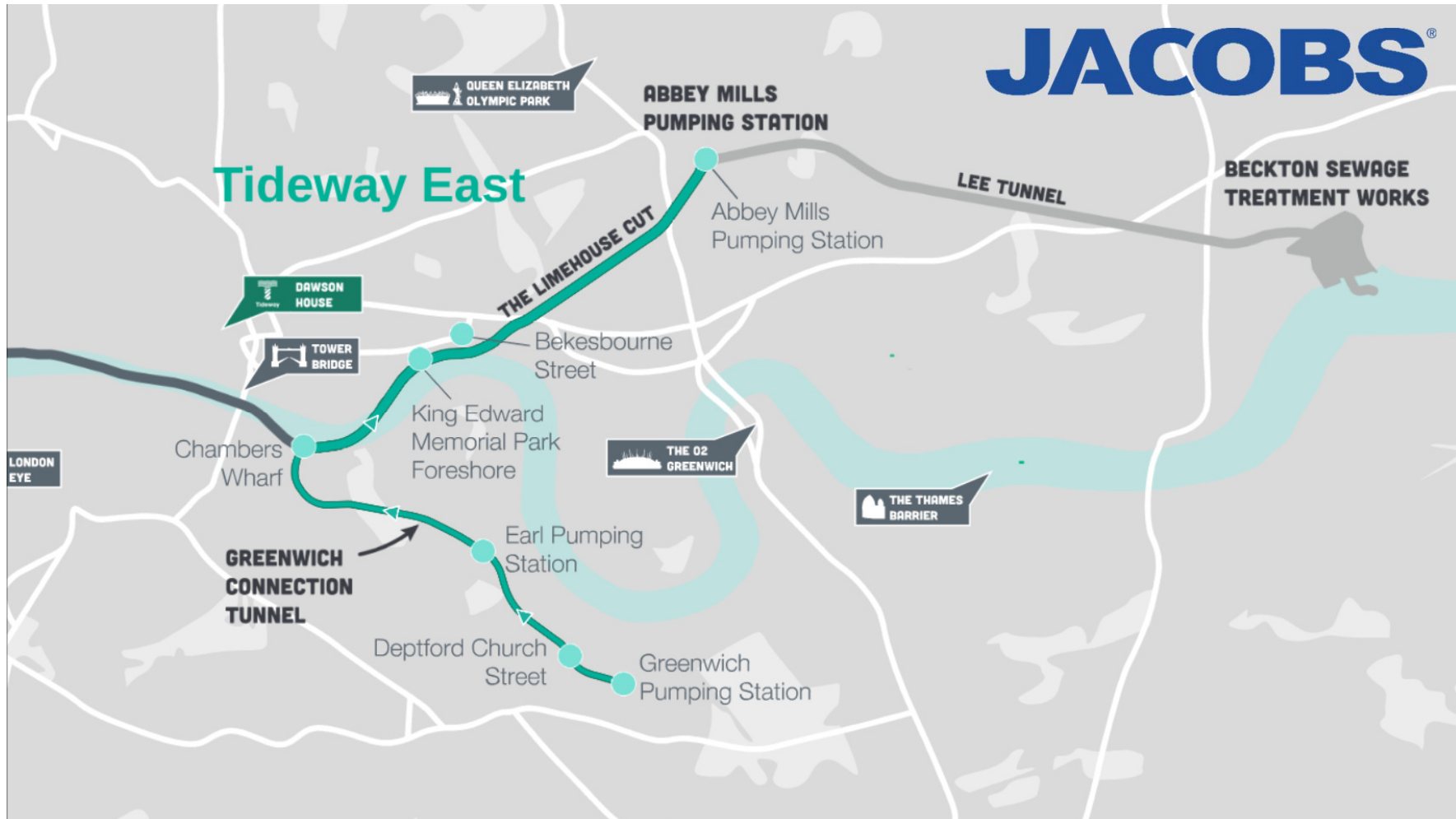




Geotechnical Challenges of TTEAS

- Chambers Wharf - Panel 15 Collapse & Recovery Works
- Deptford Church Street – Effect of Chalk Fissures on Shaft Construction
- Earl Pumping Station - Contaminated Land – Impacts on Construction
- King Edward Memorial Park Foreshore – Overcoming unforeseen ground conditions
- Greenwich Pumping Station – Jet Grouting adjacent to live Thames Water Assets



Tideway East:

- 5 nr 60m+ deep dwell shafts
- 2 slurry TBMs (8.85m & 6.65m diameter)
- Main Tunnel: 5.5 km length
- Greenwich Tunnel: 4.5 km length

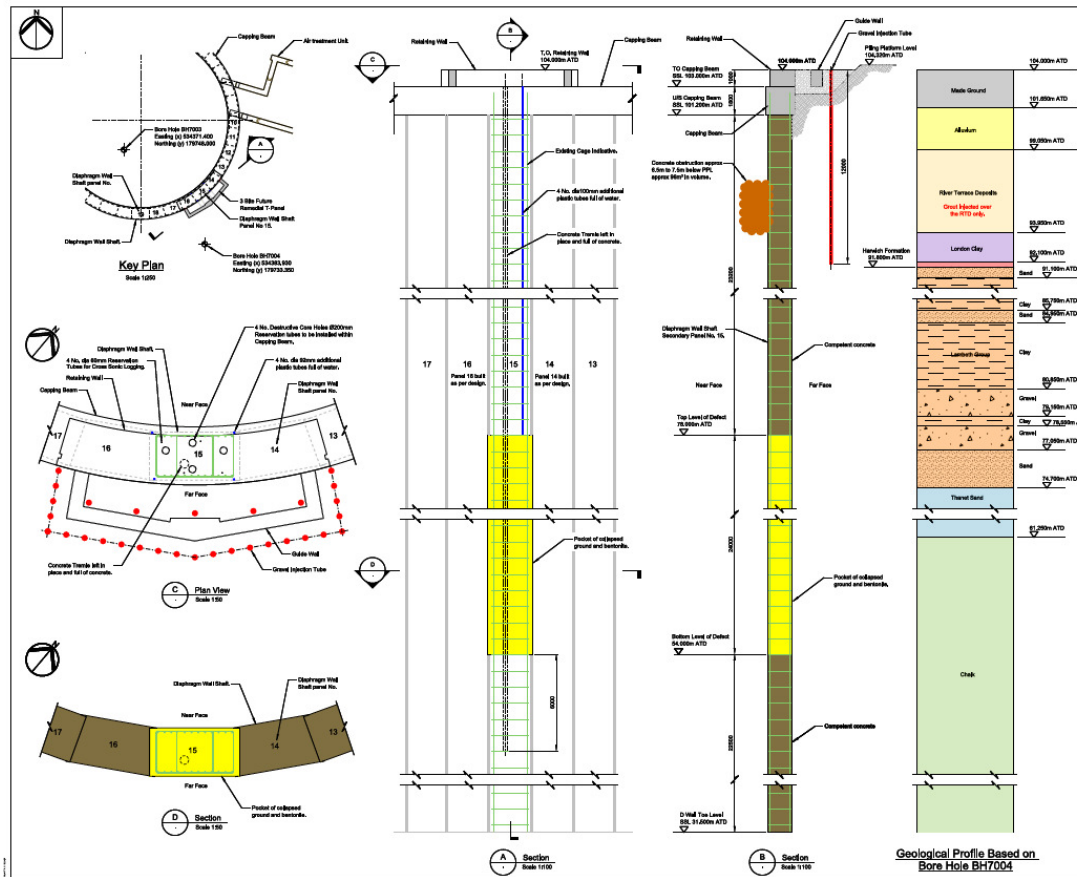




Chambers Wharf - Panel 15 Collapse & Recovery Works

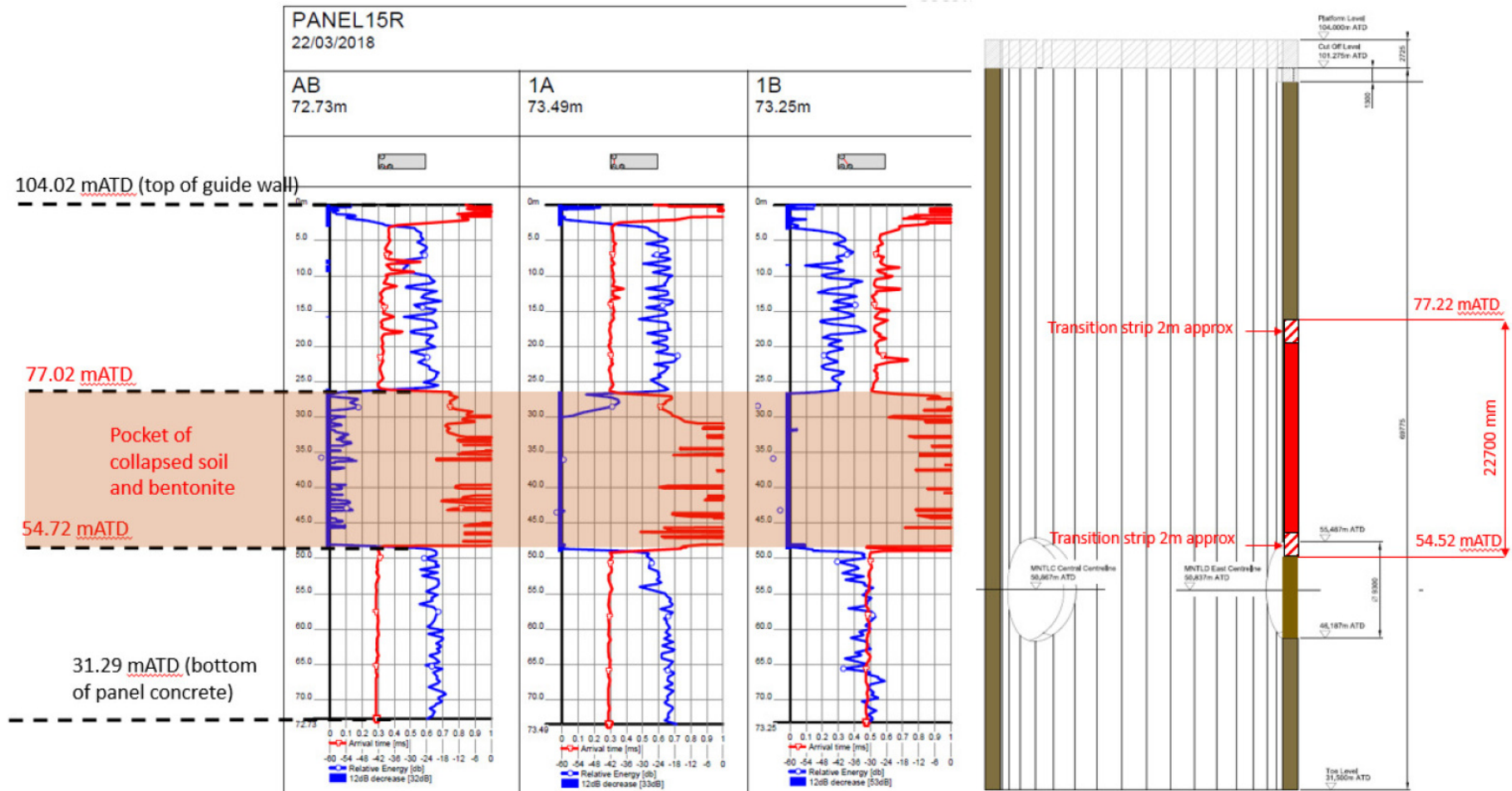
Chambers Wharf – Panel 15 – 9th March 2018

Collapse of c. 95m³ of RTDs into penultimate panel during concreting process



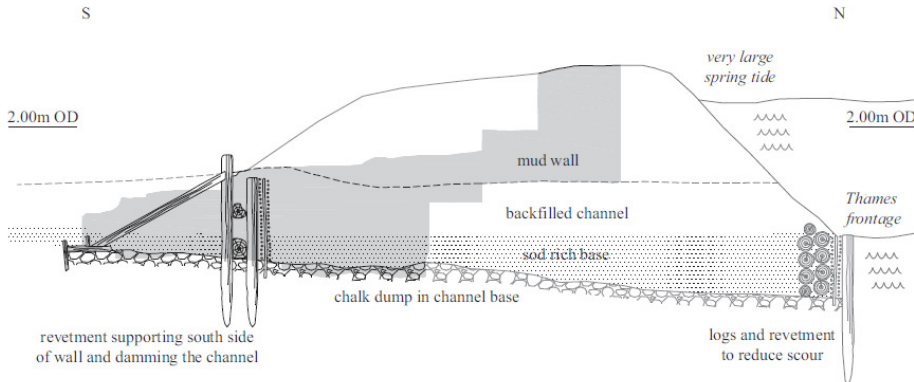
RTDs had been permeation grouted prior to dwelling based on experience during preceding chalk grouting works drilling

Chambers Wharf – Panel 15 – Evidence of the Problem

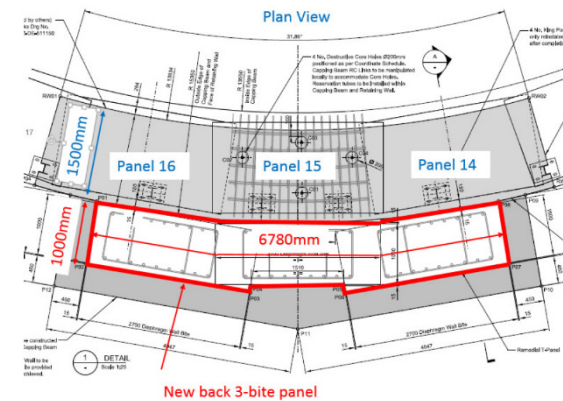
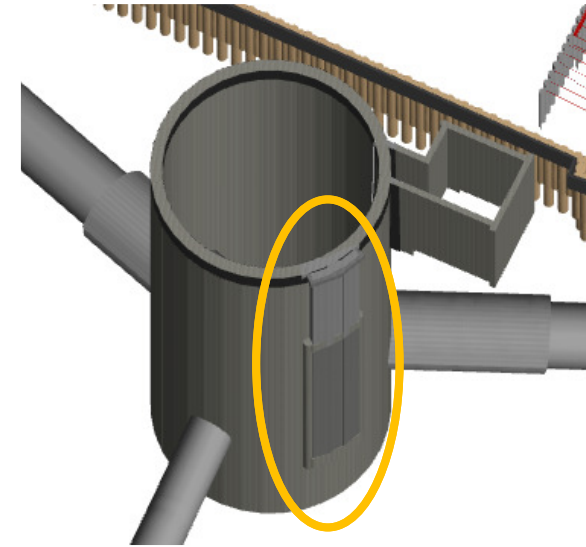
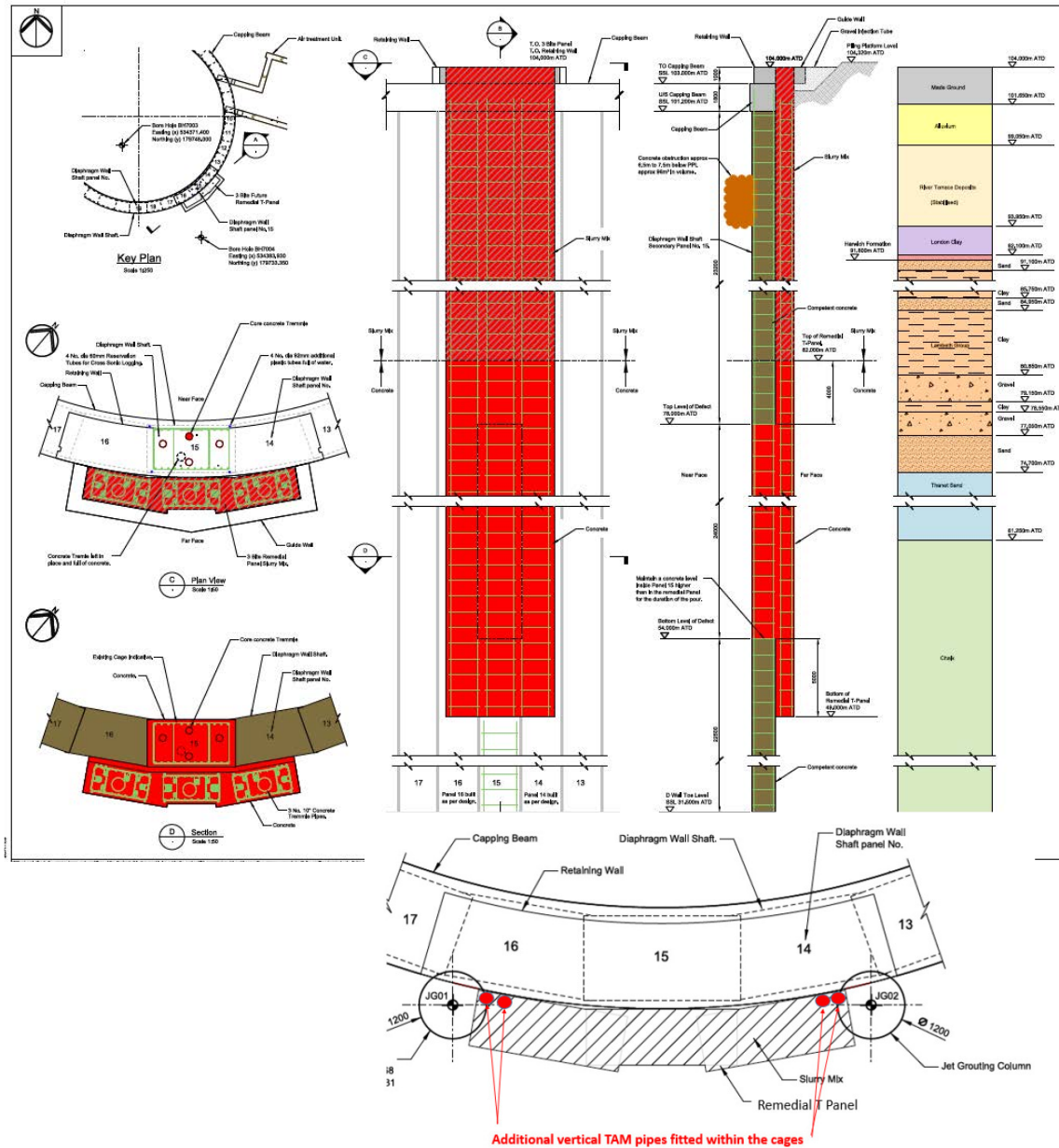


