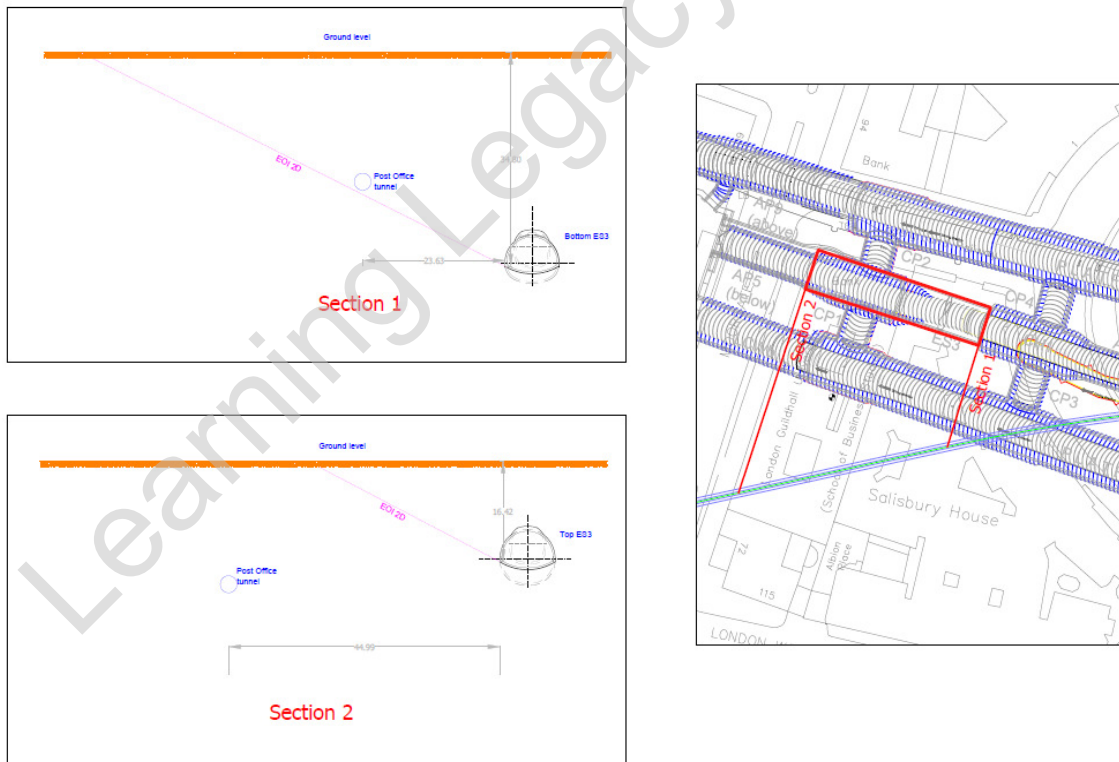
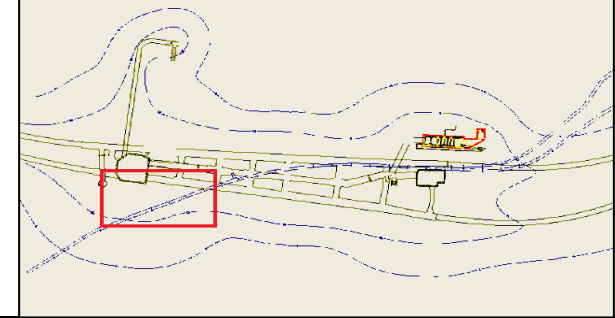


Figure 3- The position of post office tunnel in relation to ES3 sectional Plan

Figure 4 - The Post Office tunnel X, Y and Z movement within the zone of ES3 shown below



Crossrail C510 - Soldata Structural Monitoring  
Lis - POT T09S110-S190\_2  
X,Y and Z movements

