Work Area: SMM	
Work Type: I&M	
Originator Company: GEOCISA	

C435
Farringdon Main Station

CRL Lead reviewer: [redacted]	
CRL Reviewer:	

Monitoring Close-Out Report:
Section K

CRL Document Number: C435-BFK-C2-RGN-M123-51659

Supplier Document Number: N/A

Contract MDL reference C14.022

1. Contractor Document Submittal History:

Revision:	Date:	Prepared by:	Checked by:	Approved by:	Reason for Issue:
1.0	26-04-2016	[redacted]			For acceptance
2.0	25-05-2016				For acceptance
3.0	22-06-2016				For acceptance

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: _____

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

2b. Review by Stakeholder (if required):

Stakeholder Organisation	Job Title	Name	Signature	Date	Acceptance
					☐
[redacted]					☐
	[redacted]				☐

compliance with their contractual obligations and does not constitute
ds or materials developed or selected by the designer/supplier.

14/10/2016

[redacted]

3. Acceptance by *Crossrail:*

Contents

A. INTRODUCTION

In line with the C122 – M&W Specification KX10 – Instrumentation & Monitoring C122-OVE-Z4-RSP-CR001-00007, this Close-Out Report aims to address the following points in relation to the instrumentation defined in Section 2.

- Identify movements observed by the relevant instruments;
- Relate these movements to construction activities, where applicable;
- Identify trigger breaches that may have occurred;
- Demonstrate that the rate of change of the data is either in line with the required rate or such that residual risks are minimal;
- Identify any such residual risks should there be considered to be any.

Based on the above points, this close out reports will provide justification for the decommissioning of the instruments.

B. INSTRUMENTS

B.1 Description of the Instruments

This Close-Out Report relates the monitoring devices installed in Section K, all of these devices were installed at street level. See Table 1 below with the details for the devices.

Sensor	Location	Easting (m)	Northing (m)	Elevation (mATD)
C435-IE00013	38-42 Charterhouse St	82221.6155	36554.5451	115.8991
C435-SD00004	38-42 Charterhouse St	82231.2998	36571.6431	115.9000

Table 1: Details of the devices installed on Section K.

The monitoring devices in Section K at street level are shown in the following documents:

Drawings:

- C122-OVE-C2-DDA-CR001_Z-31531. Asset Protection I&M Ground surface and In-ground.
- C435-BFK-C2-DWG-M123-50042. In-ground devices installed for Farringdon Station.

Installation Reports:

- C435-BFK-C2-RGN-M123-50043. Installation Report-In ground monitoring- Inclinometer IE00013
- C435-BFK-C2-RGN-M123-50980. Installation Report-In ground monitoring- Shallow Datum SD00004.

B.2 Location of the Instruments

In ground devices associated with Section K are located on the plan below highlighted in yellow.

Figure 1 – Plan showing the Location for the device on Section K

C. MOVEMENTS

C.1 Movements Resulting from Construction Activities

C.1.1 Relevant Crossrail (BFK) Works

The construction activities affecting these instruments are outlined in the Table 2 below:

Activity	Start Date	End Date
EB TBM passage	19-01-2014	21-01-2014
PTE enlargement	23-10-2014	16-12-2014
CP6	14-11-2014	22-11-2014
CH2	30-01-2015	01-04-2015
CP7	23-02-2015	26-02-2015

Table 2 – Construction Activities associated to Section K.

C.1.2 Resulting Movements

- **Inclinometer IE00013.**

The monitoring data for the inclinometer is shown in Appendix B.

- Compensation grouting from Moorgate Shaft 2 caused 8mm lateral displacement in A direction and 6mm in B- direction from 31-07-2013 to 31-08-2013.
- EB TBM caused maximum 10mm lateral displacement in A direction, towards the tunnel and 4mm in B- direction from 01-01-2014 to 01-02-2014.
- PTE enlargement caused 14mm lateral displacement in A direction toward the tunnel and 5-6mm in B+ direction from October 2014 to November 2014.
- CP6 construction caused 16mm lateral displacement in A direction toward PTE tunnel and 8mm in B- direction between 01-11-2014 to 23-11-2014.
- CH2 (combination of pilot and enlargement) construction works caused 14-15mm lateral displacement in A- direction and 14-15mm in B- direction from 08-01-2015 to 09-04-2015.
- CP7 caused 4-5mm lateral displacement in A direction toward the PTE tunnel and 5-6mm in B direction toward CP7 tunnel from 01-02-2015 to 28-02-2015.
- Maximum horizontal movement in A direction, 25mm
- Maximum horizontal displacement in B direction, -25mm

- **Shallow Datum SD00004.**

The monitoring data for the Shallow Datum is shown in Appendix B.

- ETH excavation caused 2mm maximum of settlement from 02-07-2013 to 03-08-2013.
- Eastbound TBM caused 1-2mm maximum of settlement between 19-01-2014 and 21-01-2014.
- Compensation grouting from Moorgate Shaft 2 caused 4mm of heave in July 2014.
- Ground treatment caused 12mm maximum of heave from 01-10-2014 to 08-10-2014.
- PTE enlargement works caused 7mm of settlement from 23-10-2014 to 21-01-2015.
- Compensation grouting caused 5-6mm of heave from 06-01-2015 to 14-01-2015.
- The combination of CH2 and CP7 caused 10-12mm of settlement from 30-01-2015 to 26-02-2015.
- Maximum settlement captured by the Shallow Datum, 4mm
- Maximum heave, 14mm.

C.2 Trigger Breaches

The Instrumentation and Monitoring Plan: Farringdon Station Ground Movement and Asset Protection C122-OVE-C2-RGN-M123-50013 in section 6.1, no triggers are applicable for in-ground monitoring.

C.3 Significant Issues with the Instrumentation

No issues with these devices.

C.4 Residual Risks

No risks remain.

D. CONCLUSIONS

No triggers breached, monitoring stable. No residual risks remain. Long term monitoring to be completed by Crossrail. The rate of settlement and horizontal movement for all instrumentation within this report has been analysed and in all cases the rate is less than 2mm/year.