77mATD to 54mATD inc Lower Lambeth Group / Thanet Sand / Upper Chalk

Chambers Wharf – Panel 15 - Root Cause Analysis



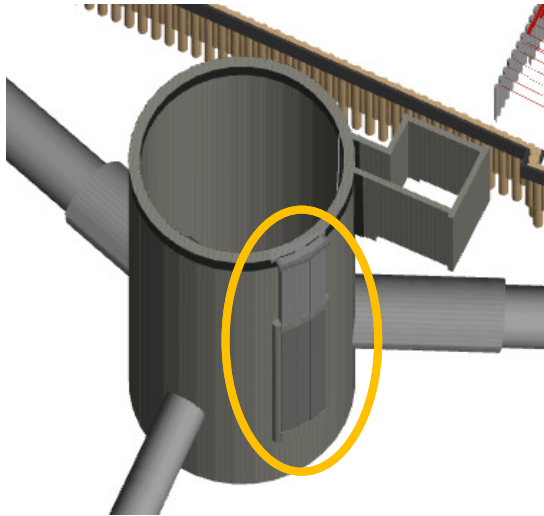
Chambers Wharf – Panel 15 – The Solution



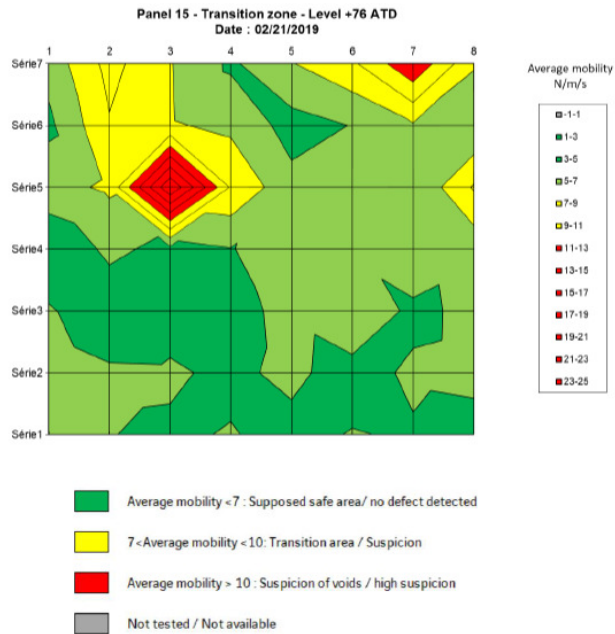
Chambers Wharf – Panel 15 – The Repair Works – Rear Panel & Reinstatement



Chambers Wharf – Shaft Internal Repair Works



Quality assessment





Infilled concrete at
73mATD



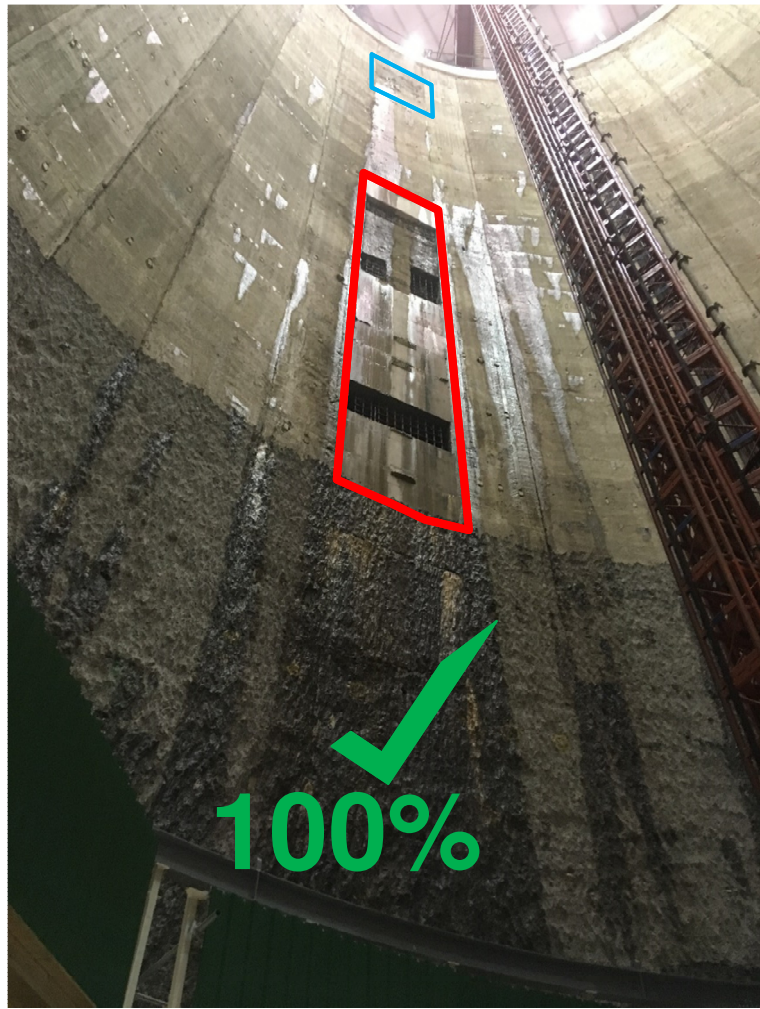
Infilled concrete at
71.5mATD



Repaired concrete
at 69mATD

Hydrodemolitioned
concrete at 67.5mATD







Civils, Geotech, Materials & Design Depts all worked together to develop engineering solutions which allowed shaft excavation, base slab casting and internal lining to proceed.

Cost and programme implications of course.

Subject of a major insurance claim.

Lessons Learnt :

Historic land uses and geomorphology can have a significant impact on below ground construction works.

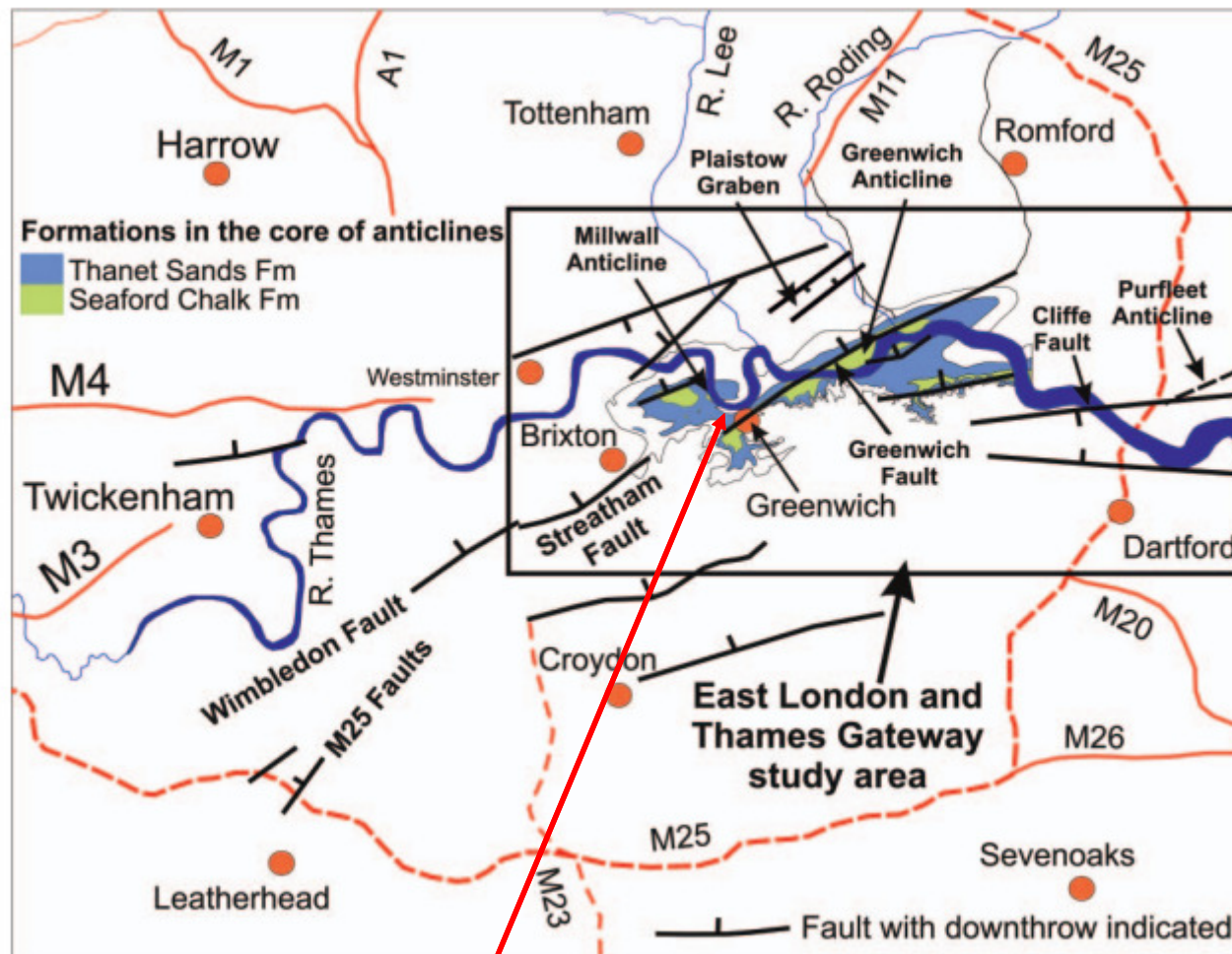
Plans were in place for pressure relief during the closing of the shaft but the location and number may have been insufficient due to the “dam” effect

Engineering solutions to major issues is always possible with the right people and teamwork





Deptford Church Street – Effect of Chalk Fissures on Shaft Construction

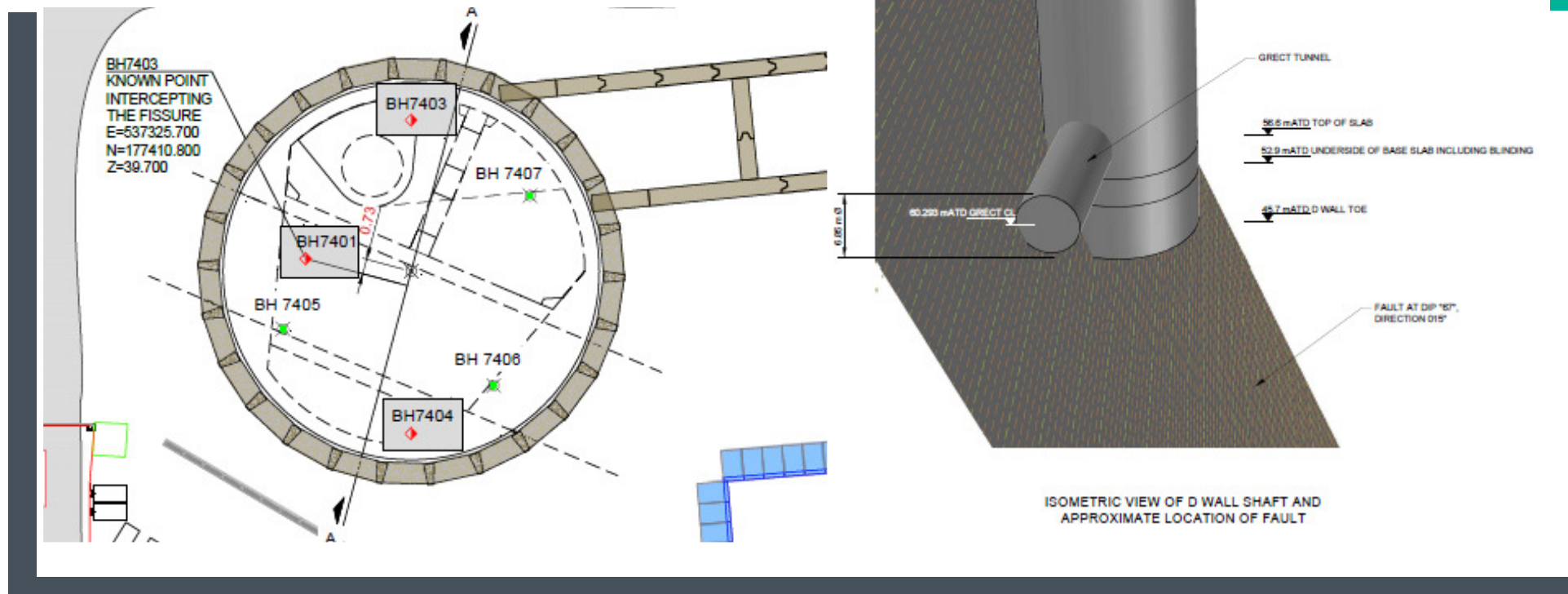


(Mortimore et al, 2011)

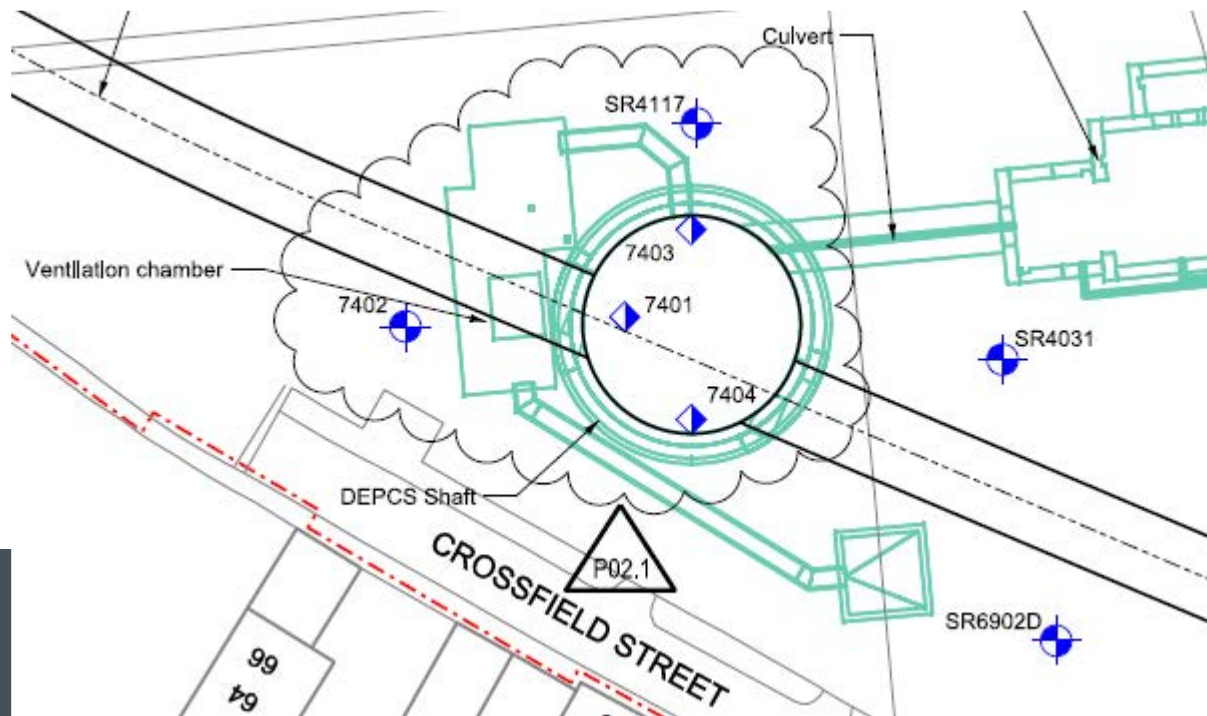
DEPCS Site

Modelling using original pump test information

- **Nov 2017** : Pre Dwall pump test yielded 12l/s (30l/s) with offsite drawdown 0.6m . Limited by discharge consent.
- 1-2 l/s Works Information limits
- Fissure identified at 66mbgl, 70° dip to north in geophysics
- Fissure projection suggested that cut off may need to extend to 90-100 mbgl on north side of the shaft.