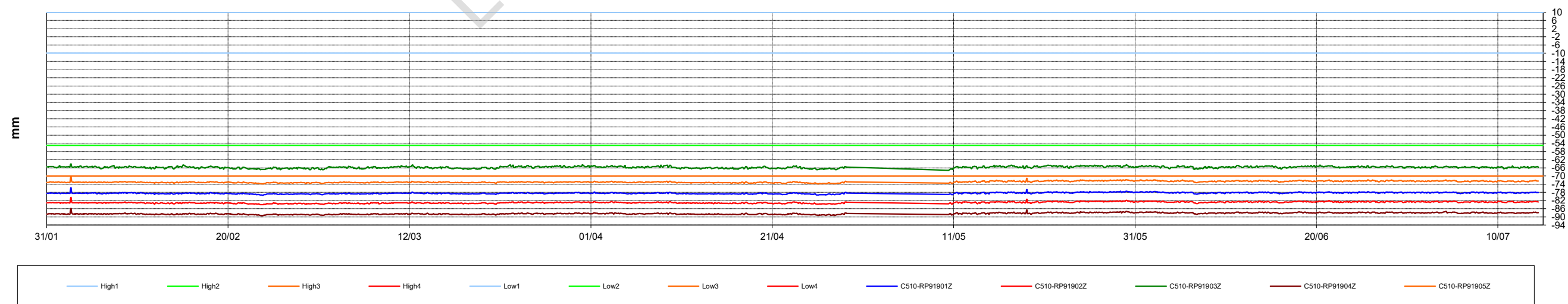
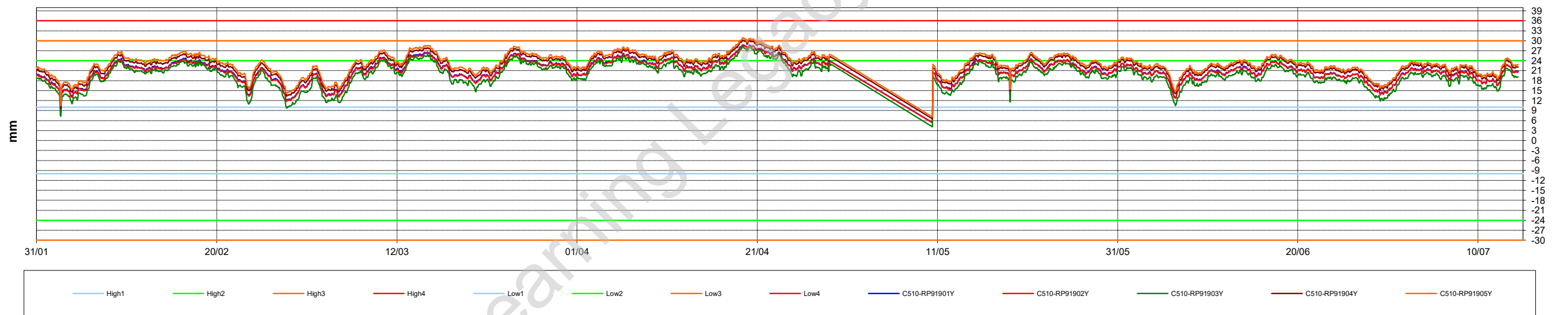
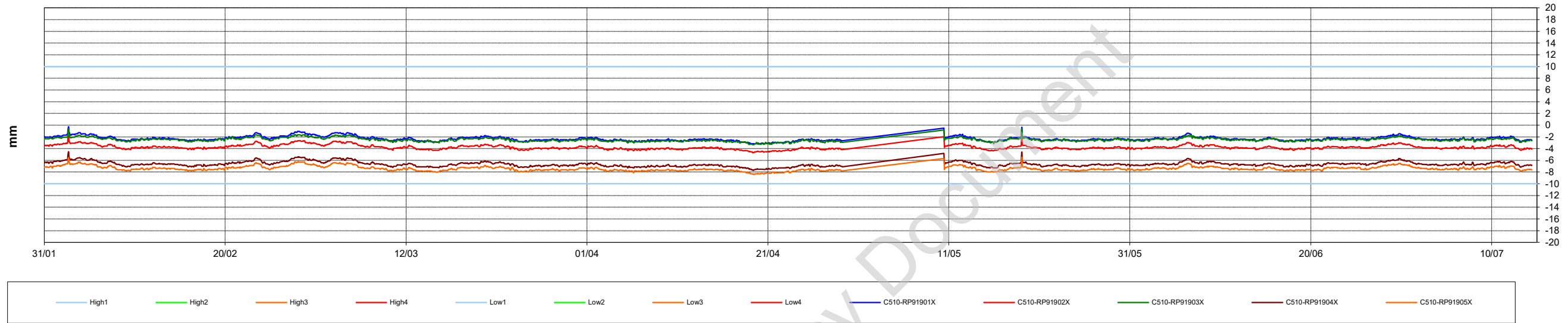