The last measurement carried out for these devices was:

- C435-IE00013 on 22-08-2015.
- C435-SD00004 on 23-09-2015.

APPENDIX A: DRAWINGS

Studs to be installed at 5m centres unless otherwise indicated

Extent of Influence of East Ticket Hall shaft excavation

Studs at 2.5m centres

New Thameslink Integrated Ticket Hall: see drawings C122-OVE-C4-DDA-CR001_Z-21257 and C122-OVE-C4-DDC-CR001_Z-21258

Farringdon Station: see section E on drawing C122-OVE-C2-DDA-CR001_Z-31537

Open cut LU retaining walls: see section D on drawing C122-OVE-C2-DDA-CR001_Z-31537

Extent of Influence of West Ticket Hall shaft excavations

Citigen Tunnel

Barbican Station: see section E on drawing C122-OVE-C2-DDA-CR001_Z-31537

Lindsey Street Bridge and Hayne Street Bridge: see sections A and B on drawing C122-OVE-C2-DDA-CR001_Z-31536

Instrumentation monitored by C435

Studs at 2.5m centres

EDF Cable Tunnel see Section A on drawing C122-OVE-C2-DDA-CR001_Z-31537

Circle, Hammersmith & City and Metropolitan line tunnel and disused Moorgate Spur: see sections B and C on drawing C122-OVE-C2-DDA-CR001_Z-31537

Snowhill Tunnel: see section J on drawing C122-OVE-C2-DDA-CR001_Z-31537

Farringdon Road retaining wall: see section G on drawing C122-OVE-C2-DDA-CR001_Z-31537

Street level studs installed by C300 and monitored by C435

Fleet Storm Relief Sewer

Fleet Sewer: see section F on drawing C122-OVE-C2-DDA-CR001_Z-31537

Post Office Tunnels Automated Total Stations with 3D Geodetic Prisms and BRE sockets installed and monitored by C300.

Instrumentation monitored by C435

Legend

Parties Installing Instruments
- By C435
- By others

Instrumentation and Monitoring
- Automated Total Station (ATS)
- Extensometer - Rod
- Inclinometer
- Studs - Precise Ground Levelling
- Monitoring Transect in Tunnels and on rail assets
- Piezometer (3 No tips per Installation)
- Sockets - BRE Type - Structures
- 3D Geodetic Prisms
- Strain Gauge
- Shallow Datum - Utilities -SD

General
- Tunnel Alignment
- 3D Geodetic Prisms on track at 2m or 5m centres
- 3D Geodetic Prisms on track at 3m centres

Existing Structures
- Bored Tunnels
- Cut & Cover Tunnels
- Main Sewers (Greater than 1.5m Dia.)
- Major Utilities
- Extent of influence of shaft construction. See note 11.

Notes:

1. Ground surface, in-ground and subsurface asset monitoring is shown on the drawing. These are for Asset Protection. The monitoring specified on this drawing is to be procured as part of C435. Total Instrumentation requirements are given in the schedule drg no. C122-OVE-C2-DDJ-CR001_Z-31531.
2. A network of primary survey control, provided by CRL, shall be used by C435 as vertical and horizontal references for all ground movement monitoring.
3. Real-time/ data logged monitoring is to be undertaken by Contract C701 within the selected rail assets (LUL, NR and Thameslink) as specified on the drawings. C435 is responsible for carrying out manual monitoring of the same assets to confirm and back up the real- time monitoring provided by C701 during SCL construction.
4. Trackside and in-rail tunnel monitoring of 3rd party assets will be undertaken during engineering hours.
5. All Instrumentation to be maintained throughout construction period and immediately replaced / reinstated if damaged/defective or unreadable.
6. These drawings and schedules provide the minimum requirements for Asset Protection I&M. Any additional Instrumentation required to ensure the safe construction of works shall be specified and implemented by the Contractor.
7. All Instrumentation shall be installed and baselined before any work with the potential to induce ground movements is undertaken on the site.
8. The location of Instruments on these drawings are indicative. Final locations should be established on site and agreed with the Project Manager.
9. These drawings shall be read in conjunction with the Materials & Workmanship Specification for Instrumentation and Monitoring.
10. The works shown are based on Alignment T and RIBA F station layout.
11. For construction works for the shafts/boxes asset protection I&M within the 'Extent of Influence' of the respective shafts/boxes is to be installed and baselined prior to these works and monitored during and after the shaft/box works.
12. Contours are "green field" ground movements at street level based on settlements calculated using methods set out in CEDS part 7 & 8 using Set(ii) tunnel volume loss values In Table 7.1 of CEDS part 7.
13. Inclinometers and extensometers instruments at sections K and G also used for design verification of the SCL tunnels. Inclinometers to be in-place type and extensometers to be rod type. Both Instruments types are to be remotely read and provide real-time monitoring. Refer to drawings:
    - C121-MMD-C4-DDA-M123_6-00010
    - C121-MMD-C4-DDD-M123_Z-00031
14. The instrumentation for design verification and control of the construction process of shafts is shown separately on drawings:
    - C136-SWN-C2-DDA-M123_Z-40060
    - C136-SWN-S-DDA-M123_Z-85000
    - C136-SWN-C2-DDA-M123_Z-86201
    - C136-SWN-S-DDL-M123_Z-76960
15. Regular manual monitoring shall be undertaken to verify all automated instrumentation.