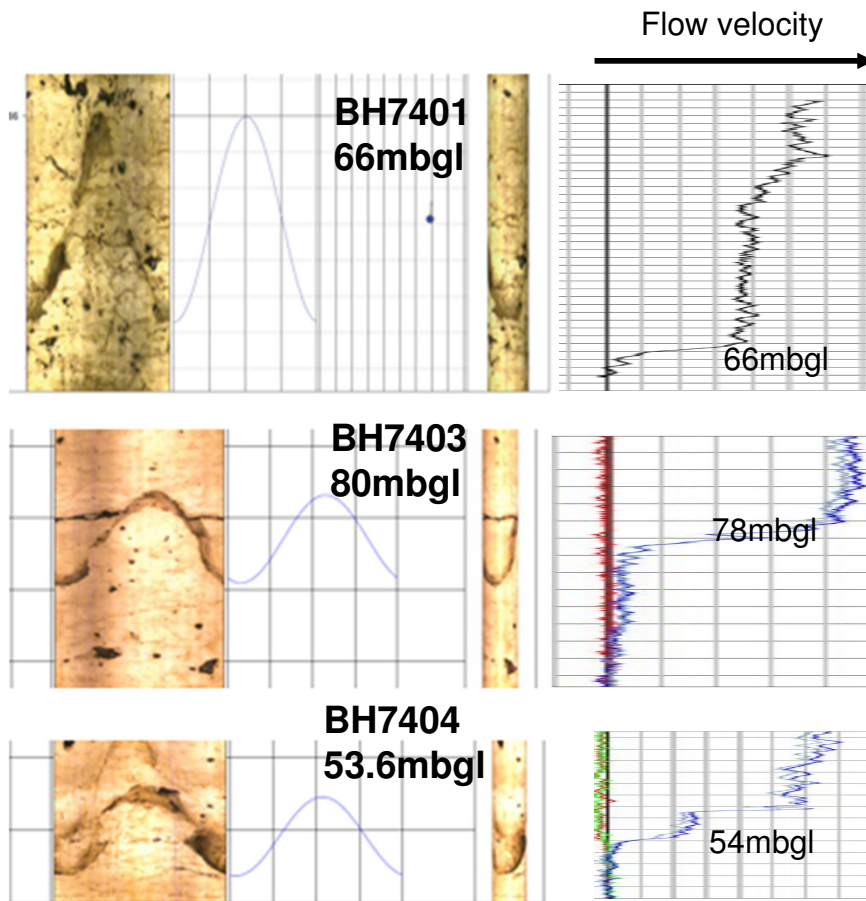
Targeted Ground Investigation April '18 : BH7403/BH7404



BH7403	100m	9 permeability packer tests from 50 to 99mbgl.	<p>✓ Simultaneous working by both contractors across the two boreholes reduced programme. Use of experienced contractors ensured quality results.</p>
BH7404	75m	7 permeability packer tests from 39 to 75mbgl.	<p>✓ Core reviewed in real time by CVB/Mott MacDonald to select and agree packer test zones with review panel, key marker horizons noted. Expected fracture projection targeted as well as other areas of apparent fracturing outside projection and typical chalk areas for comparison.</p>

Pumping test and geophysical data

Geophysical surveys of BH7403 and BH7404 were undertaken. The results were compared with BH7401. Confirmed fissure projection – > decision to grout.



Similar yield indicating interception of the same hydraulic feature.

Similar orientations in depth range of fracture projection.

Drilling flush losses and packer testing results suggested higher flow zones but not conclusive.

Pumped flowmeter testing indicated 90% of the pumped flow being supplied by the fissure location (velocity reduction)

Packers and drilling flush were a guide to the apparent fissure location but not conclusive – pumped flow instrumental in defining flow horizon.

May '18 : Fissure grouting

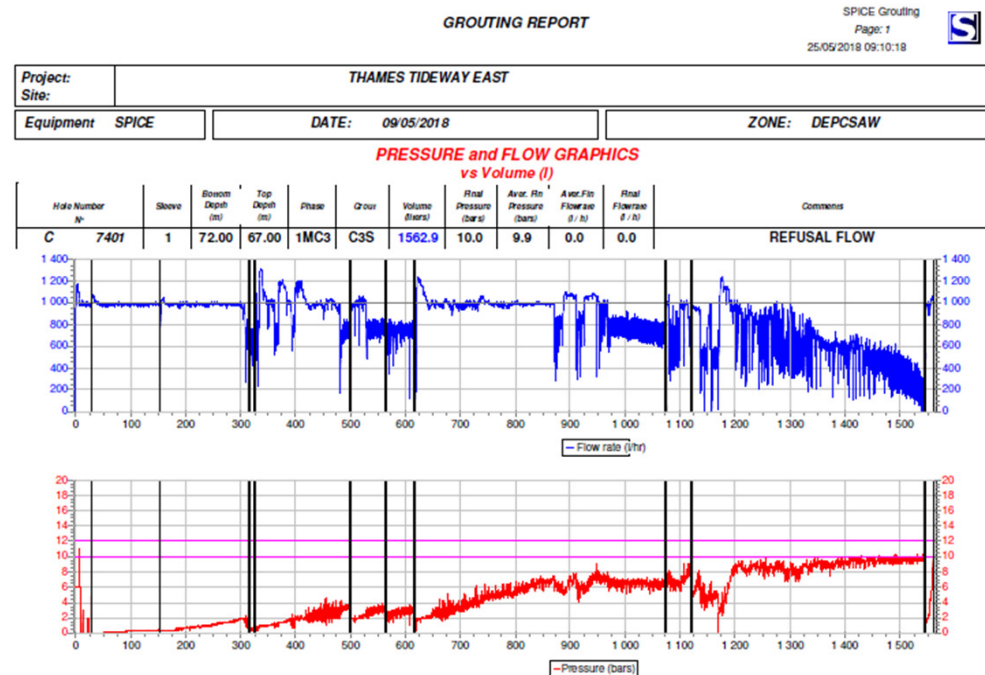
- Assumed fissure volume (assuming 50mm wide continuous) ~ 50m³ target
- Injection grouting proposed – up dip advancement – grouting sequence BH7403 (lowest point), BH7401 (mid point) and BH7404 (high point).

	Theoretical hole volume	Net volume
BH7403	3.12m ³	6.18m ³
BH7401	2.25m ³	10.292m ³
BH7404	2.36m ³	2.749m ³

Predicted infill of fissure with grout= 38%



Use of Bachy Soletanche Grout I.T. software suite to prepare and to control / record the quantity of grout used during the works.



D-walling

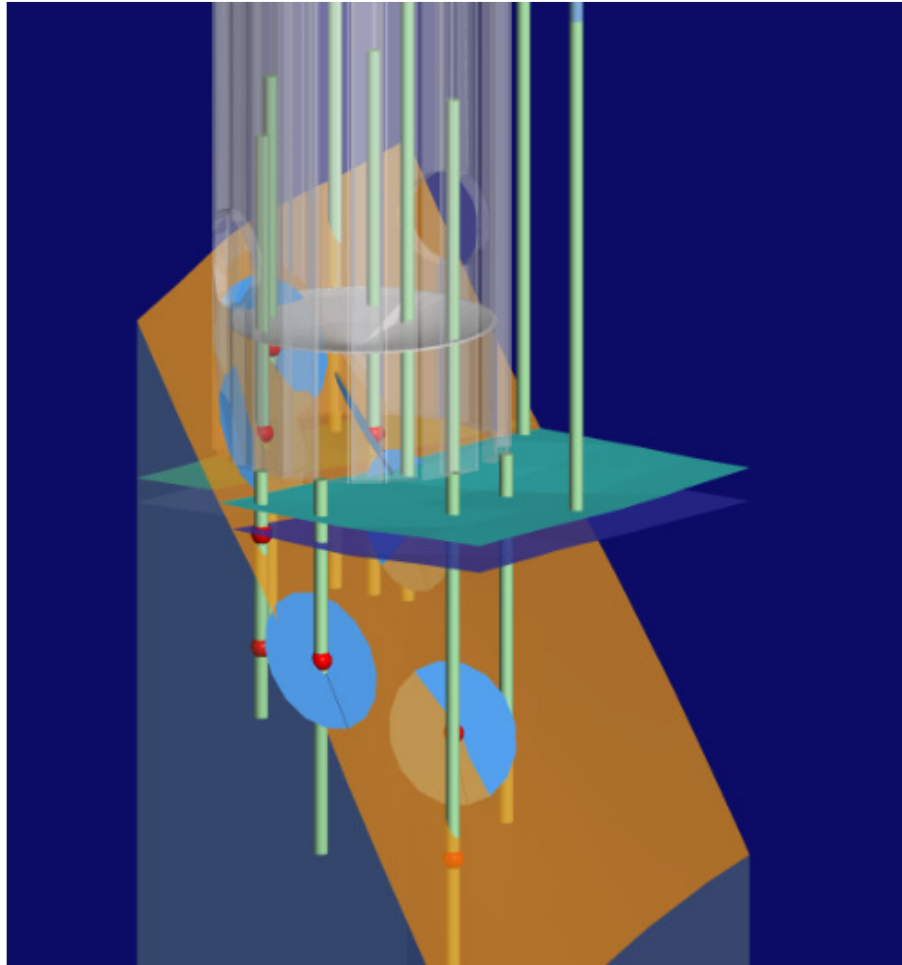
June - Aug 2018 : Broadly in line with programme



Value of model refinement and data summits

3D ground model incrementally updated by Mott MacDonald with new data.

- Initial site GI data
- Additional pump well data on fractures and grout take records.
- Subsequent post grouting and dwall information



Collaborative approach to data review

'Live' review of modelling on screen

Site visits + core walkovers

Information fundamental to pragmatic and timely decision making

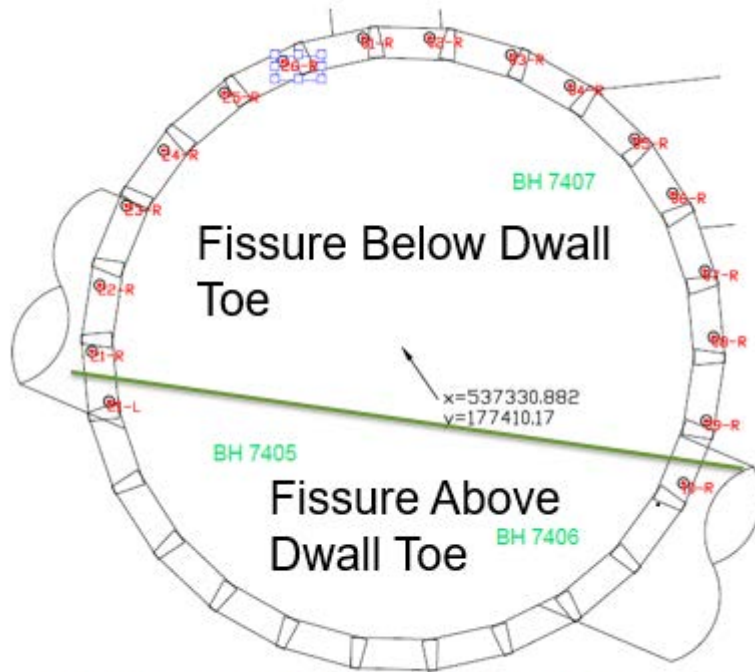
3D visualisation innovative and instrumental

Detailed understanding- conveyed within and between teams

Test and validate solution for assurance

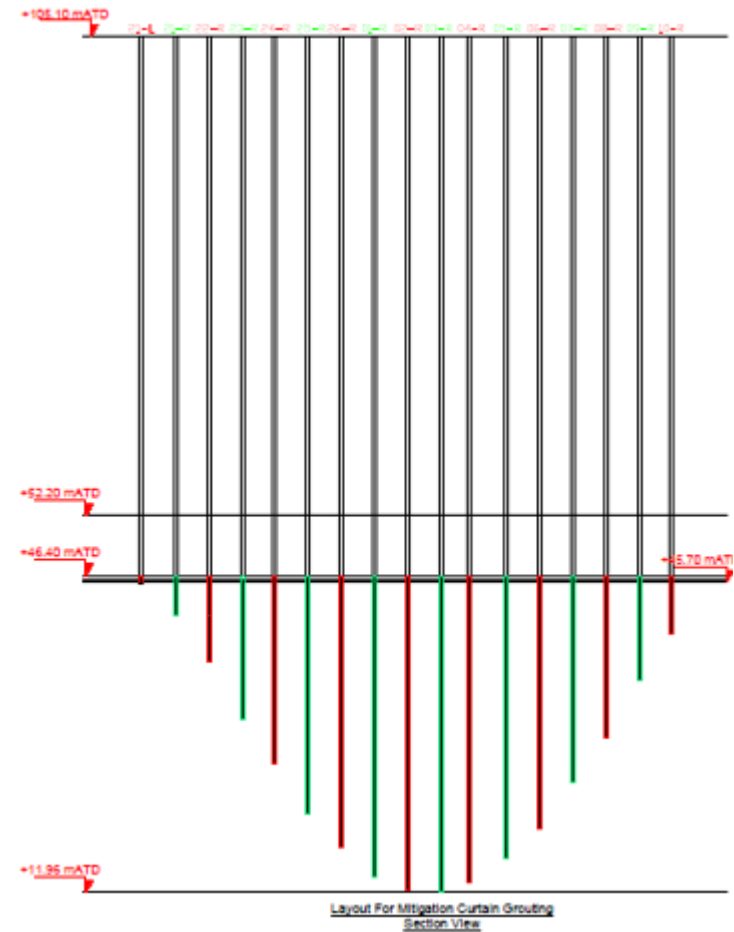
Value engineering: grout curtain

The improved ground model allowed CVB JV to design a partial grout curtain, should this be required on completion of the diaphragm wall



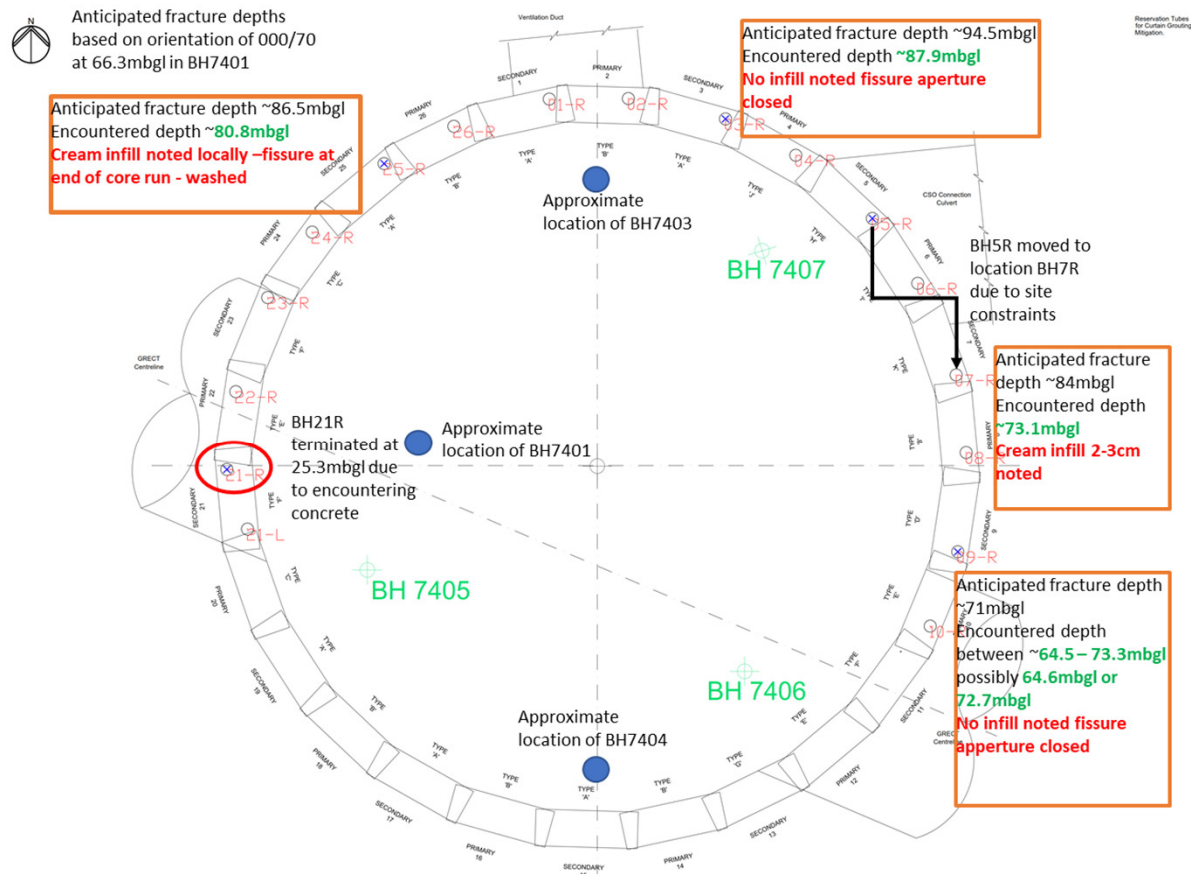
Grouting up to 35m below diaphragm toe level

- More planning time but savings in construction costs if realised were significant.
- Targeted ground investigation and advanced modelling allowed for the partial grout curtain to be designed in a relatively short space of time.