Zone: 1PO

Instrument type: ATS

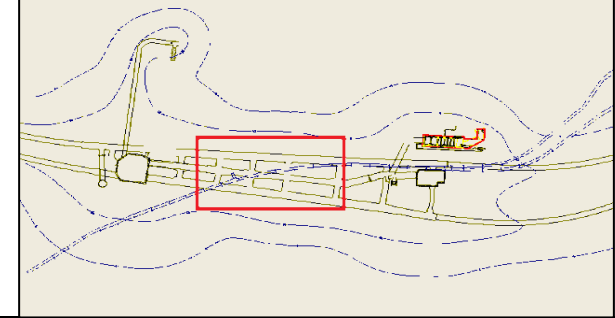
Printed: 14/07/2017

14/07/2017





Crossrail C510 - Soldata Structural Monitoring  
Liverpool Street - POT T09S210-S290\_1  
X,Y and Z movements

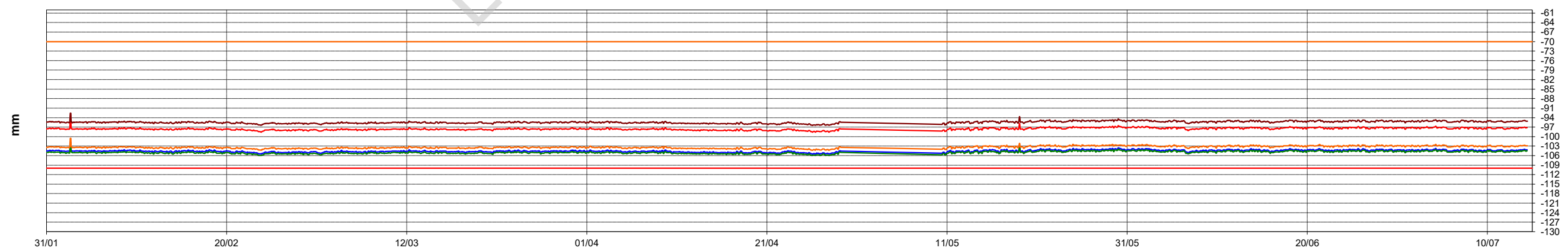
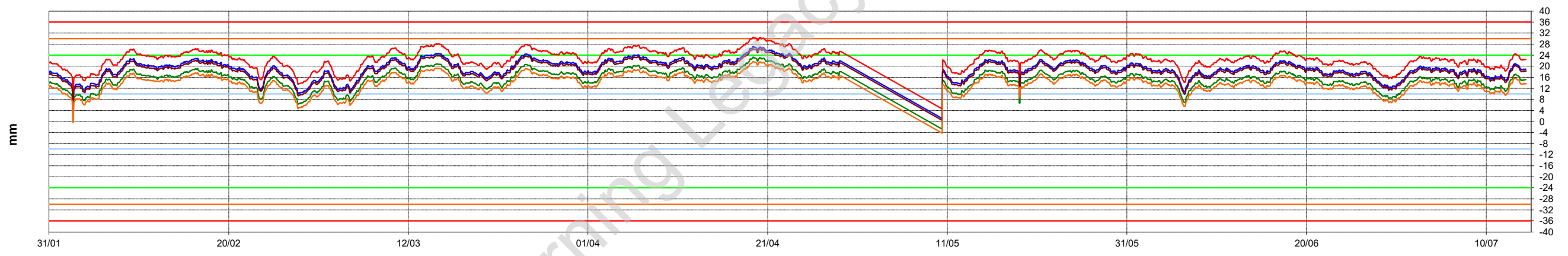
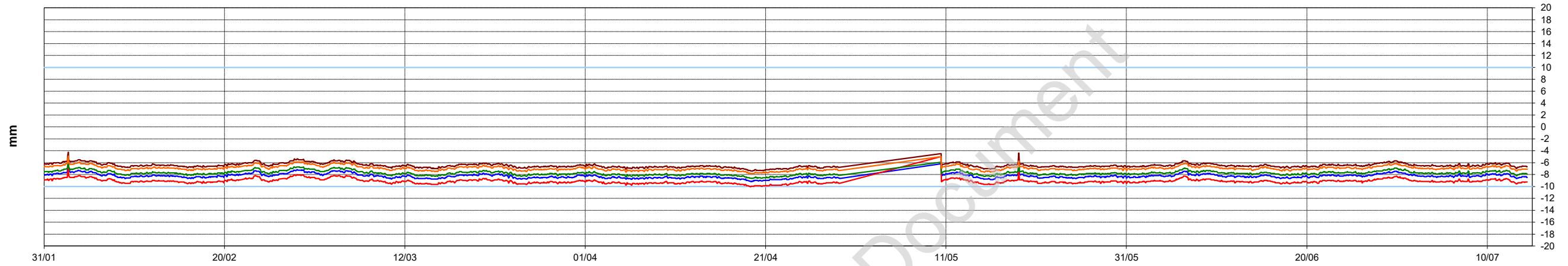