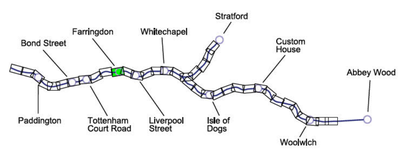
Safety Health and Environmental Information:

1. Notes below are additional to hazards and risks normally associated with this type of work:
   - CI; The presence of existing below ground utilities may act as an obstruction for grout shaft construction and potential for hazardous live service strike during borehole construction to install instrumentation
   - CDM Risk Register: C122-OVE-N3-LRG-M123-00001 GMY-FAR-004.
   - CIi; Working at height installing monitoring equipment Fall from height of persons or materials / plant could result in personnel injuries
   - CDM Risk Register: C122-OVE-N3-LRG-M123-00001 GMY-FAR-012.
   - CIii; Possible presence of unrecorded buried Unexploded military ordnance of WWII origin. Risk of explosion caused by uncovering / striking ordnance during monitoring installation work
   - CDM Risk Register: C122-OVE-N3-LRG-M123-00001 GMY-FAR-017.
   - CIv; Potential for workers to come In contact with railway power or traction currents, potential for causing electrocution, burns of C435 personnel (potentially fatal).
   - CDM Risk Register: C122-OVE-N3-LRG-M123-00001 GMY-FAR-012.7.
   - Cv; Potential for electro magnetic interference with existing 3rd party systems due to siting of Instrument
   - CDM Risk Register: C122-OVE-N3-LRG-M123-00001 GMY-FAR-012.4.
   - CvI; Poor positioning of Instrument such as a ground stud or prisms, causing operatives of public to trip or be injured.
   - CDM Risk Register: C122-OVE-N3-LRG-M123-00001 GMY-FAR-012.2.
2. See Designers CDM Risk Register Ref: Doc. No: C122-OVE-N3-LRG-M123-00001 for full hazard, risk and mitigation details for C435 Work.
3. These notes are based on experienced and competent contractors carrying out the work using an approved safe method of working.

Rev.	Date	Description	By	Chkd	App	Auth
P01	01/11/2010	First Issue	JG	CC	PC	
P02	09/12/2010	Issued for Tender Purposes	JN	AN	RM	
P03	28/02/2011	Reissued for Tender Purposes	JN	HJ	RM	
P04	28/03/2011	Issued for ITT	JN	AC	PC	
P05	06/05/2011	Issued for C435 ITT Addendum	JN	CC	PC	
P06	10/05/2011	Reissued for ITT Addendum	GK	CC	PC	
P07	19/05/2011	Reissued for ITT Addendum	JN	CC	RM	
P08	06/06/2011	Issued for ITT Addendum	JN	PC	RM	
P09	08/11/2011	Minimum requirements for instrumentation and monitoring	GK	JW	PC	
C01	11/11/2011	Issued as Fit for construction	GK	JW	PC	IT
P10	11/04/2012	Minimum requirements for instrumentation and monitoring	GK	JA	PC	-
[redacted]	17/04/2012	Issued as Fit for construction	GK	JA	PC	IT

P10

Key Plan



N

20m 0 20m 40m 60m 80m 100m
1:1000

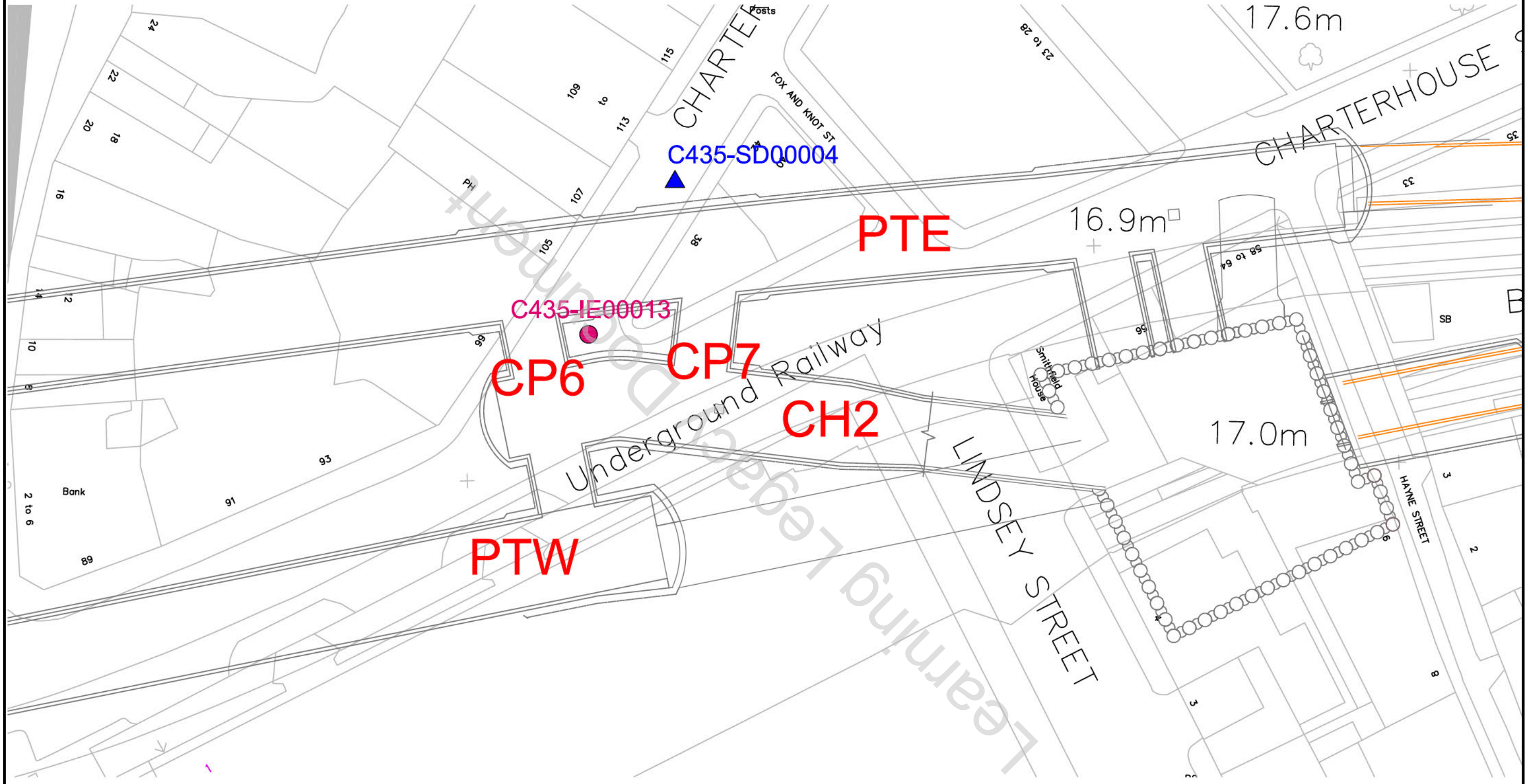
Crossrail Limited
25 Canada Square
Canary Wharf
London
E14 5LQ

www.crossrail.co.uk

Contract : Bored Tunnels (Alignment and Track)
Originator : Ove Arup & Partners Limited
Location : Crossrail General
Title : Asset Protection I & M
Ground Surface and In- Ground
Farringdon Station
C435
By : [redacted]
Chk : [redacted]
App : [redacted]
Auth : [redacted]
Scale : 1:1000 @ A1
Drawing and CAD file No : C122-OVE-C2-DDA-CR001_Z-31531
Rev : [redacted]
Suitability : A