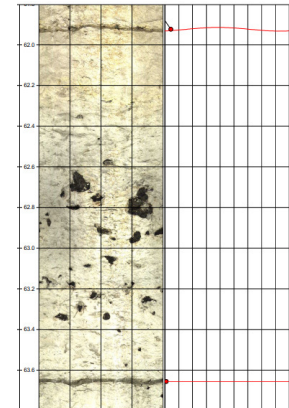


Post diaphragm wall validation

- Reservation tubes within cages utilised to drill chalk below the Dwall toe.
- Offset across the fissure confirmed at ~1m.
- Effectiveness of grouting assessed through identification of fissure infill? **To be investigated...**



Marker horizons in geophysical logs

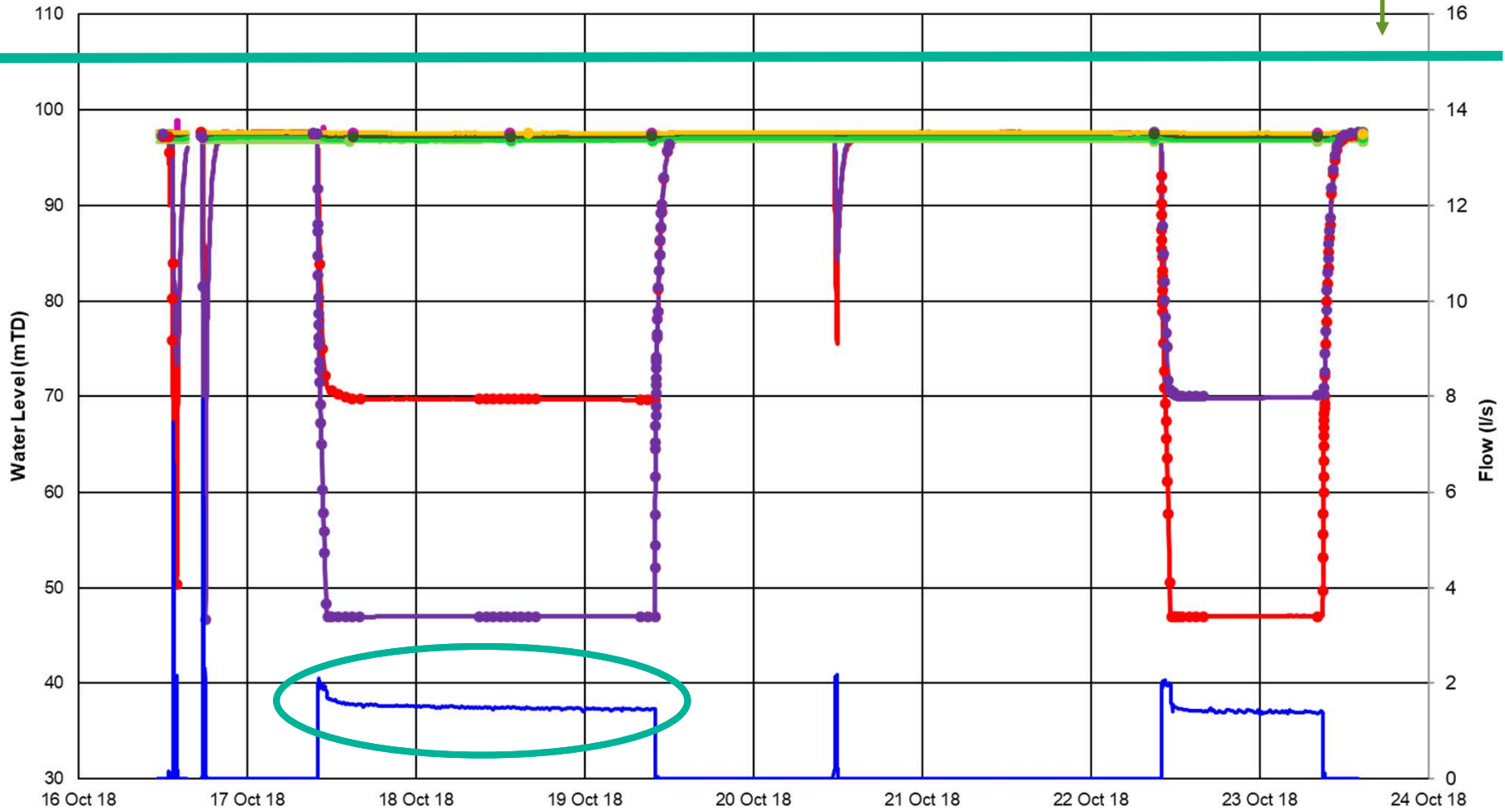


Marker horizons in core



Post diaphragm wall pump tests

Pre D-wall pumping test flow rates

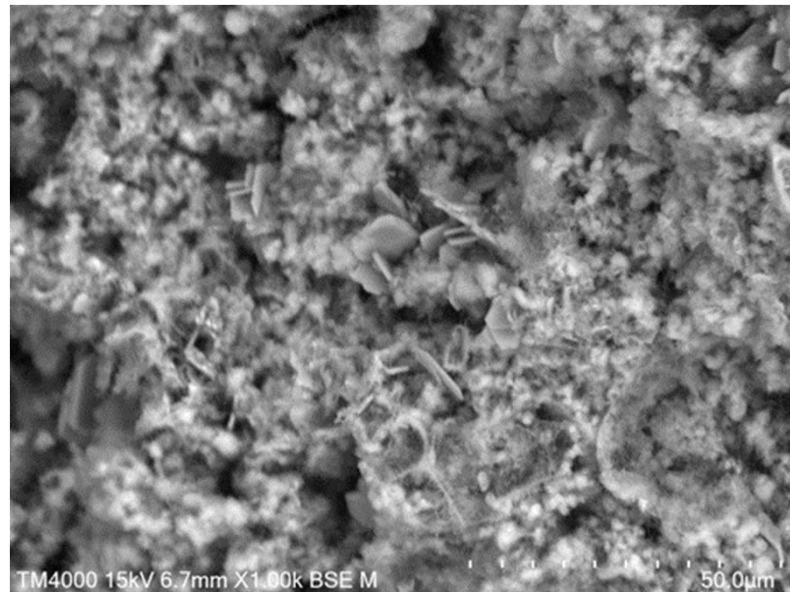


- BH7405(CK)
- BH7406(CK)
- SR4031 (RTD)
- SR6902D (CK)
- BH7402 (CK)
- BH7402 (RTD)
- SR4117 (CK)
- SR4114 (CK)
- Flow

NOTE: Manual dips shown as solid dots in same colour

Further assurance

- Infill observed in two fractures at projected levels of fissure
- Material described as firm cream silt/clay
- Imperial College sample comparisons, physical observations and SEM analysis.
- CVB and IC labs in agreement that the material was most likely grout



SEM Images at x1000 magnification shows the fissure in-fill material to have the same characteristics as the grout sample.

Summary

Collaborative thinking to mitigate a significant ground risk without serious impact to the construction programme.

Innovative approaches such as:

- multi-contractor drilling on the same well
- extensive use of geophysics
- use of computerised pressure grouting
- 3D visualisation within review meetings
- specialist materials testing of grout

The resulting ground model provided the assurance that was required to safely delete the requirement of the partial grout curtain from the programme.



Lessons learnt

- 1) Whilst the GBR clause seemed unlikely, there had been previous evidence that this type of feature might be found.
- 2) Small offset meant that feature could easily be missed
- 3) True understanding of the location and geometry was only apparent following multiple investigations over and above what may normally be anticipated.



**Earl Pumping Station - Contaminated Land -
Impacts on Construction**

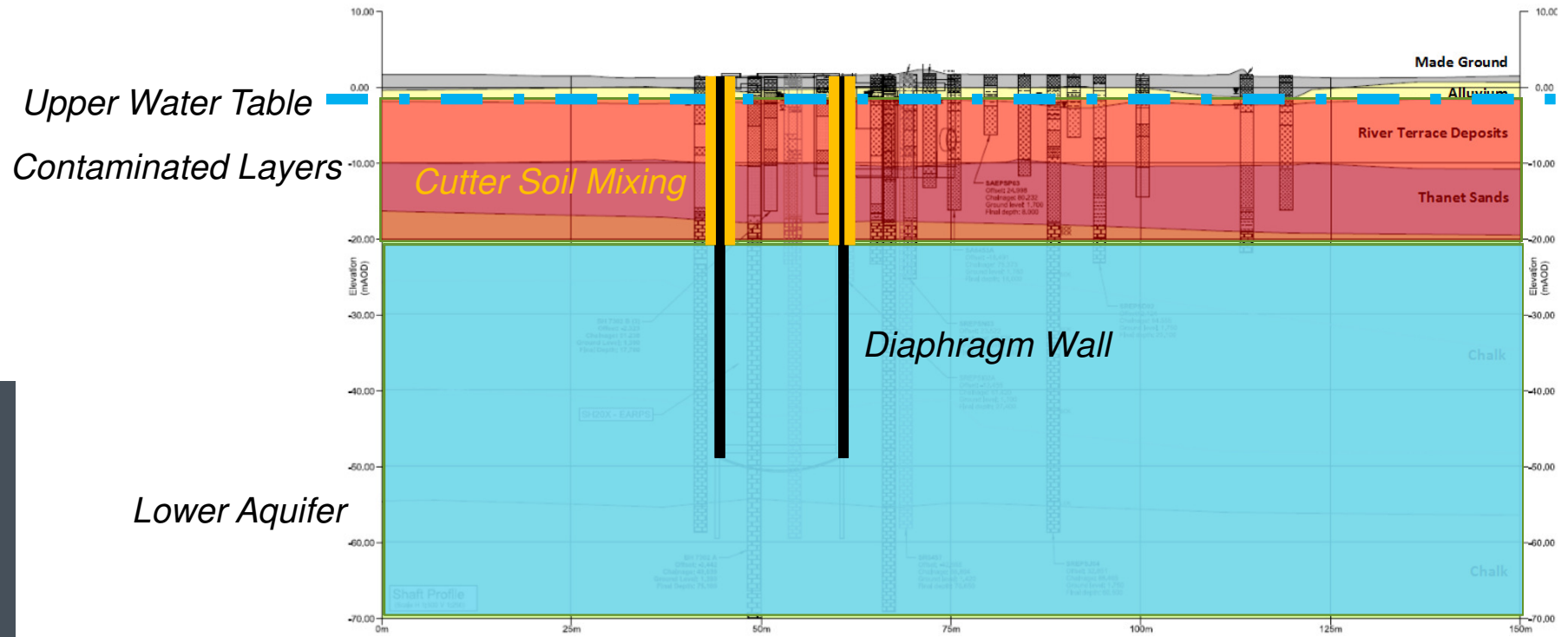
Site History

From the 1870's until the early 1900's, a former asphalt works was identified in the south east of the site.

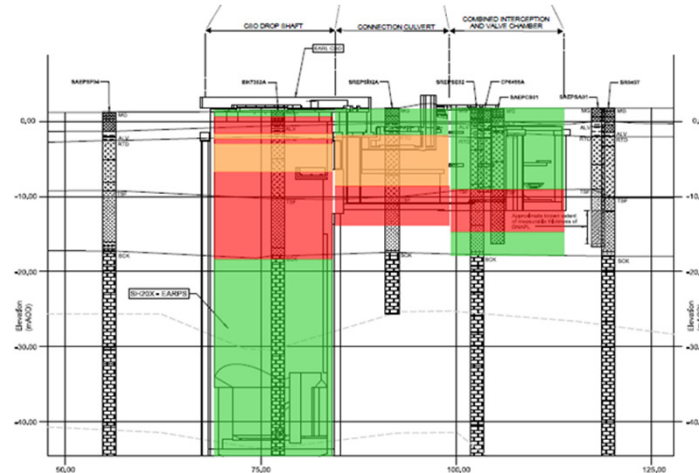
A tar, pitch, naphtha and creosote works was shown to extend south from the southern boundary with a wider tar works noted beyond. This larger tar works was situated on a plot known as Cannon Wharf, which has recently been redeveloped for residential and commercial purposes.



Geological profile

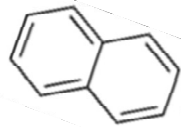


Contamination Constraints

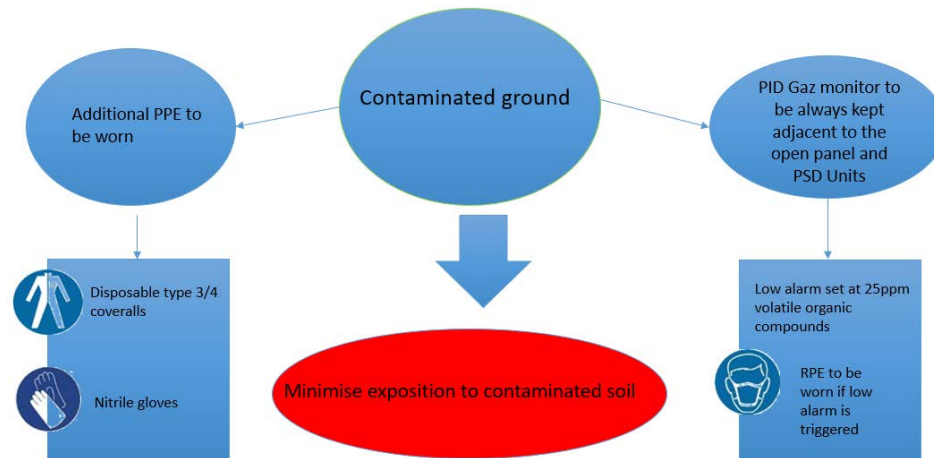


Contaminants of Concern:

- TPH Aromatics
- Naphthalene
- General Hydrocarbons



Presence of a significant and measurable thickness of Dense Non-Aqueous Phase Liquids (DNAPL). Based on the monitoring data collected over several years this contamination appeared to be confined to the TSF and is recoverable through the use of low flow pumping techniques.



Contamination management: Cutter Soil Mixing



Dropshaft excavation and passive dewatering



Dropshaft excavation and passive dewatering

All Tideway East shafts have been constructed using diaphragm walls to act as a means of cutting off any discrete water pressures above the chalk.

Therefore, it is groundwater pressures within the chalk, below the toe of the diaphragm wall that need to be managed during shaft construction.

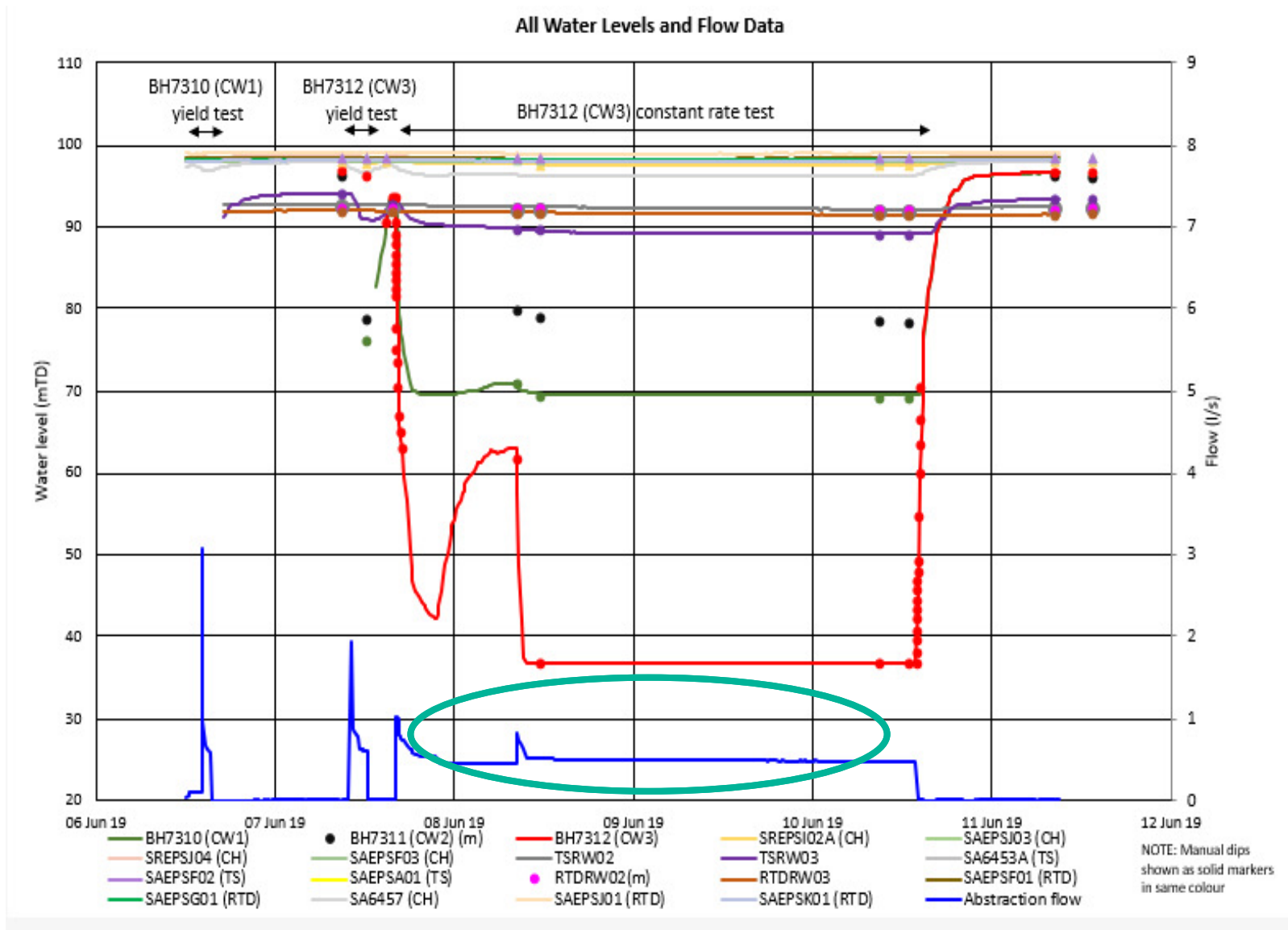
Passive relief wells were installed to enable passive dewatering from below the toe of the structure.