Zone: 1PO

Instrument type: ATS

Printed: 14/07/2017

14/07/2017



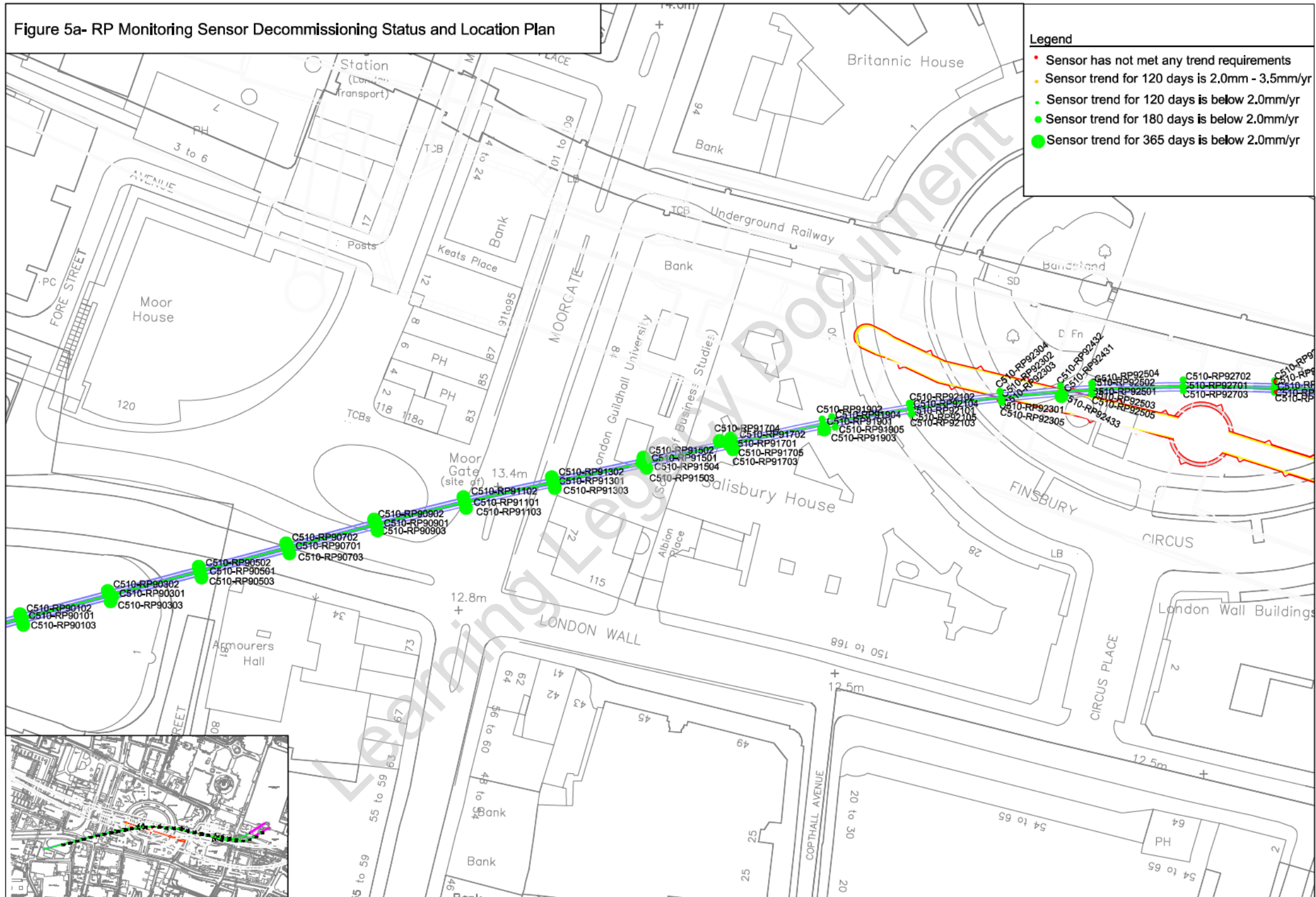
#### 5.4 Monitoring sensor Location Plan and Decommissioning Status

The following plots provide a visual representation of all Post office tunnel 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 are two plots for Post office tunnel monitoring sensors:

- Figure 5a & 5b - RP Monitoring Sensor Settlement Status and Location Plan
- Figure 6a & 6b - LP Monitoring Sensor Settlement Status and Location Plan

Learning Legacy Document

Figure 5a- RP Monitoring Sensor Decommissioning Status and Location Plan



- Legend**
- Sensor has not met any trend requirements
  - Sensor trend for 120 days is 2.0mm - 3.5mm/yr
  - Sensor trend for 120 days is below 2.0mm/yr
  - Sensor trend for 180 days is below 2.0mm/yr
  - Sensor trend for 365 days is below 2.0mm/yr