RESTRICTED

Fit for construction



Rev.	Date	Description	By	Chkd	App	Auth

Notes:

Crossrail

BFK Bam | Ferrovial | Kier

GEOCISA

C/ Los Llanos de Jerez 10-12
28823- MADRID
www.geocisa.com

Contract : BORED TUNNELS (ALIGMENT AND TRACK)

Originator : OVE ARUP & PARTNERS LIMITED

Location : CROSSRAIL GENERAL

Title : IN-GROUND DEVICES INSTALLED FOR FARRINGDON STATION

By [redacted]

Chk

App

Scale : @ A3

Drg No : C435-BFK-C2-DWG-M123-50042

Rev :

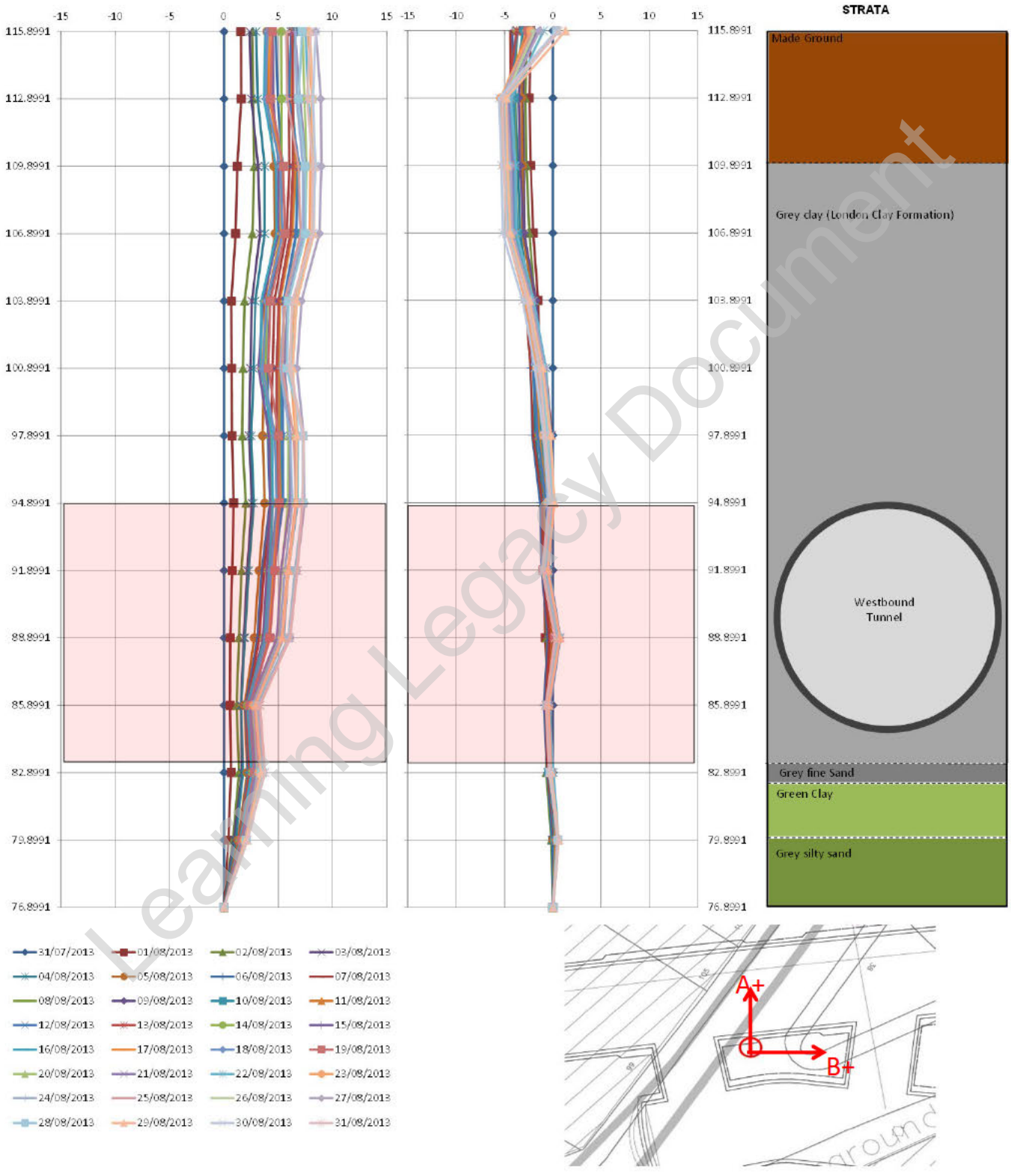
Sult :