However, the groundwater control strategy needed to adhere to works information requirements:

dewatering shall only be permitted where the lowered groundwater levels or reduced pore water pressures are constrained to within the physical extents of the Worksite.

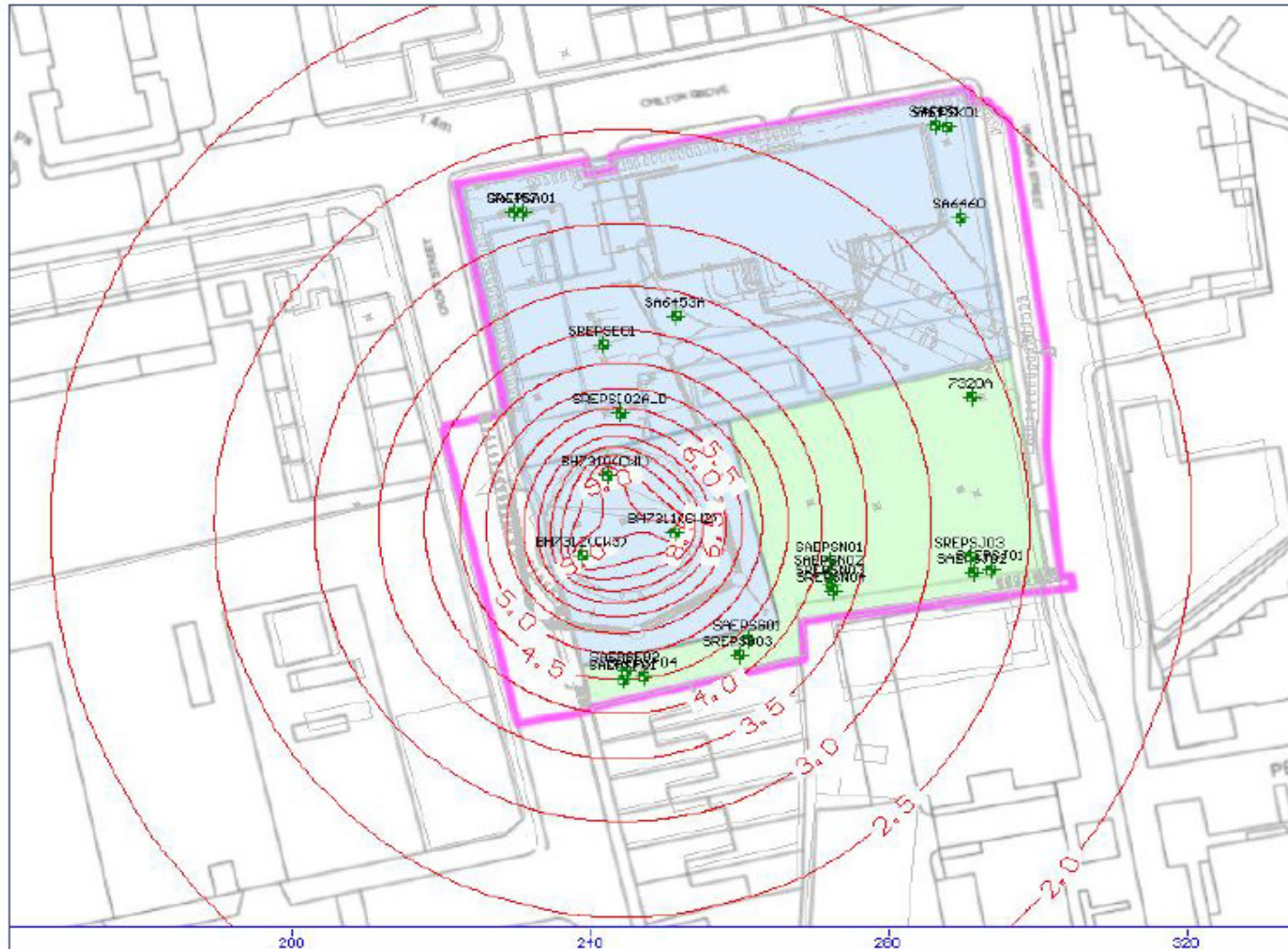


Post diaphragm wall pumping test



Modelling of passive dewatering

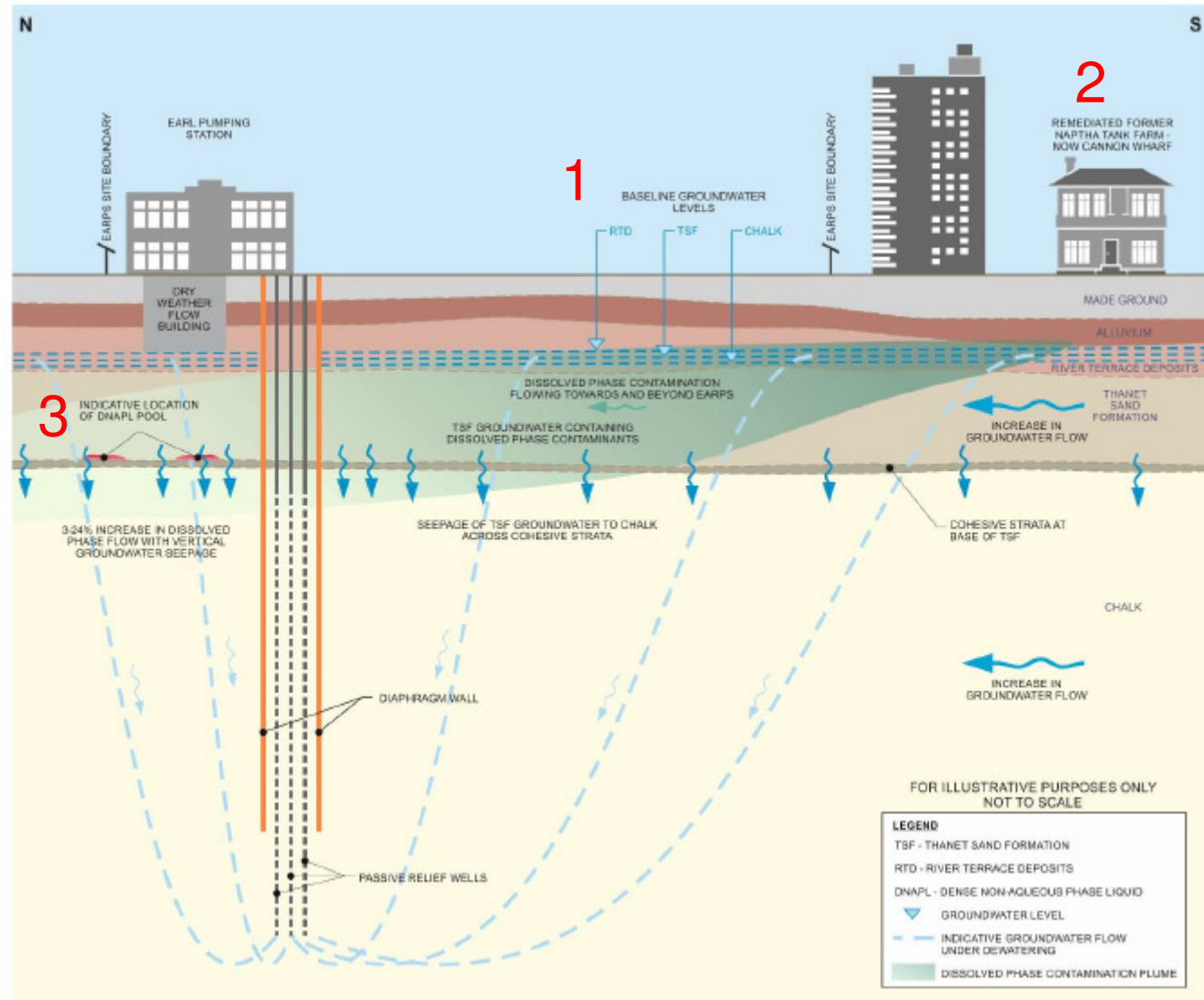
Steady state 3D numerical model



Contamination assessment

Three potential risk scenarios that could have arisen during the proposed dewatering for shaft construction.

- 1) Dissolved phase contamination originating on-site, but outside of the shaft footprint
- 2) Dissolved phase contamination originating from off-site sources in the TSF and Chalk being drawn into zone of PRW
- 3) Mobilisation of the known DNAPL source in the north west corner of the site, pooled at the base of the TSF

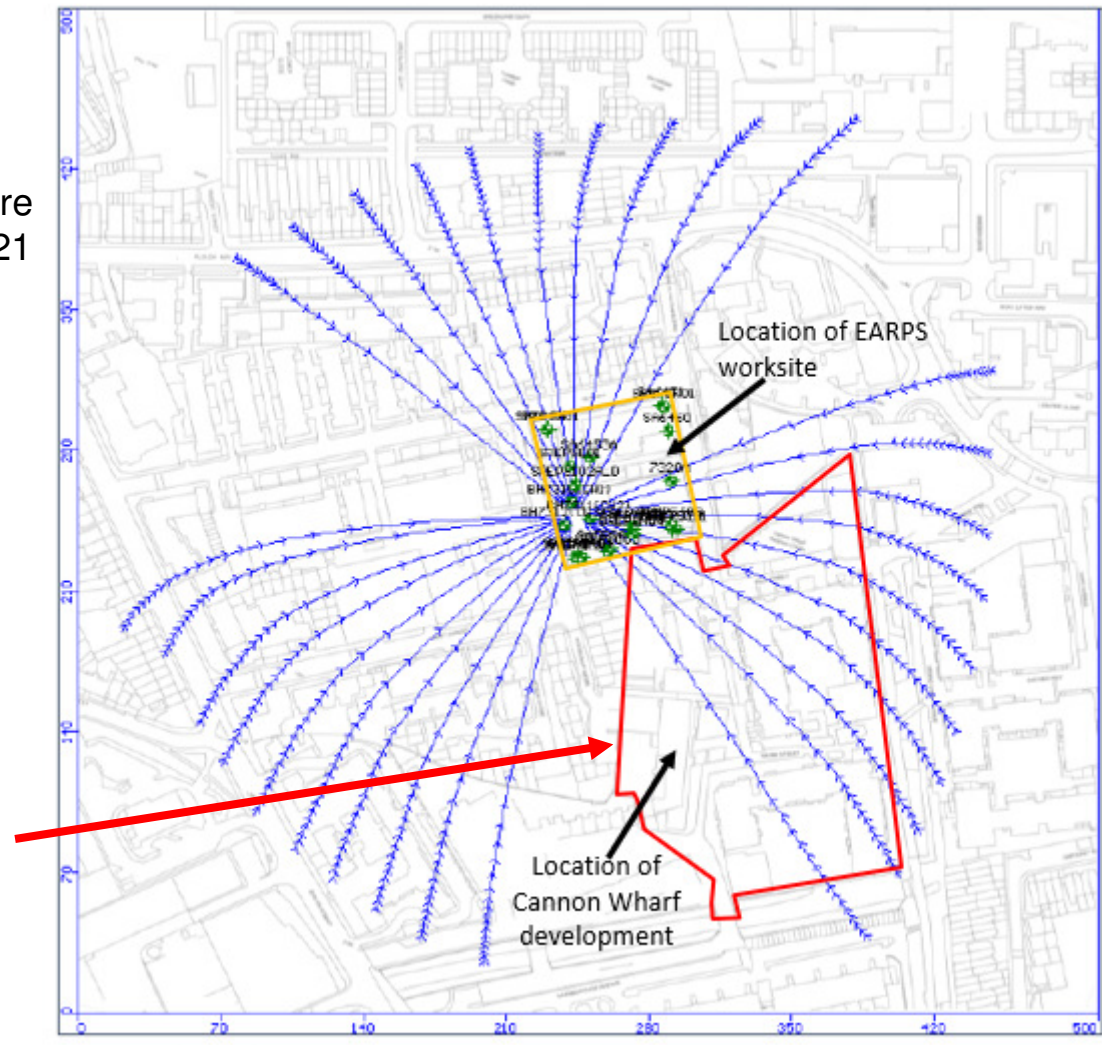


Contamination assessment

Potential dissolved contamination capture modelled over an operational period of 21 months.

Markers spaced approximately monthly.

This contribution is predicted to come from dissolved phase contaminations (both on and off site) to the south, extending in a plume of up to 120m towards the former Naptha works to the south.



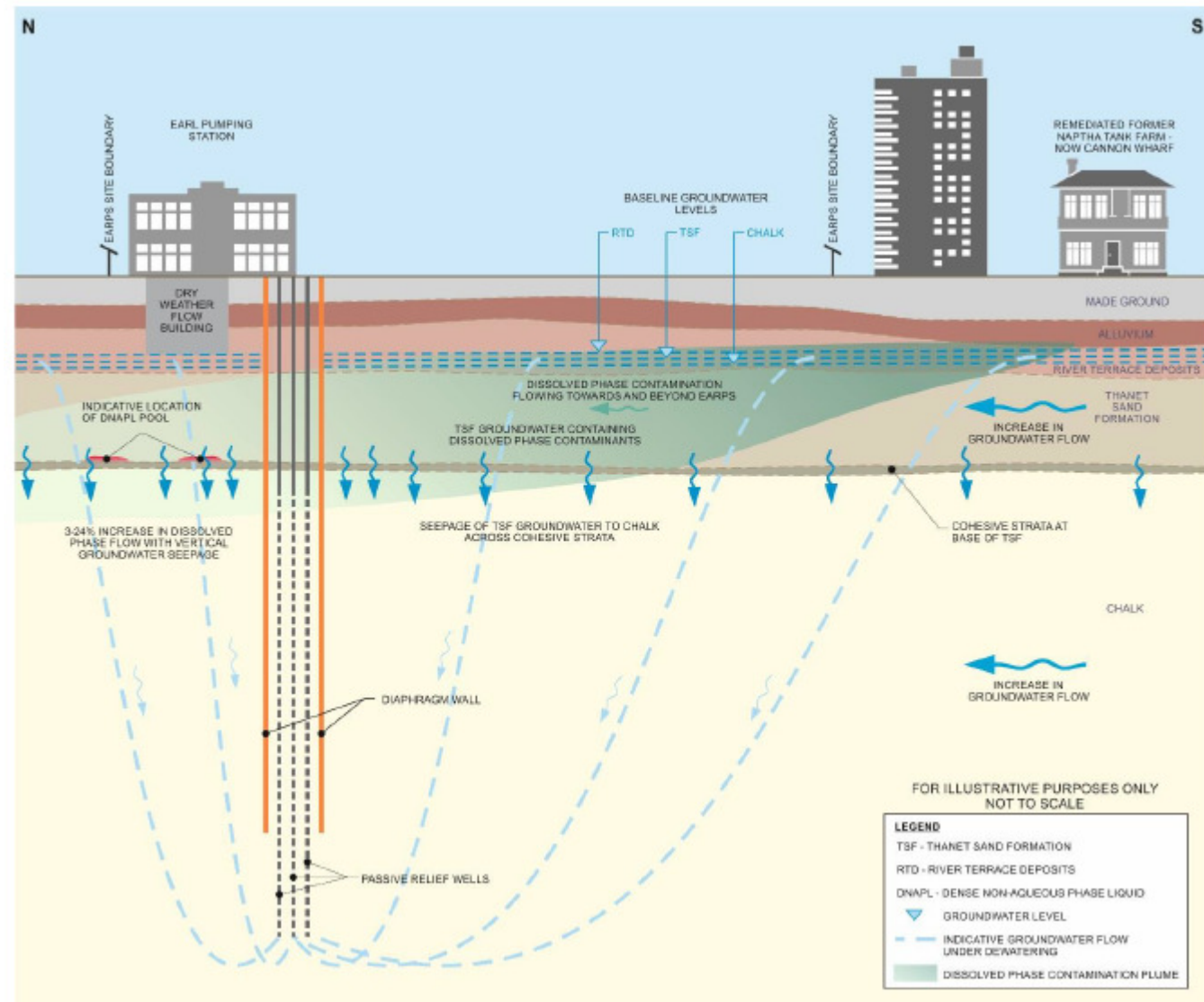
Contamination assessment

Upper aquifer

- Negligible change expected during the dewatering works due to minimal drawdown in the RTD and TSF

Lower aquifer

- Short term- Greater contribution of dissolved phase contamination entering from the upper aquifer
- Medium to long term- groundwater quality from off-site sources flowing beneath the worksite could be beneficial rather than detrimental to dissolved phase contaminant concentrations.