Figure 5b RP Monitoring Sensor Decommissioning Status and Location Plan

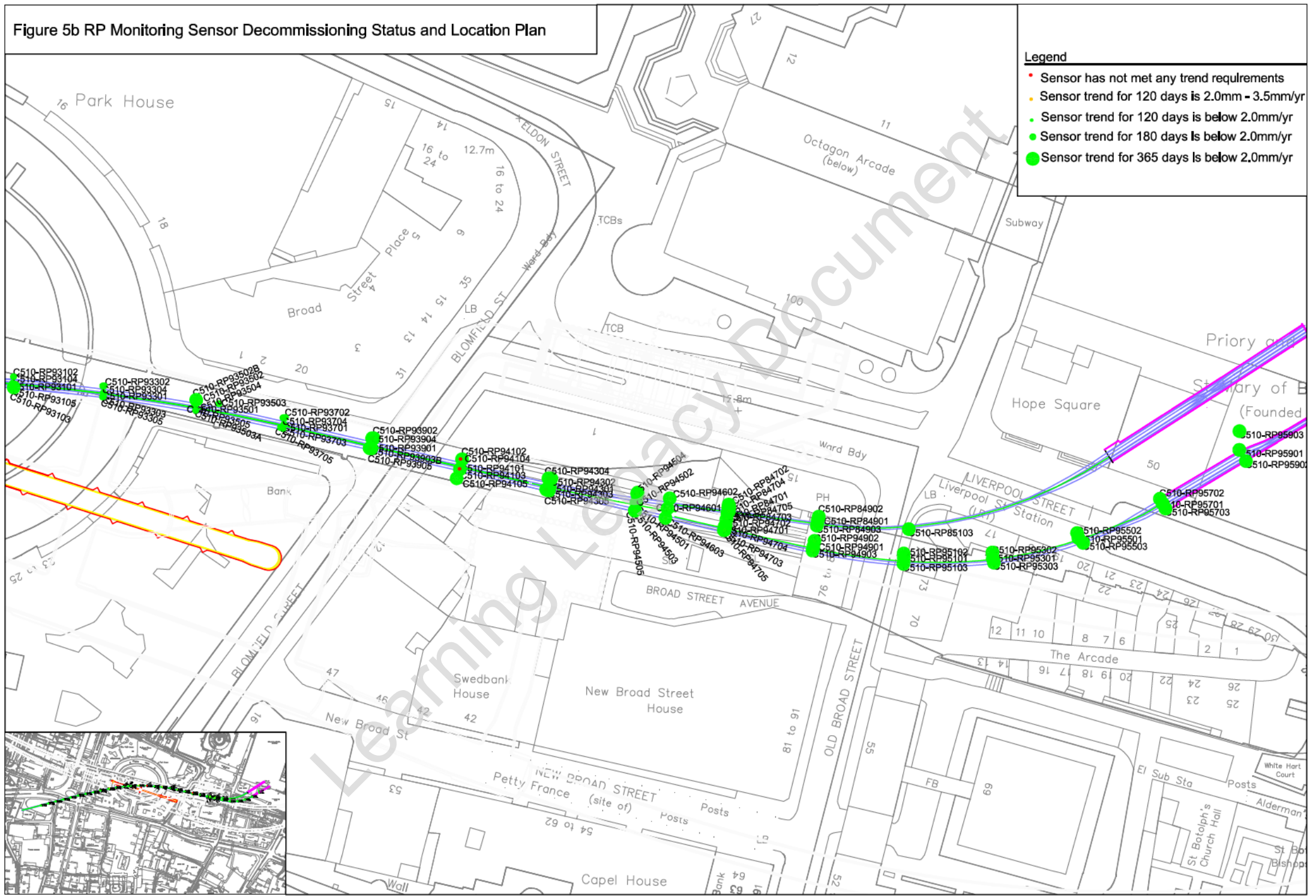




Figure 6a LP Monitoring Sensor Decommissioning Status and Location Plan

- Legend**
- Sensor has not met any trend requirements
  - Sensor trend for 120 days is 2.0mm - 3.5mm/yr
  - Sensor trend for 120 days is below 2.0mm/yr
  - Sensor trend for 180 days is below 2.0mm/yr
  - Sensor trend for 365 days is below 2.0mm/yr