Auth : GEOCISA

Pby

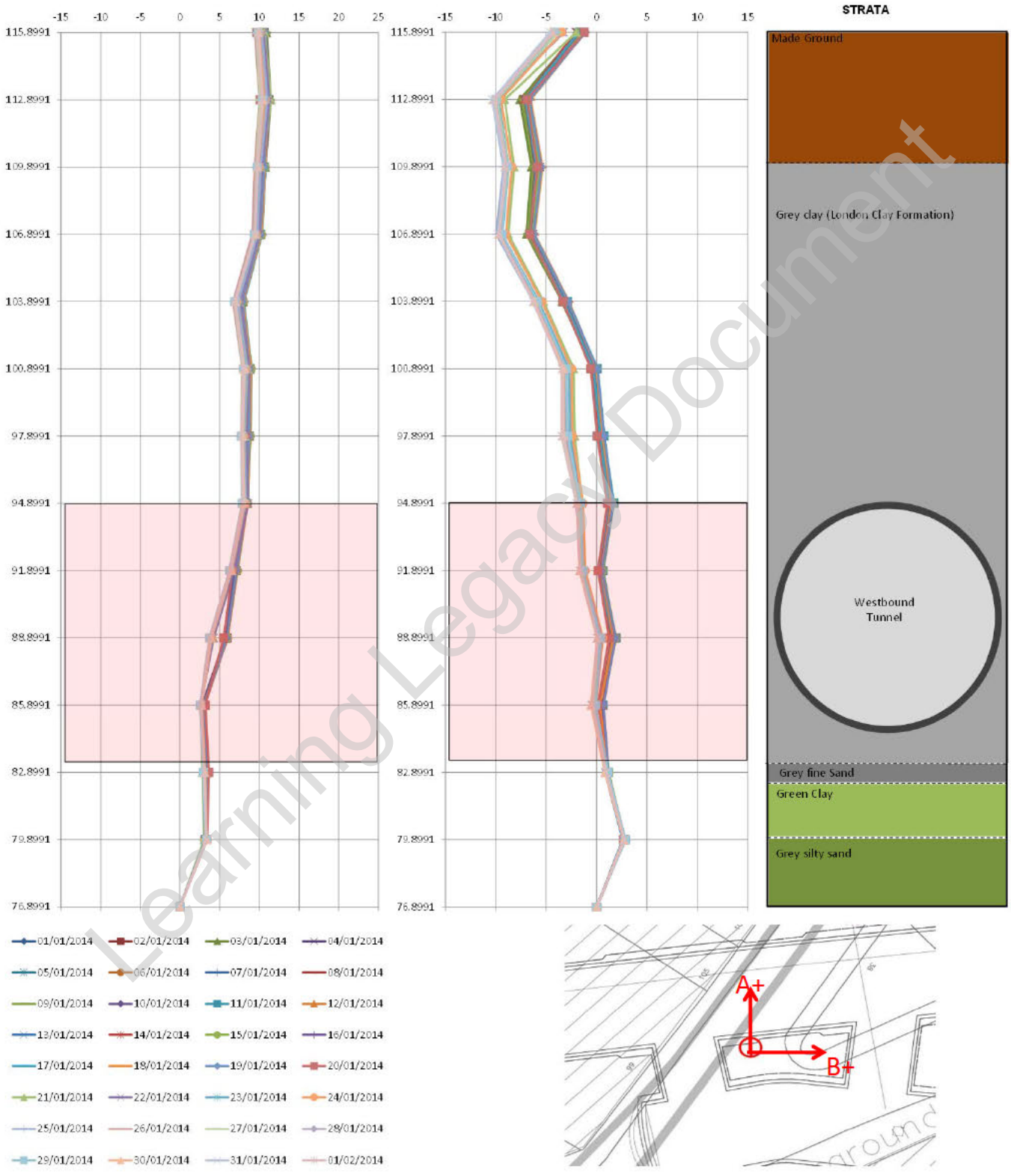
APPENDIX B: GRAPHS

REPORT: Automatic Inclinometer
LOCATION: Charterhouse St
DEVICE: Inclinometer C435-IE00013
Before TBM



REMARKS:

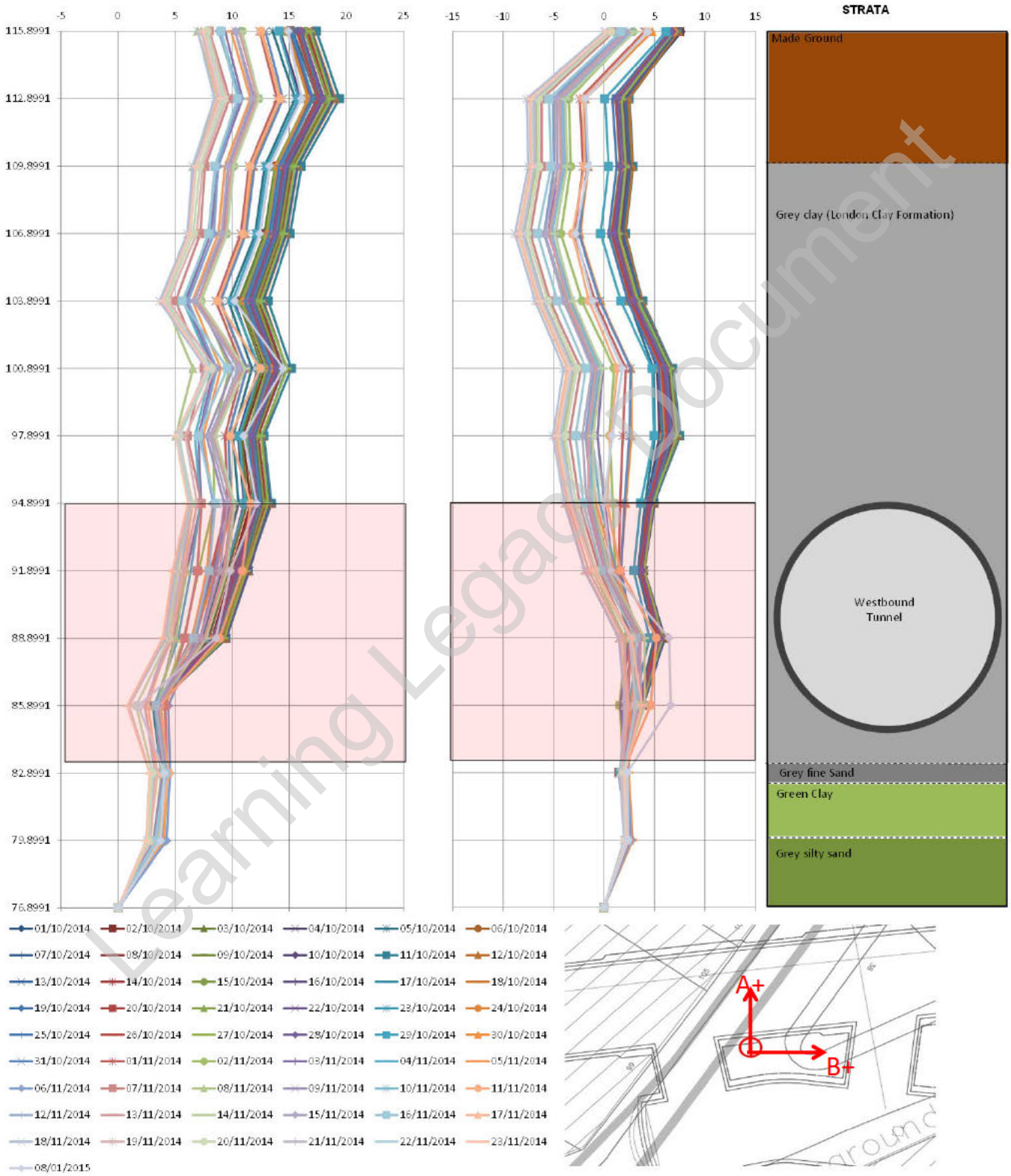
REPORT: Automatic Inclinometer
LOCATION: Charterhouse St
DEVICE: Inclinometer C435-IE00013
During TBM