Consenting the dewatering

- Abstraction license for groundwater dewatering- usually takes 4 months to apply for and consent.
- Submission of groundwater monitoring plan and groundwater control method statement- to EA and Client for formal acceptance. Detailing control measures and monitoring strategy.
- Preparation of contractual report assessing the risks of the dewatering, in order to deviate from the works information requirements.
- Preparation of a non technical report for Thames Water to review, for approval of proposed dewatering and subsequent quality impacts



EARL PUMPING STATION


Shaft excavation dewatering works

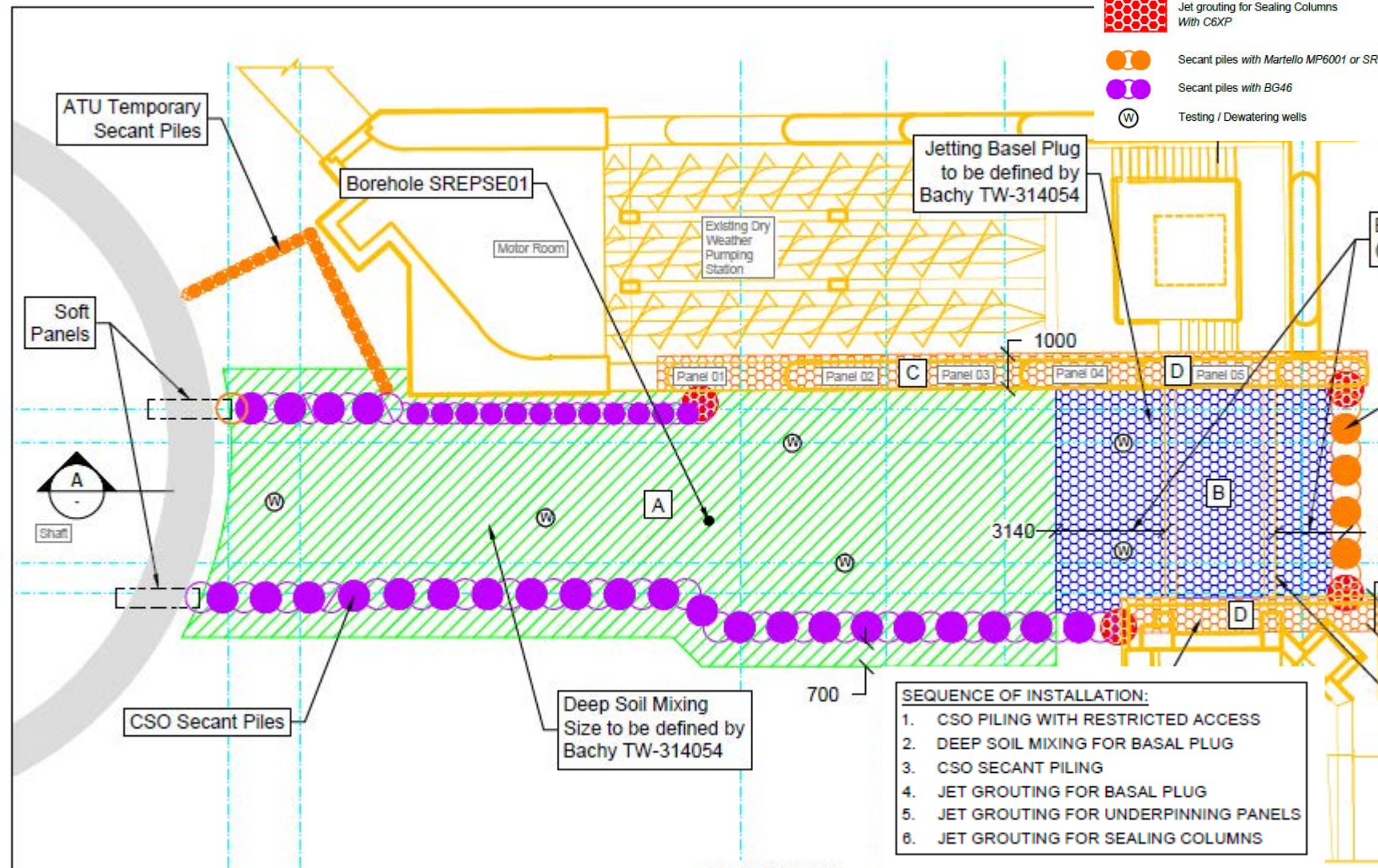
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Function	Organisation			Location	Work Type	Content	Doc. Type	Number																		
S	S	0	0	C	V	B	J	V	E	A	R	P	S	1	8	2	X	Z	R	G	0	0	4	S	7	6
Date				15/08/2019				Revision				P			0			1								

Tideway Project Manager/Supervisor Review and Acceptance Decal	
<input type="checkbox"/>	Accepted. Work May Proceed
<input type="checkbox"/>	Accepted with Comments. Revise and resubmit. Work may proceed subject to incorporation of changes indicated
<input type="checkbox"/>	Rejected. Revise and resubmit. Work may not proceed
<input type="checkbox"/>	Received for information only. Receipt is confirmed
Reviewed/Accepted by (signature):	
Print Name:	Date:

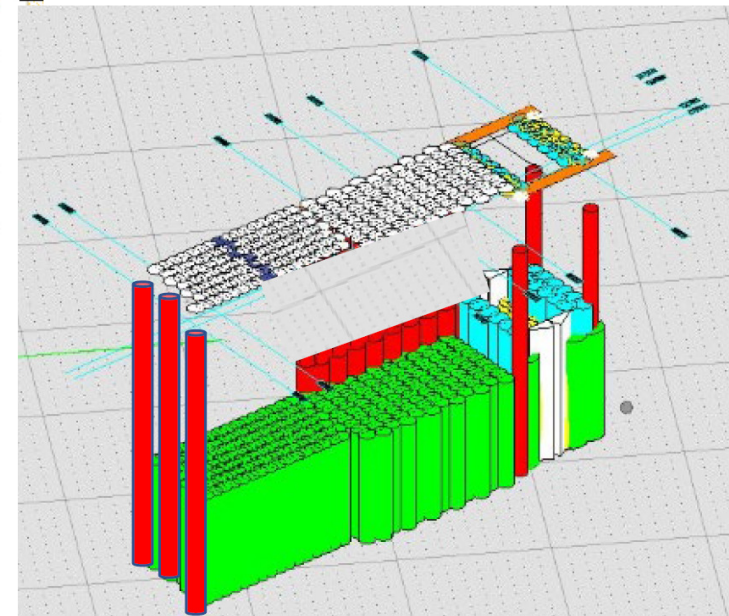
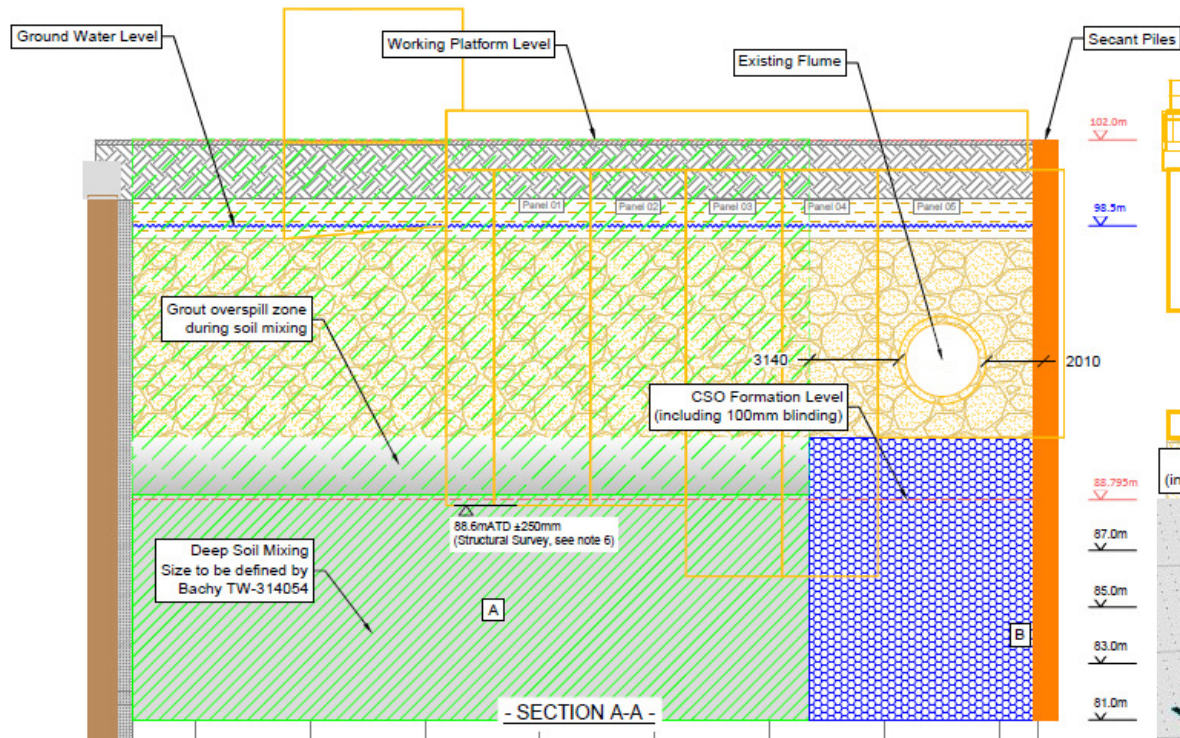
2021 - Construction of interception chamber

Ground improvement requirements:
refer to TW-314203 Gate 5

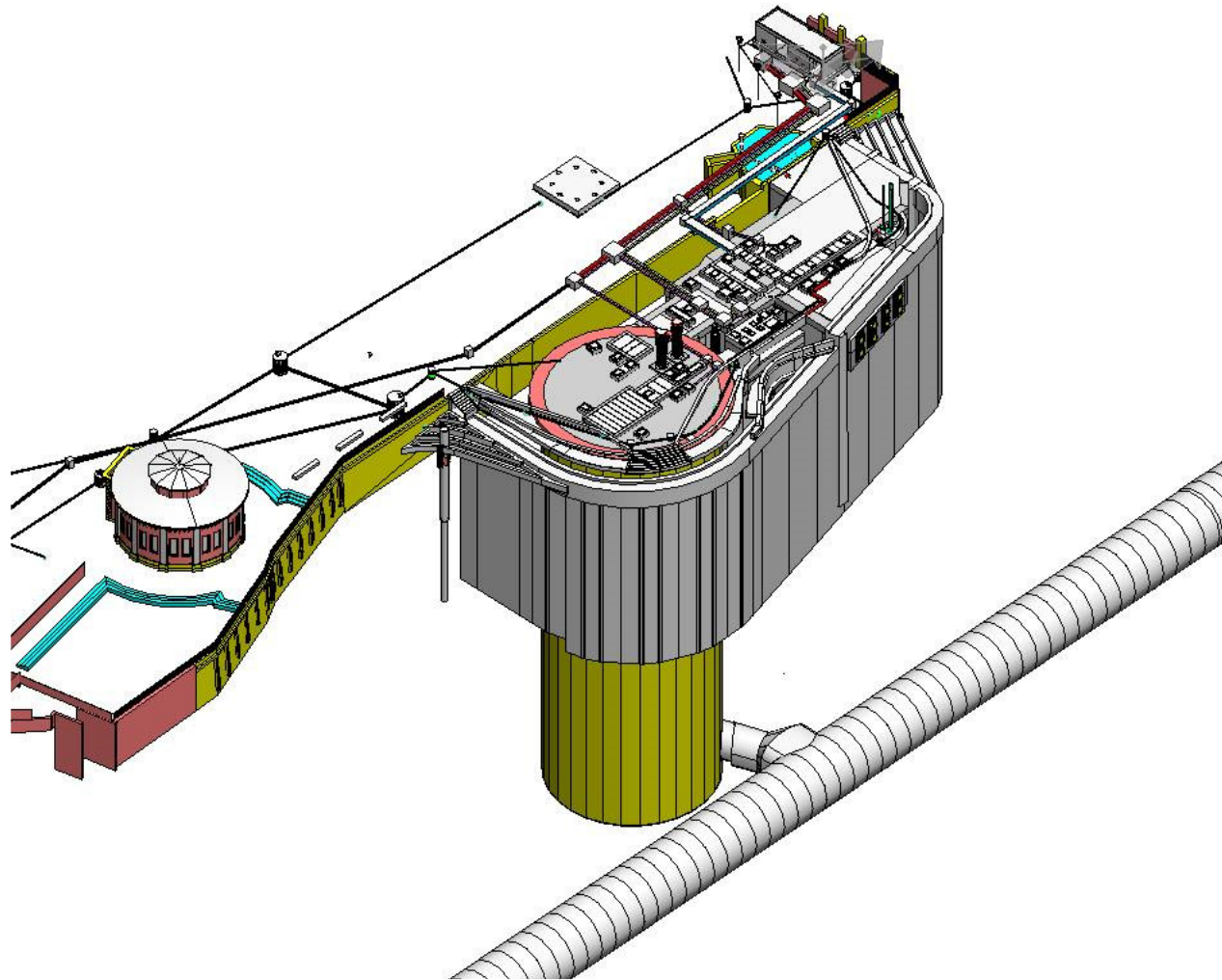
-  Deep Soil Mixing for Basal Plug
With BG46
-  Jet grouting for Basal Plug
With C6XP
-  Jet grouting for Underpinning Panels
With C6XP
-  Jet grouting for Sealing Columns
With C6XP
-  Secant piles with Martello MP6001 or SR-45 rotary pile
-  Secant piles with BG46
-  Testing / Dewatering wells



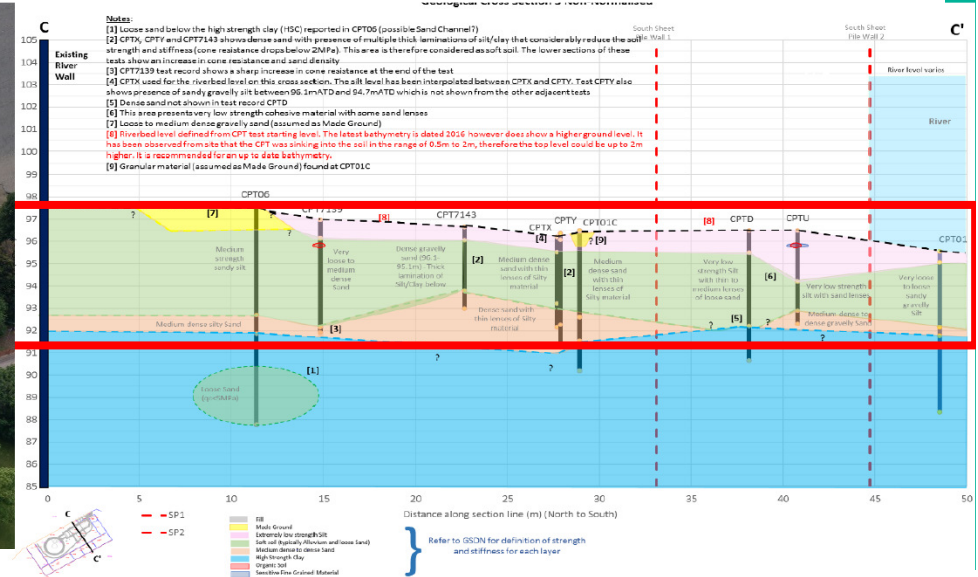
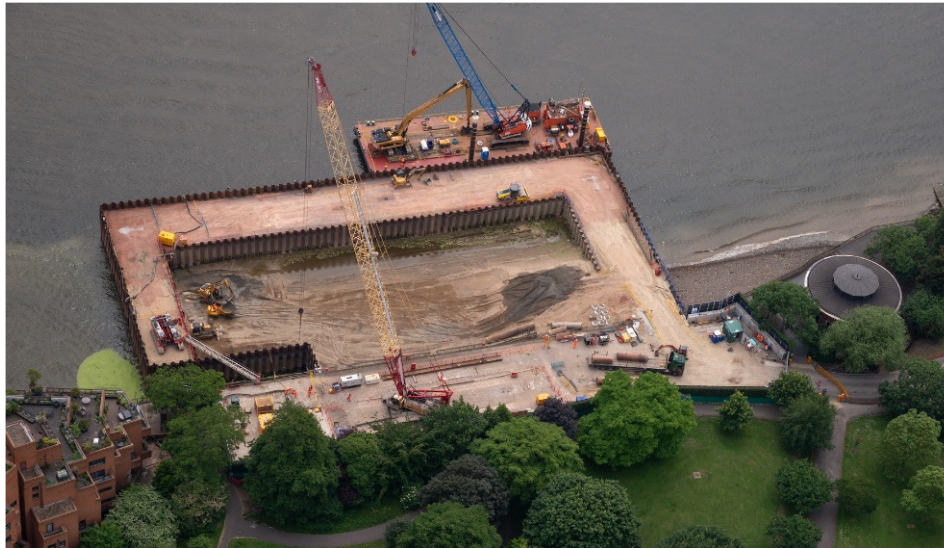
Future developments: Construction of interception chamber