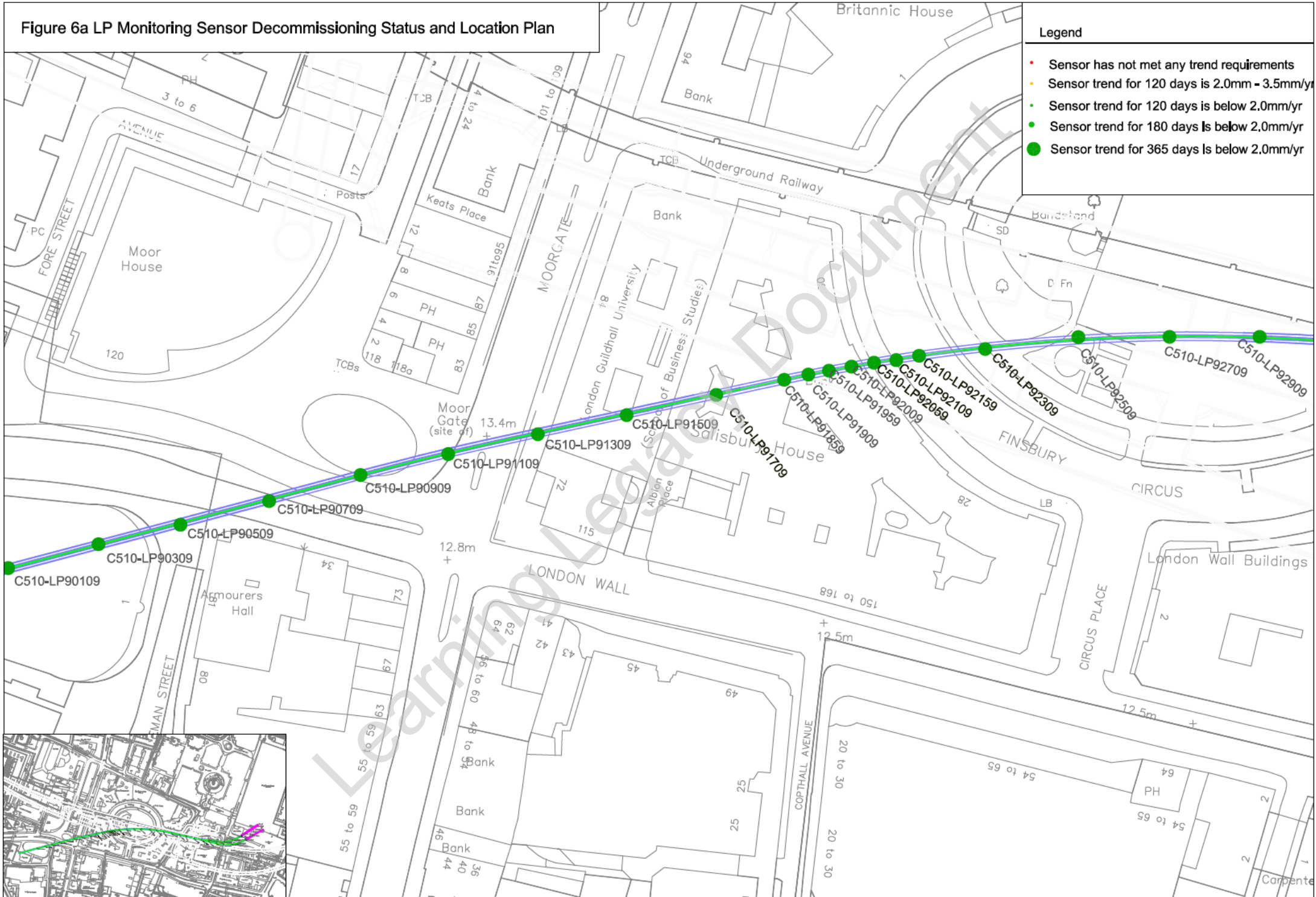
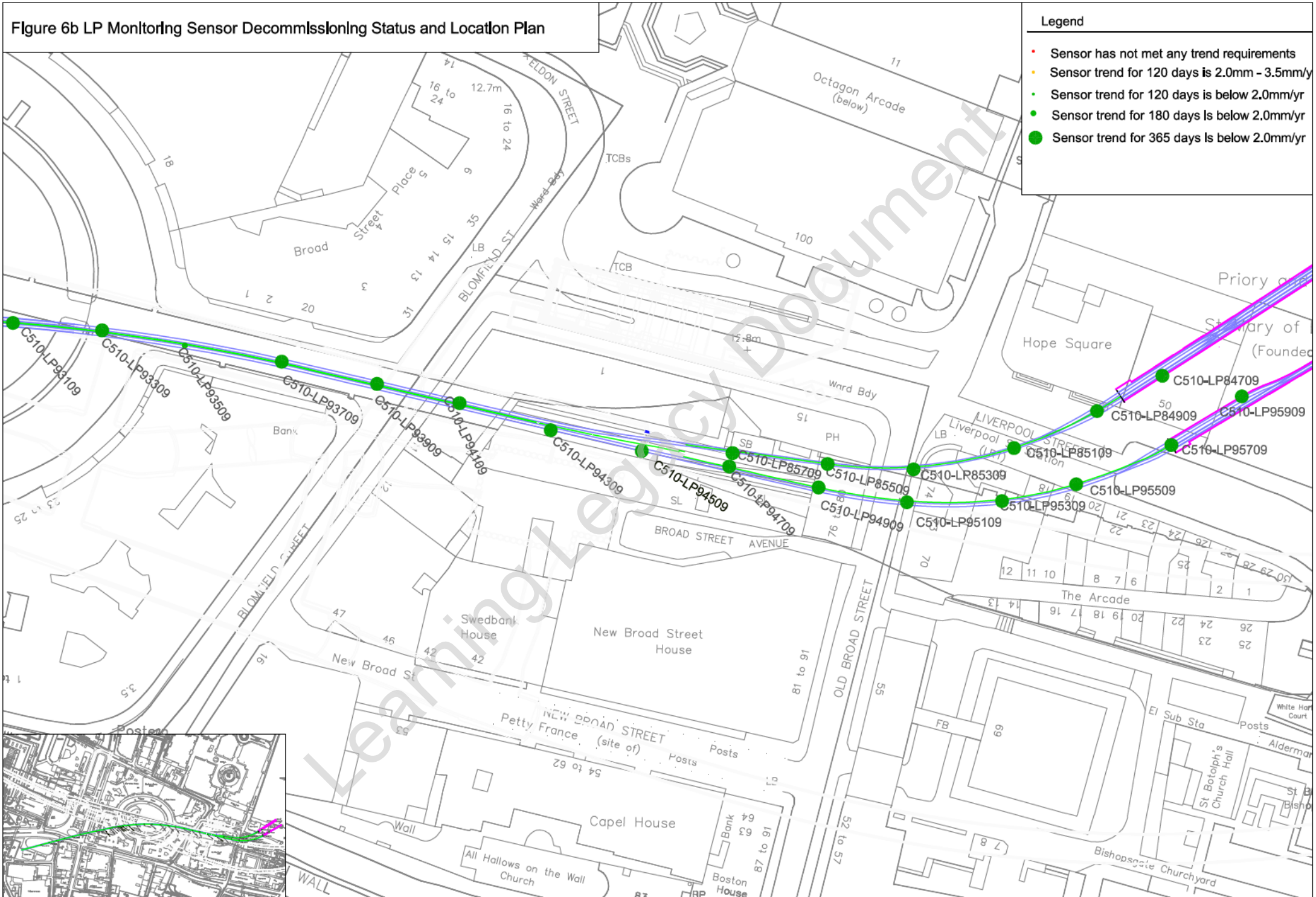


Figure 6b LP Monitoring Sensor Decommissioning Status and Location Plan

- Legend**
- Sensor has not met any trend requirements
  - Sensor trend for 120 days is 2.0mm - 3.5mm/yr
  - Sensor trend for 120 days is below 2.0mm/yr
  - Sensor trend for 180 days is below 2.0mm/yr
  - Sensor trend for 365 days is below 2.0mm/yr



## 6 Decommissioning Recommendations

Through the monitoring assessment process in Section 5, it is purposed that all automated monitoring sensors in post office tunnel sensors are to be decommissioned. Also, all manual monitoring sensors road studs (LP) in post office tunnel have met the monitoring specification of less or equal to 2mm/year.

All manual monitoring sensors met the monitoring specification over the period of a year, except for one sensor over the period of 9 months. Table 2 & 3 Decommissioning Tracker lists all post office tunnel monitoring sensors decommissioning status and the supporting 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.

Learning Legacy Document