REMARKS:

The TBM cross the area between 19th and 21st of January 2014

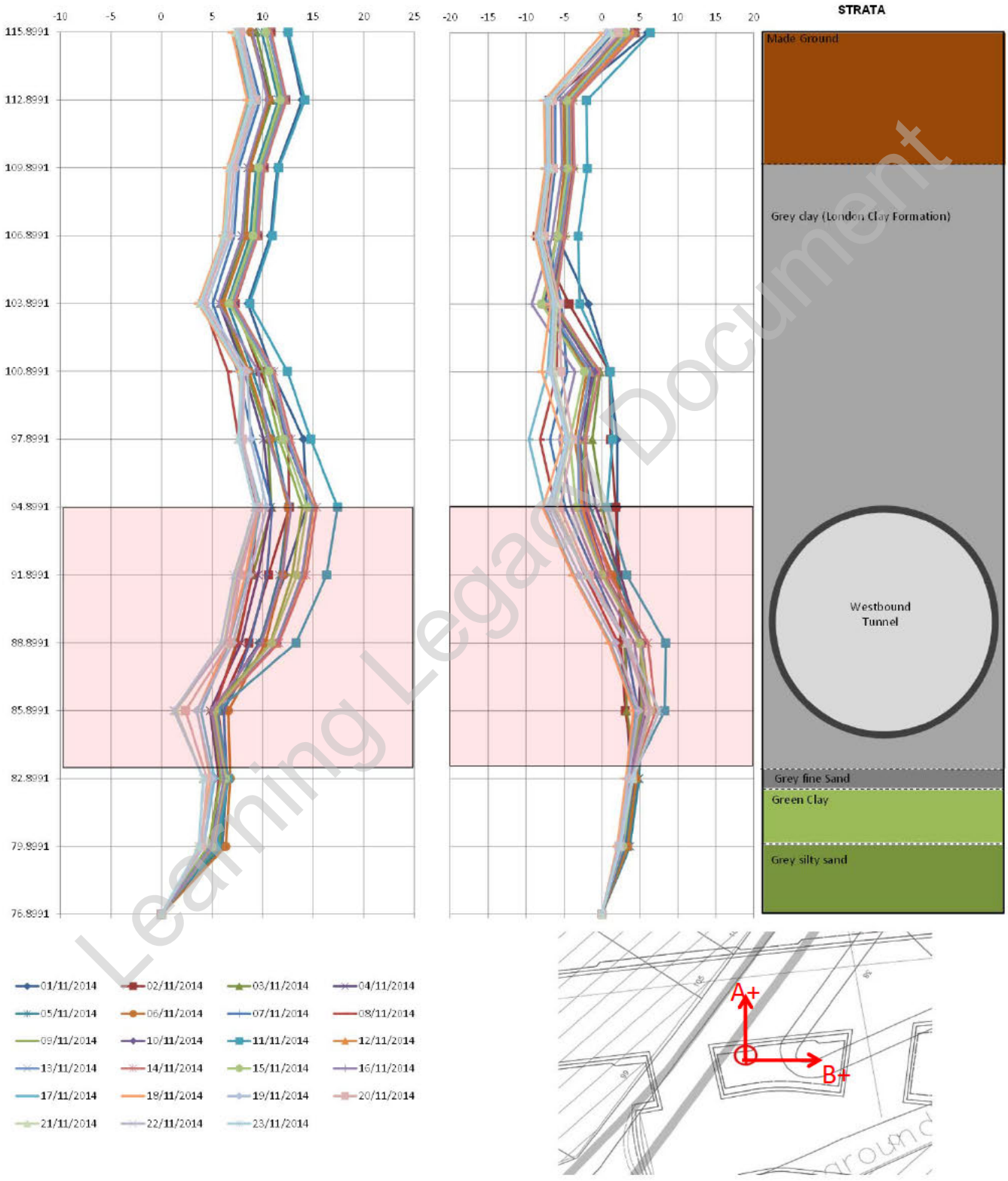
REPORT: Automatic Inclinometer
LOCATION: Charterhouse St
DEVICE: Inclinometer C435-IE00013
During PTE



REMARKS:

The inclinometer was inside of the influence area for PTE from 23-10-2014 to 16-12-2014