King Edward Memorial Park Foreshore – Overcoming unforeseen ground conditions



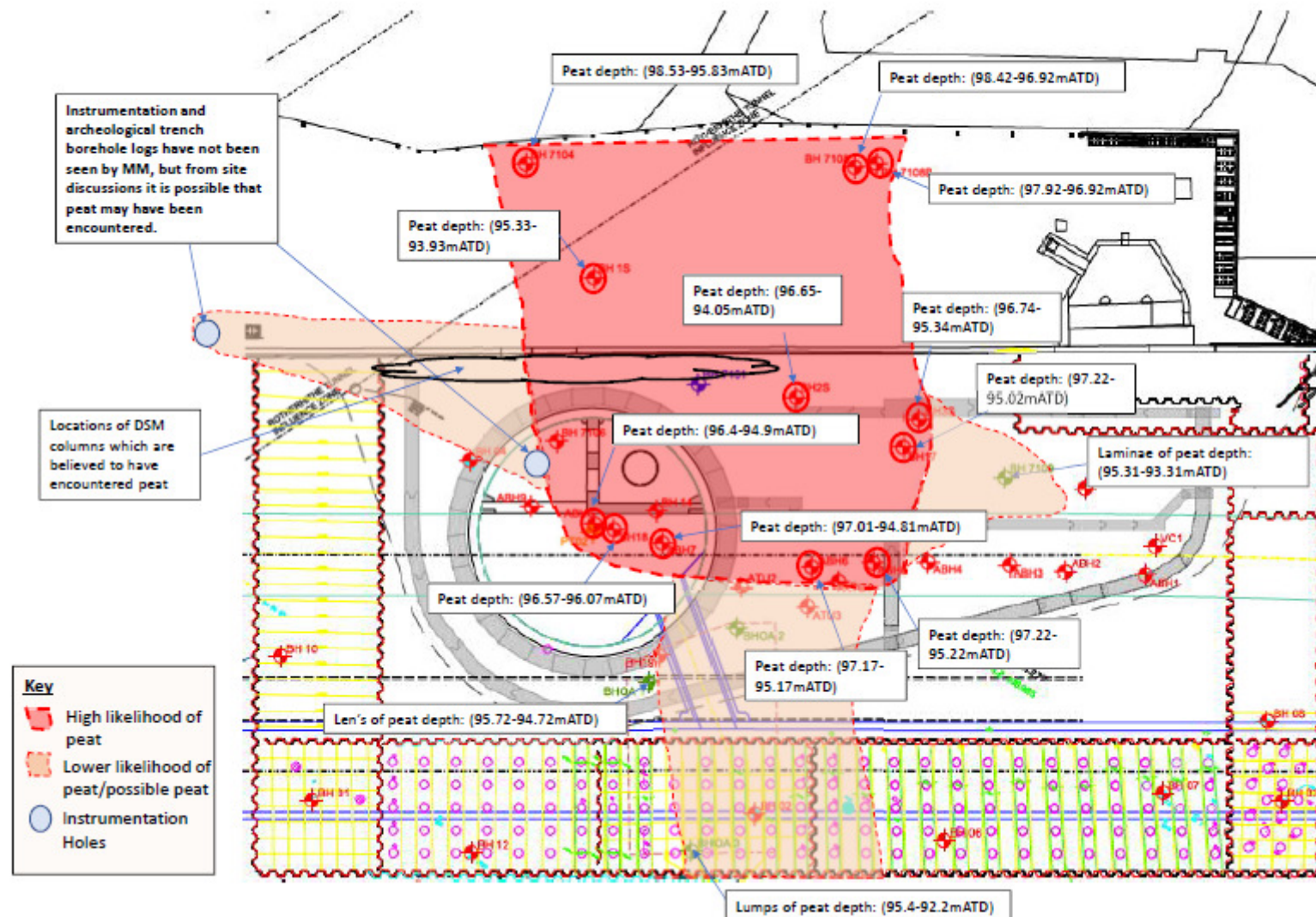
KEMPF Geotechnical Challenges



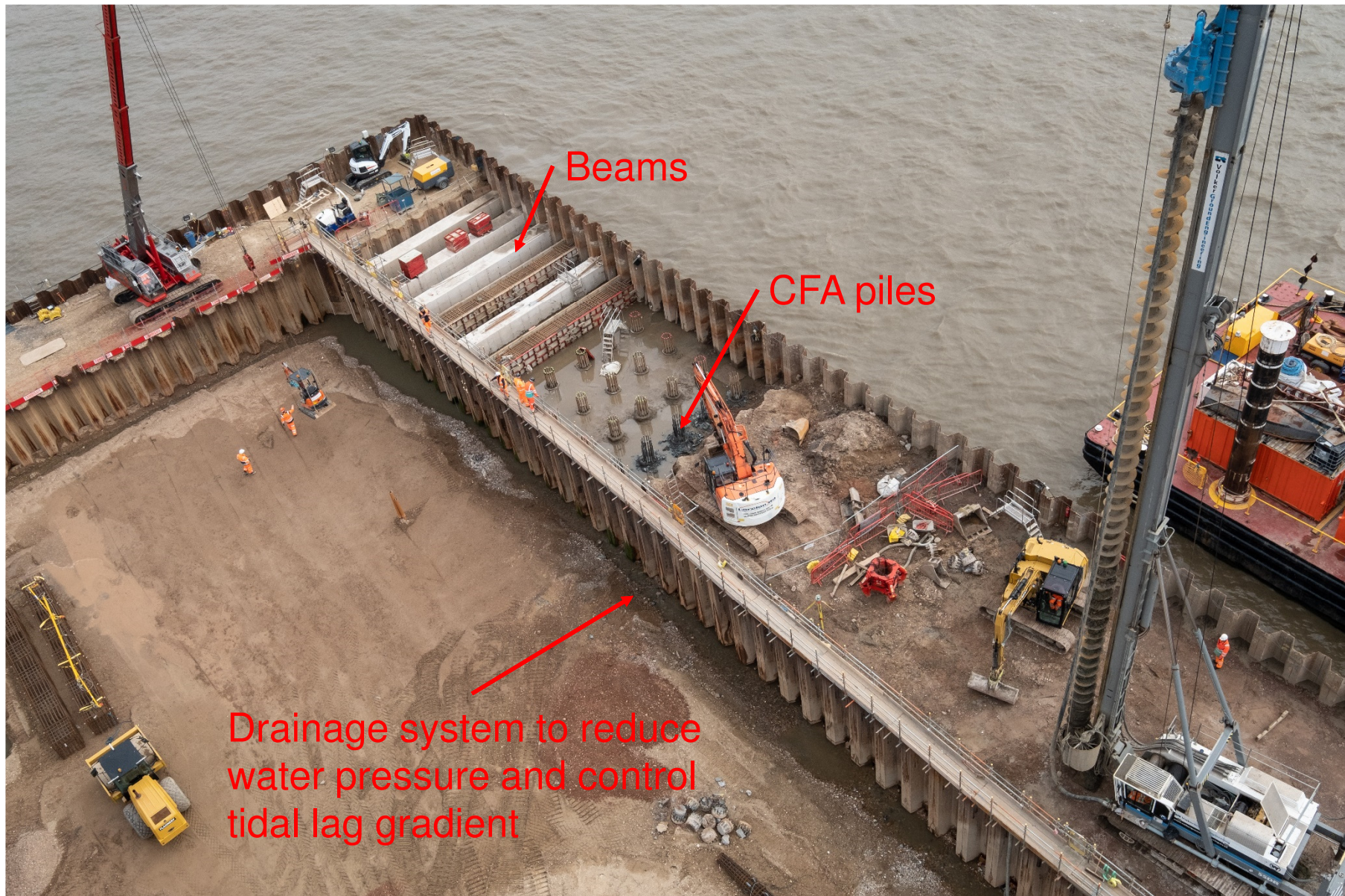
- Sheet pile deflection observed during twin wall backfilling operations
- Campaign of >50 CPTs and >15 BHs in the cofferdam footprint undertaken
- Significant variation of material type laterally & vertically across footprint
- Presence and variation in thickness of extremely low strength alluvial silt / clay (1.5 to 6m thick). c' of between 0-2kPa. C_u of 1-20kPa. Bulk density 10-20kN/m².
- Compressible material - > potential for differential loading on temporary & permanent works and differential settlement
- Variation or even absence of RTD thickness
- Lower than expected strength at the top of the Lambeth Group cohesive layer.
- Root cause = historic channel feature entering the foreshore from the NE of the cofferdam and trending S across footprint ? Possibly linked to a historic river tributary or sewer but nothing shown on maps >1746AD ?

KEMPF Geotechnical Challenges

Plan 2 Interpreted peat zones based on peat encounters on KEMPF foreshore

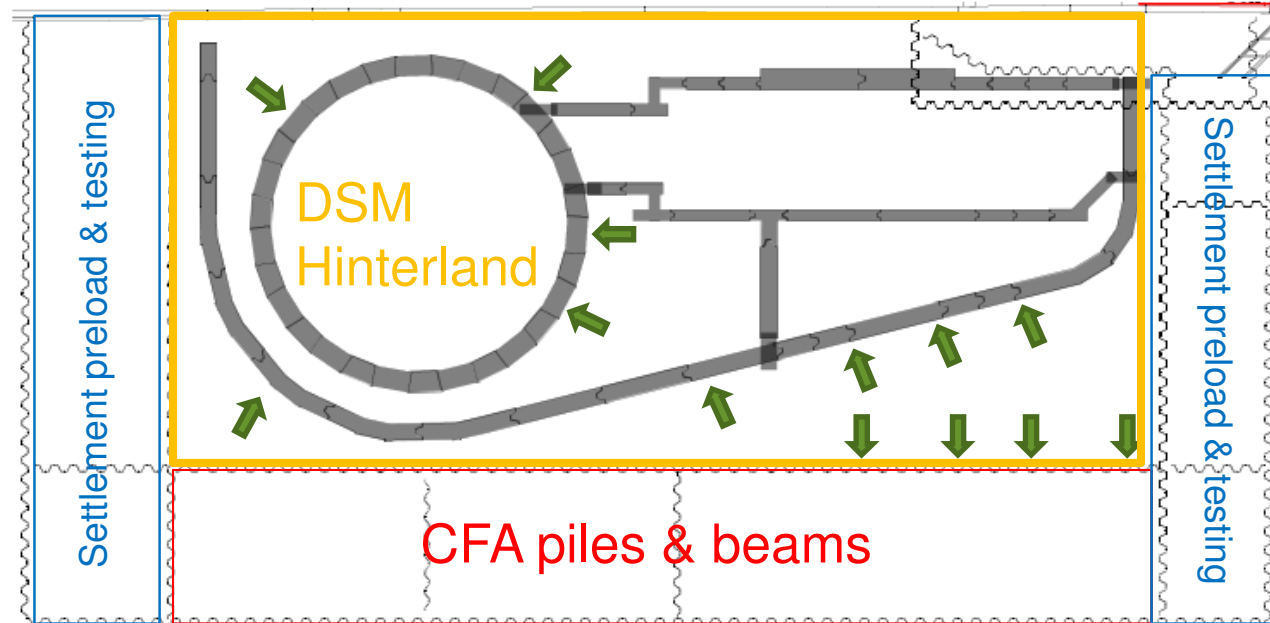


KEMPF Initial Mitigation Measures



KEMPF Deep Soil Mixing Mitigation

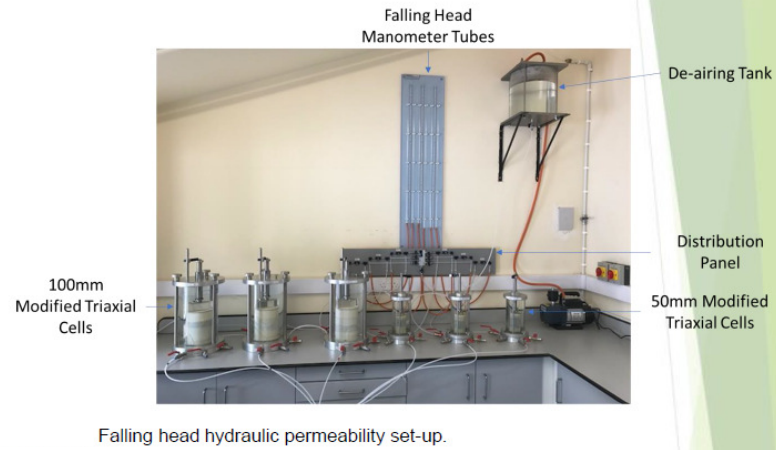
- **Guide walls stability**
- **D-walls stability while excavating**
- **Lower pressure on cofferdam**
- **Lower pressure on river wall and CSO**
- **Settlement control**



KEMPF Mix Design Binder Dosage Trials



Figure 3: The addition of bentonite mix to the horizontal pan mixer



Falling head hydraulic permeability set-up.



Figure 1: Photograph of the Silverson L4RT homogeniser used to thoroughly mix the separate slurry and binder mixes.



Figure 2: A photograph of the mud balance and density marsh cone viscosity tests which ensure the consistent quality of testing materials.



Figure 4: A photograph of the vibrating table used to remove air bubbles from the bentonite/ slurry mix.

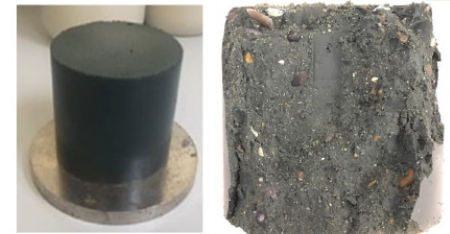


Figure 4.1. 100mm monolithic specimen from RTD MD1.

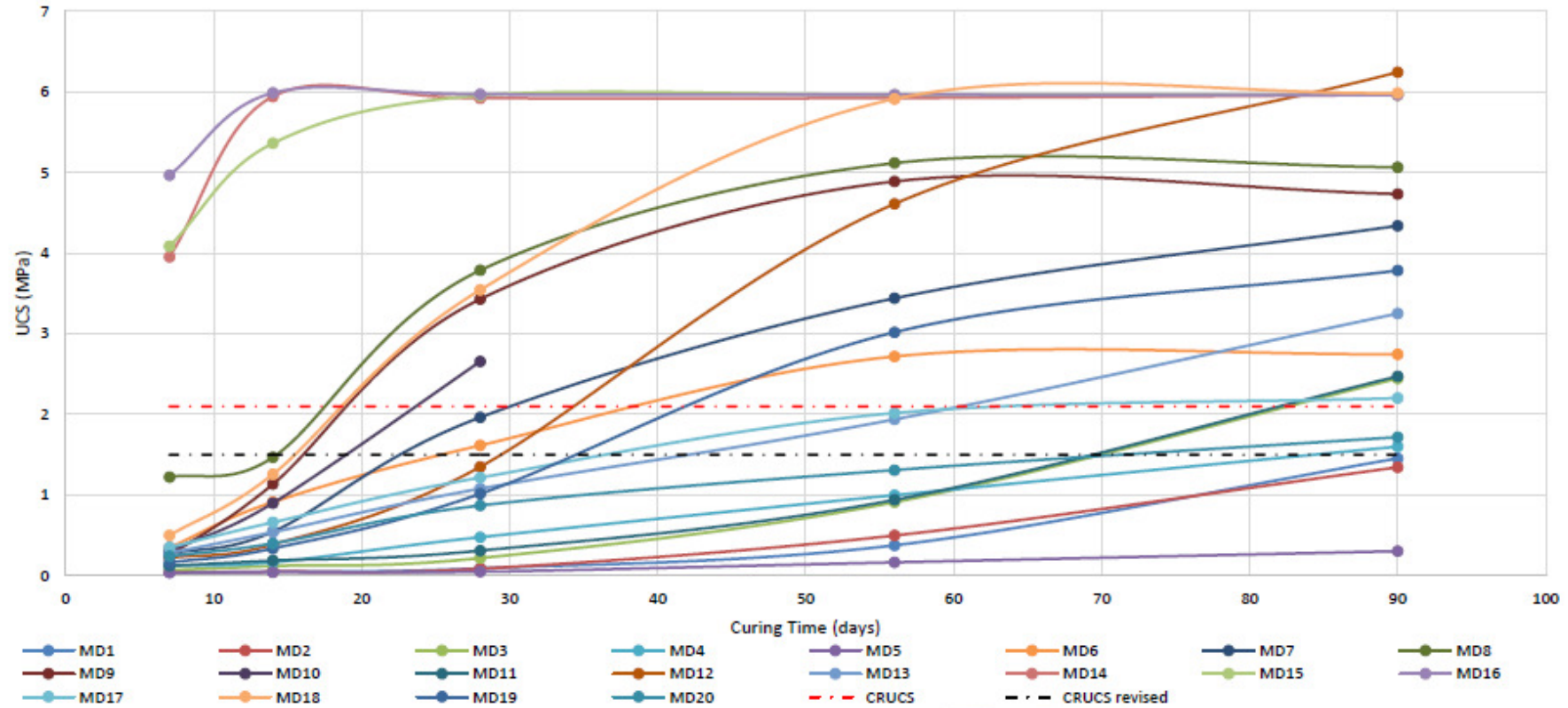


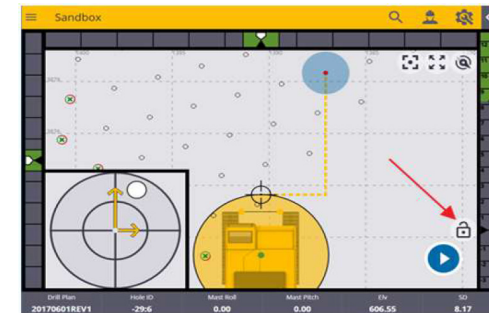
Figure 6.1 Average UCS (n=3 for 7, 14, 56 & 90 day) (n=6 for 28 day).