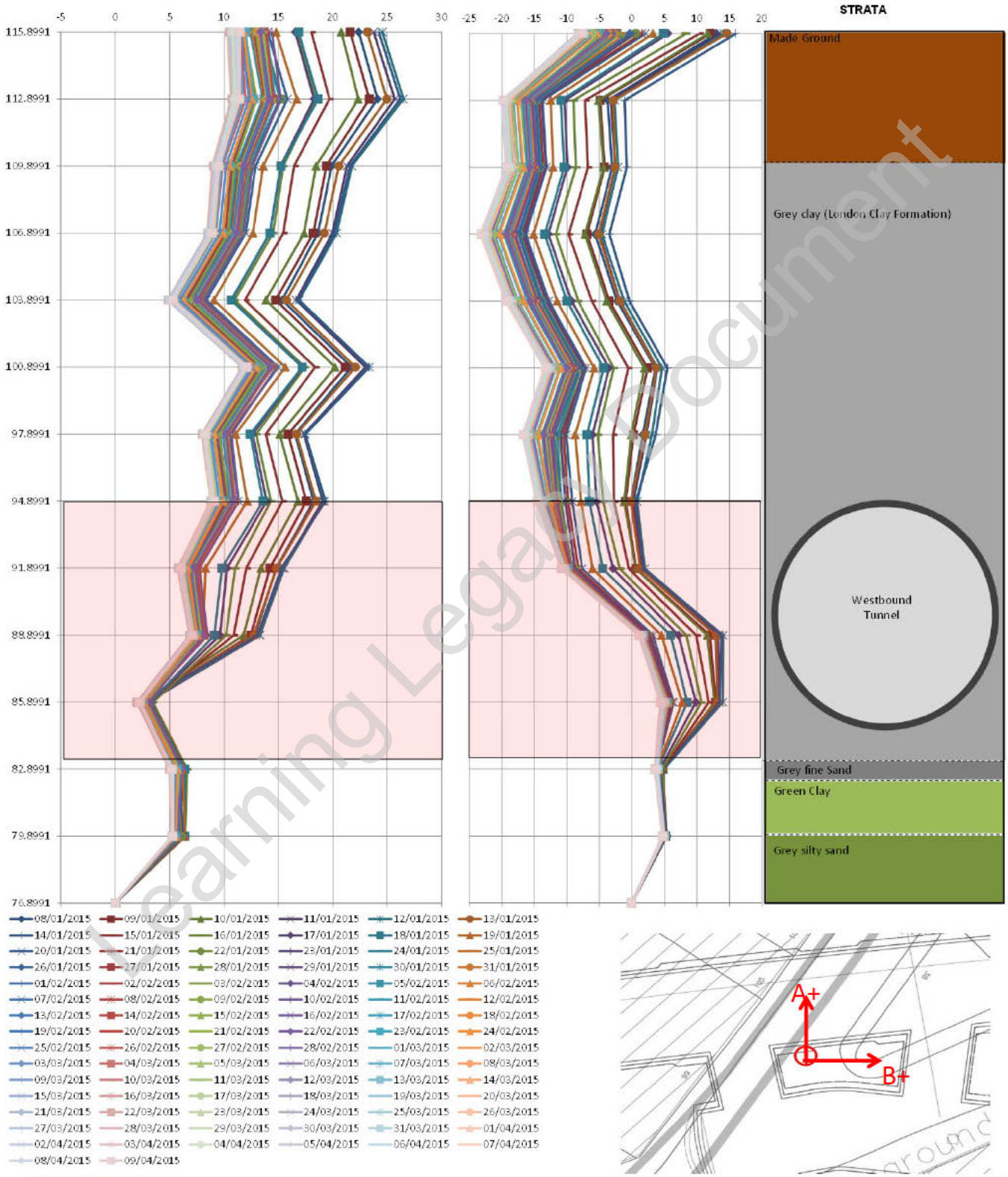
REPORT: Automatic Inclinometer
LOCATION: Charterhouse St
DEVICE: Inclinometer C435-IE00013
During CP6



REMARKS:

The inclinometer was inside of the influence area for CP6 from 14-11-2014 to 22-11-2014

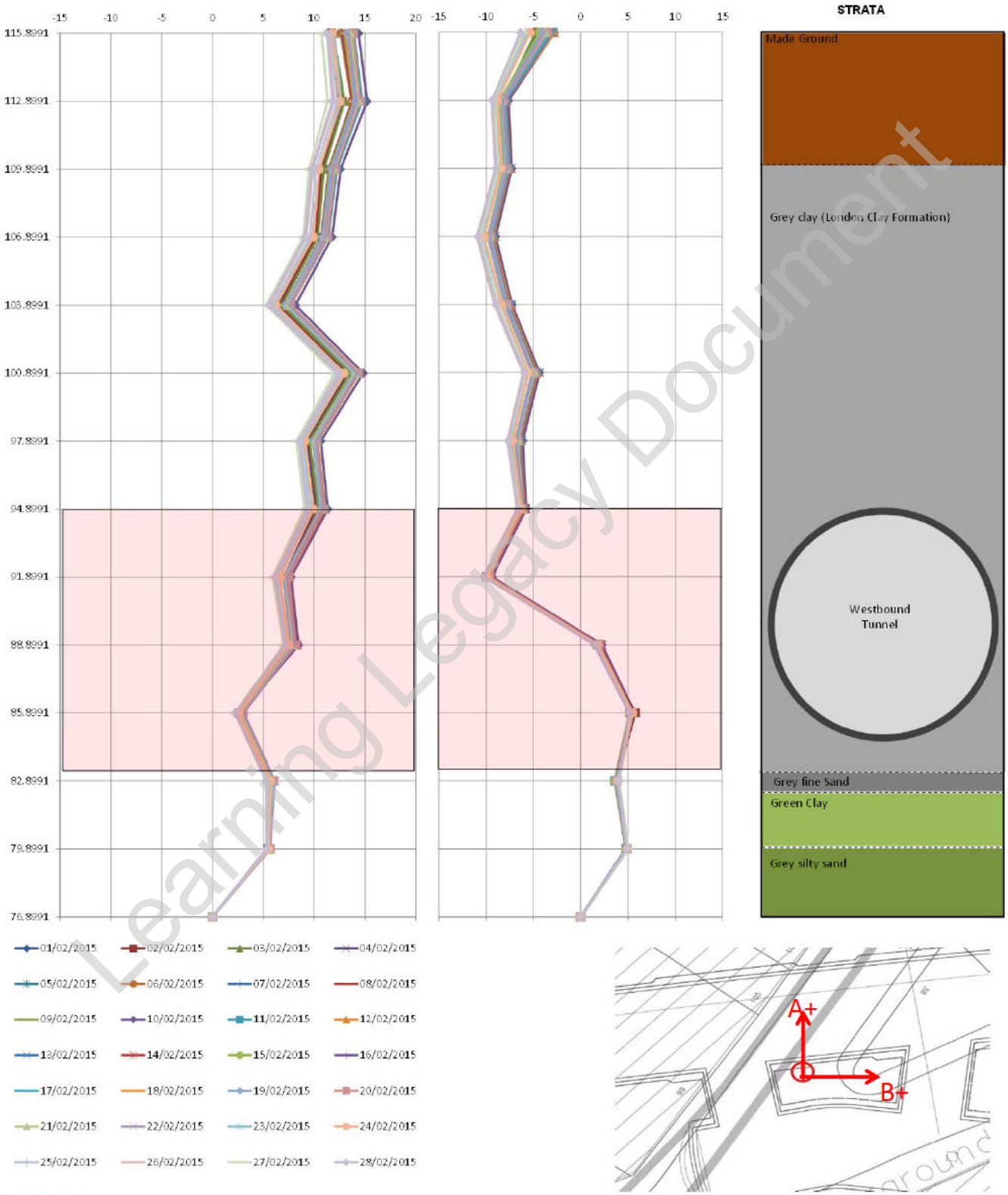
REPORT: Automatic Inclinometer
LOCATION: Charterhouse St
DEVICE: Inclinometer C435-IE00013
During CH2



REMARKS:

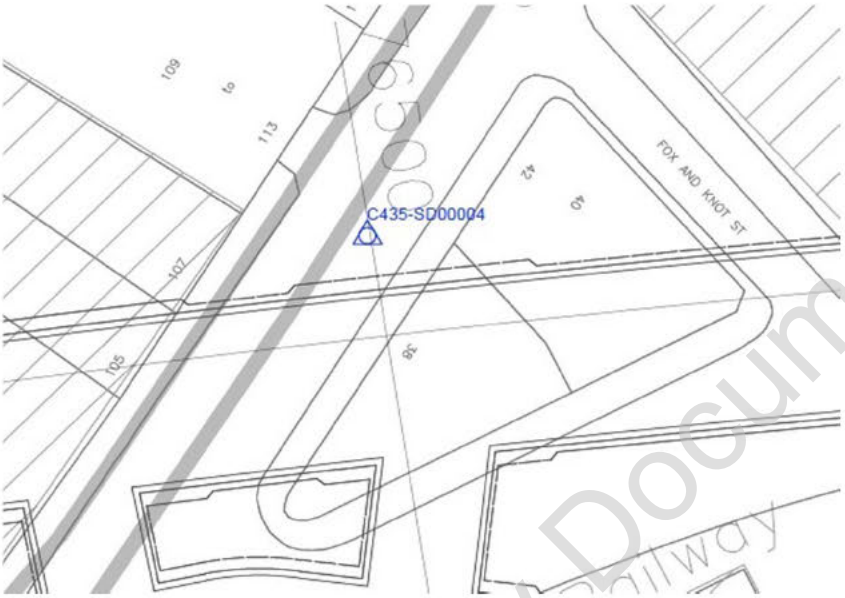
The inclinometer was inside of the influence area for CH2 from 30-01-2015 to 01-04-2015

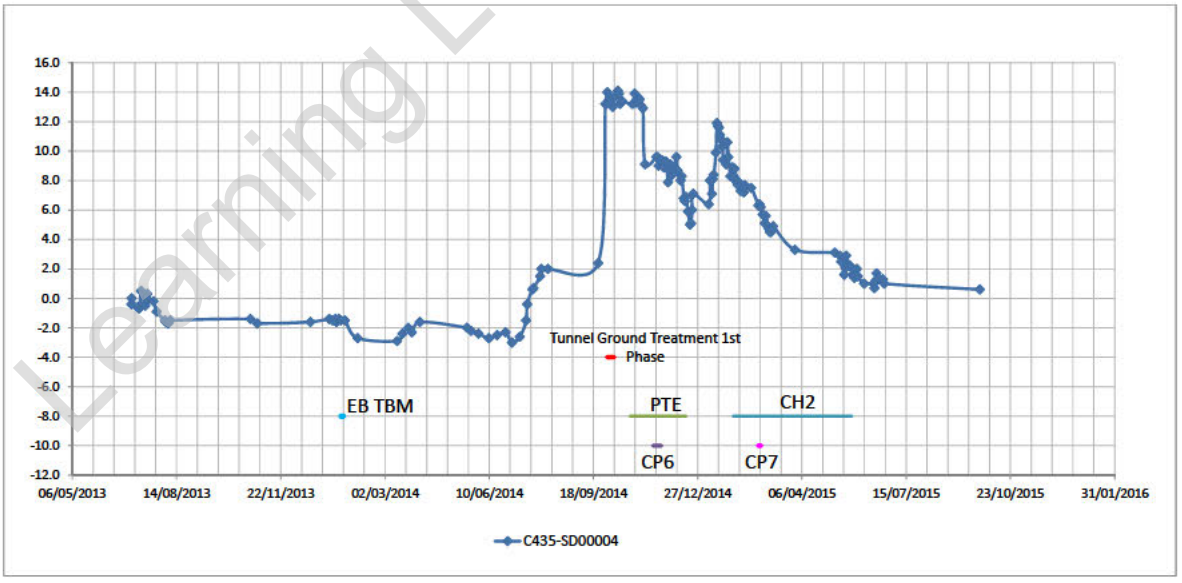
REPORT: Automatic Inclinometer
LOCATION: Charterhouse St
DEVICE: Inclinometer C435-IE00013
During CP7



REMARKS:

The inclinometer was inside of the influence area for CP7 from 23-02-2015 to 26-02-2015





REMARKS:

APPENDIX C: GLOSSARY

ATS	Automatic Total Station.
ETH	Eastern Ticket Hall.
WB	Westbound.
TBM	Tunnel Boring Machine.
EB	Eastbound.
PTW	Platform Tunnel West.
PTE	Platform Tunnel East.
CP	Cross passages.
CH	Concourse Hall.
VA	Ventilation Adit.
STE	Stub Tunnel East.
STW	Stub Tunnel West.
RTE	Running Tunnel East.
ES	Escalator Shaft.
TAM	Tube a Manchette.