20 different mix designs trialed

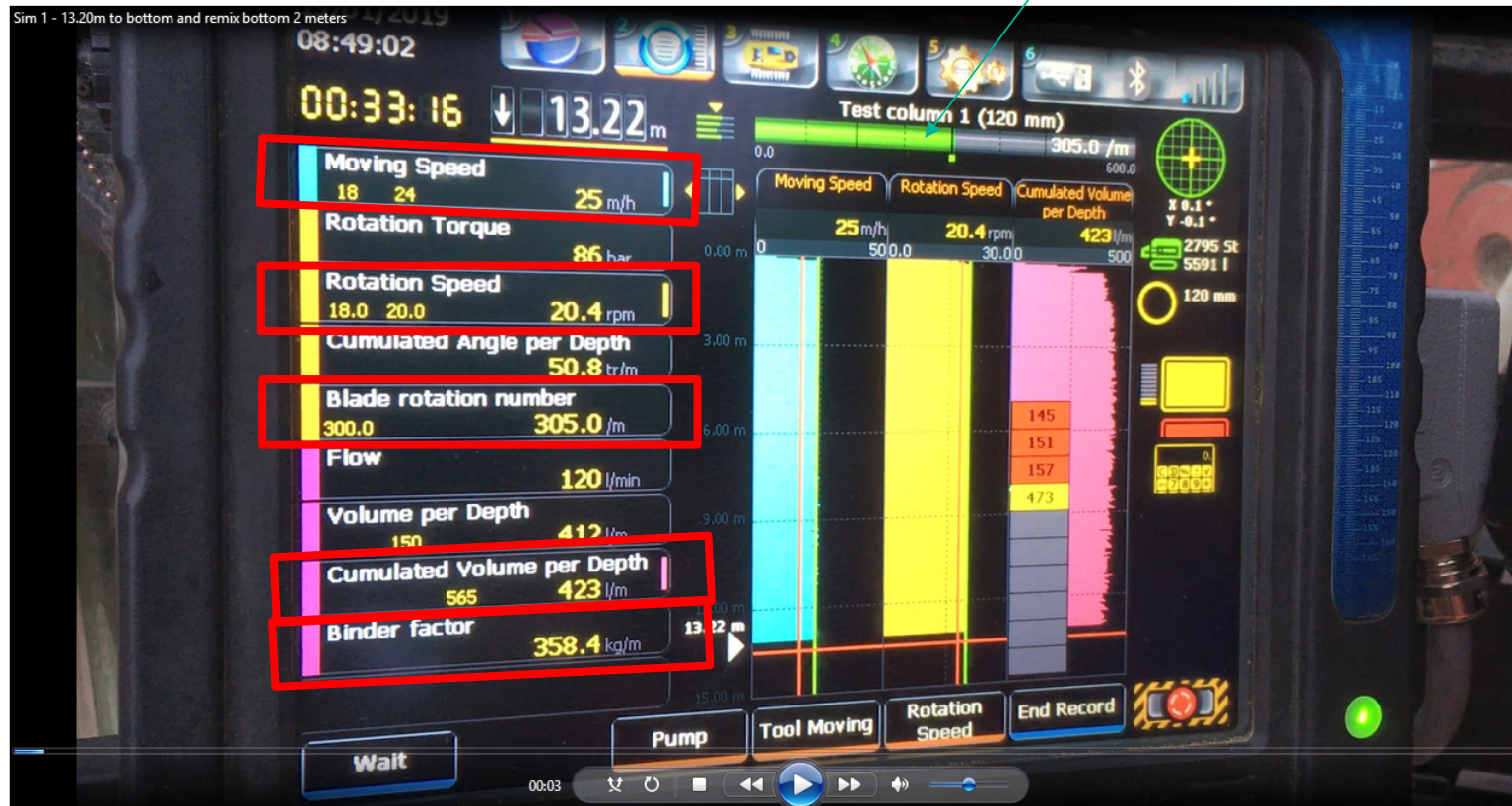
CEMI / GGBS	Lithology	Mix Design	Binder Dose kg/m ³	90x50mm specimens no.	100x100mm specimens no.	100x200mm specimens no.
20/80%	Made Ground I	MD1	220	0	18	6
	Made Ground I	MD2	275	0	18	6
	Made Ground I	MD3	325	0	18	6
	Peat I	MD4	300	18	0	6
	Peat I	MD5	225	18	0	6
	Peat I	MD6	435	18	0	6
	Alluvial Clay	MD7	220	18	0	6
	Alluvial Clay	MD8	445	18	0	6
	Alluvial Clay	MD9	325	18	0	6
35/65%	Made Ground I	MD10	325	1	8	6
	Made Ground II	MD11	325	18	0	6
	Made Ground II	MD12	400	18	0	6
	Made Ground II	MD13	435	18	0	6
	Hinterland	MD14	220	0	18	6
	Hinterland	MD15	275	0	18	6
	Hinterland	MD16	325	0	18	6
	Peat II	MD17	435	18	0	6
	Made Ground III	MD18	500	0	18	6
	Made Ground III	MD19	367	0	18	6
	Made Ground IV	MD20	500	18	0	0

KEMPF Deep Soil Mixing Controls

- Groundworks Trimble system for positioning
- Directing the rig on top of the column +/- 25mm accuracy



BRN



KEMPF Deep Soil Mixing Mitigation

DSM & Coring production
12/09/2019

- Today
- from Start of works
- ▣ Restricted areas
- Obstructions
- Double mixed
- Cores backfilled

Columns Done : 1237

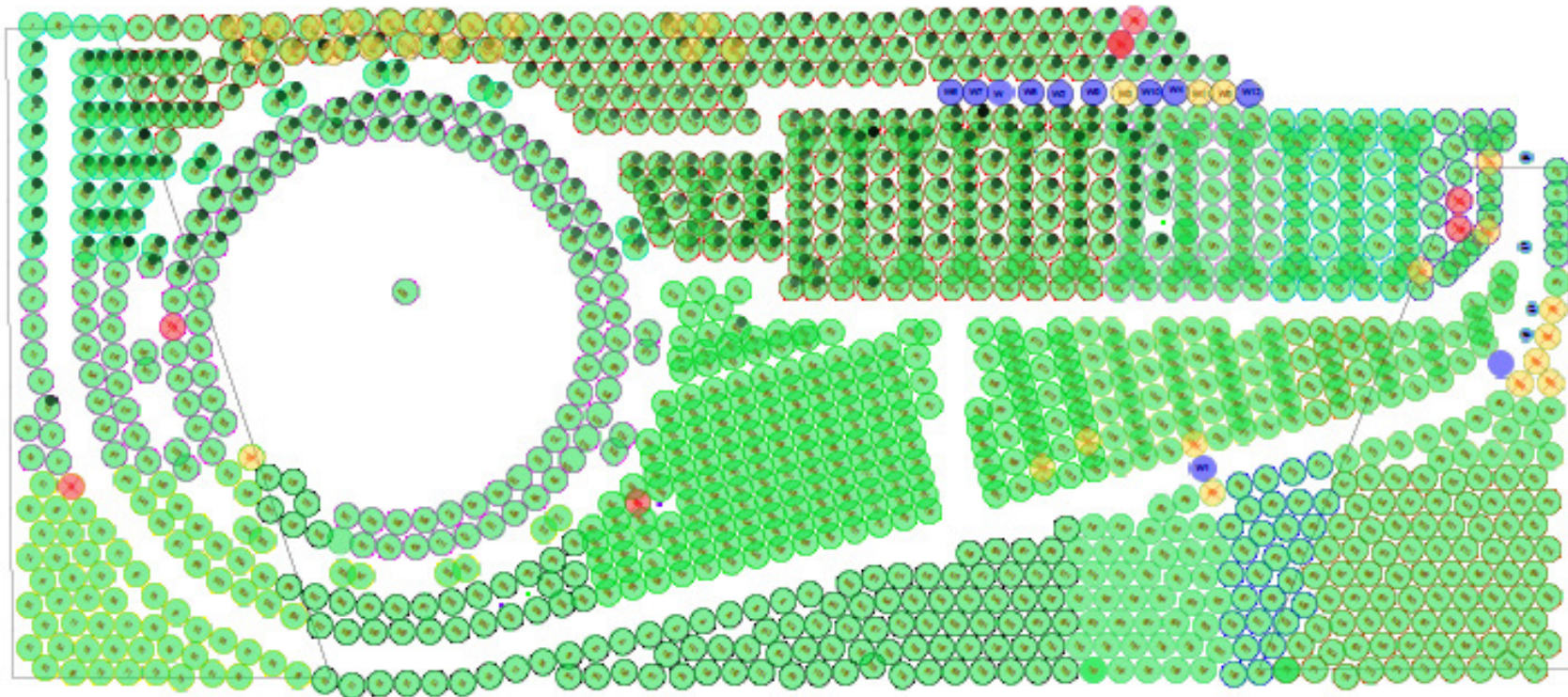
Columns Remaining : 0

Obstructions left as is : 7

Obstructions cored : 16

Remedial piles done : 19

Remedial bored piles remaining: 0



KEMPF Deep Soil Mixing Mitigation

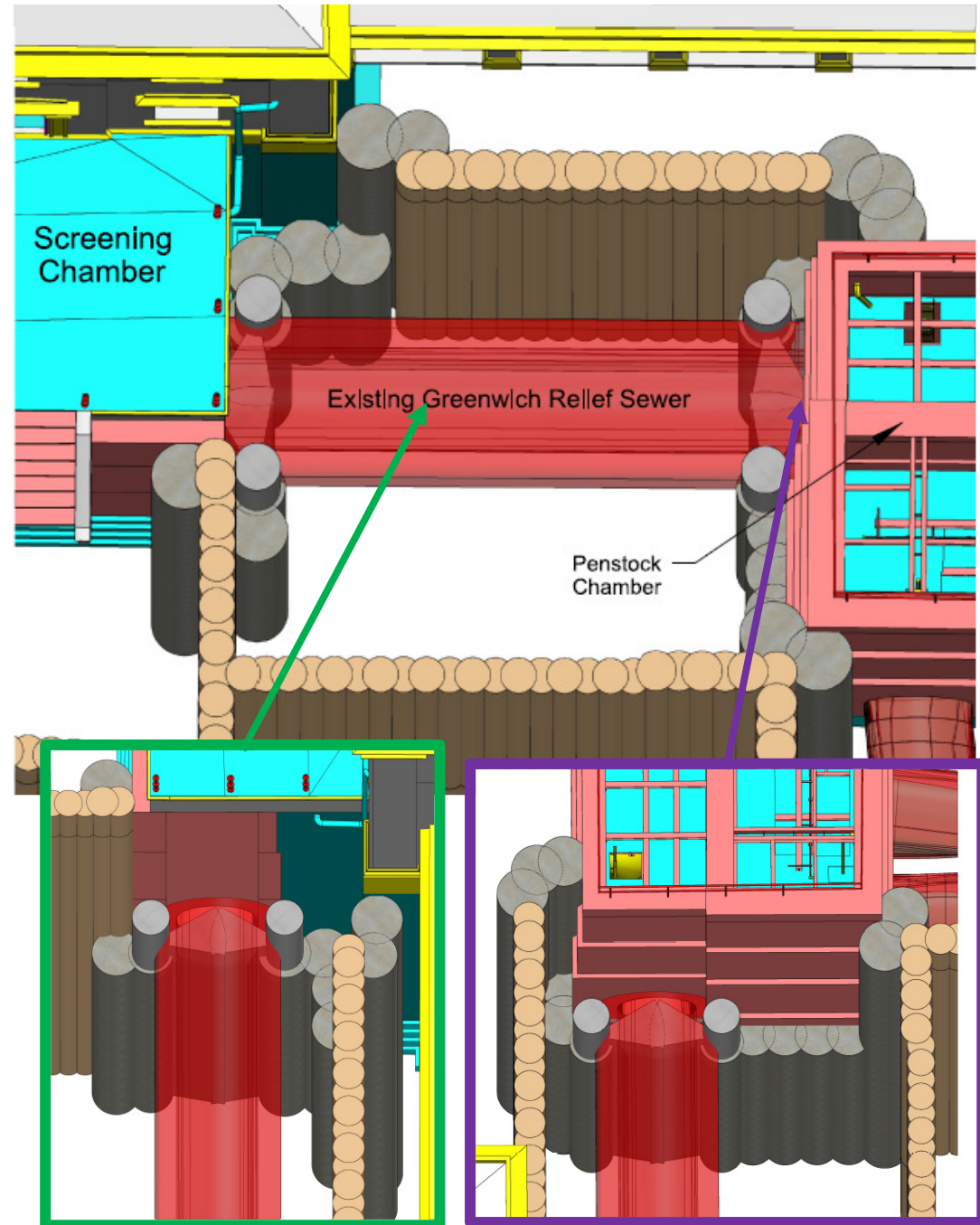




**Greenwich Pumping Station – Jet Grouting
adjacent to live Thames Water Assets**

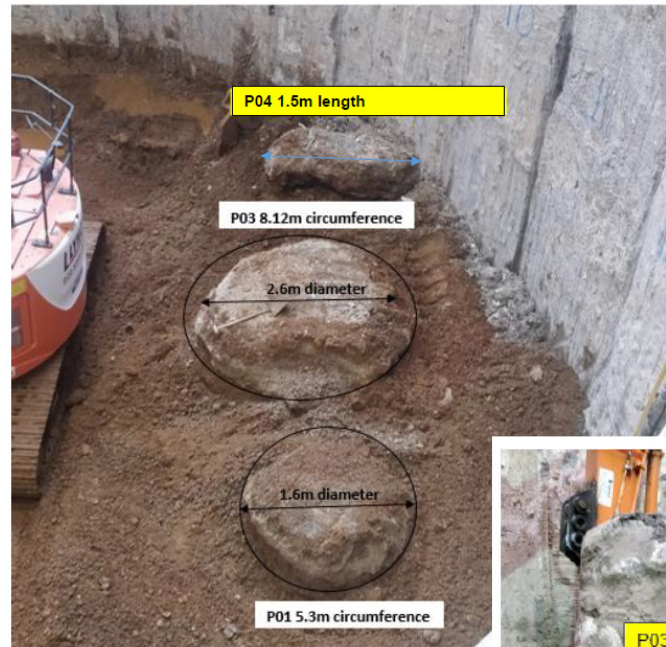
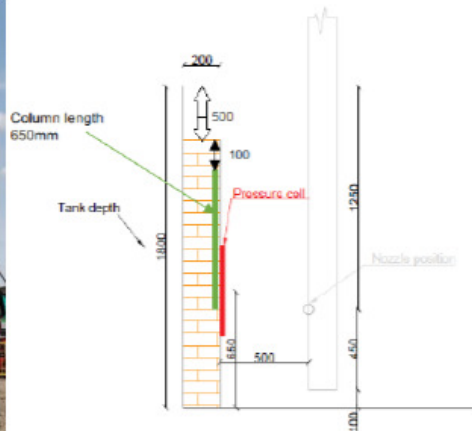
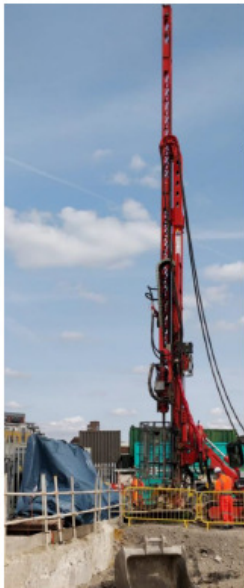
Greenwich Pumping Station – Jet Grouting

- 22 jet columns (1.2 or 1.4m dia)
- Panel jet x 4 under sewer
- Positions as close as 300mm from asset
- Undertaken during COVID
- c. 2,450m³ grout used
- 225-330 ltrs/min pump rate
- 240-400 bar at the nozzle
- c. 180 hrs jetting in total



Greenwich Pumping Station – Jet Grouting Trials (July '18)

Pressure Sensor Trial



Trial columns in shaft in RTDs and TSF

Greenwich Pumping Station – Jet Grouting Impact Modelling

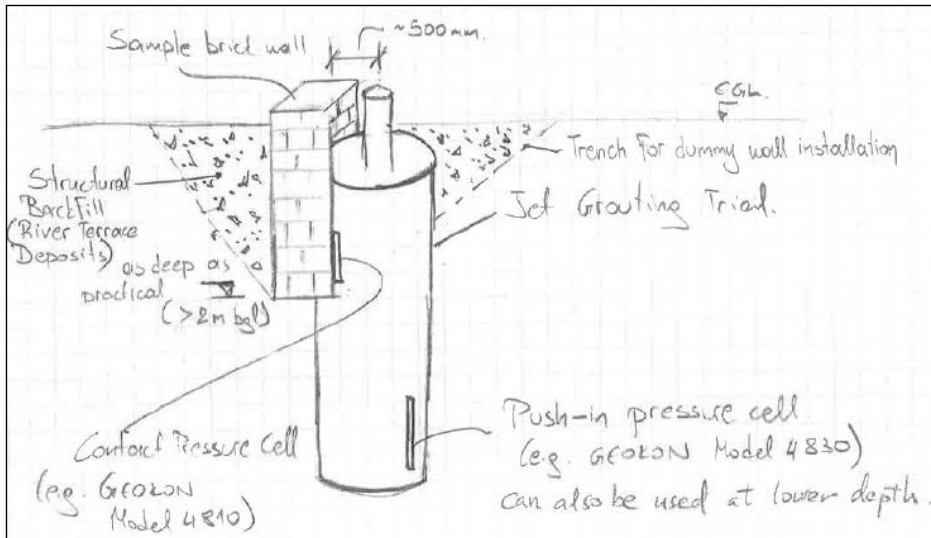


Figure 8.8 – Cross section of Screening Chamber with applied horizontal pressures

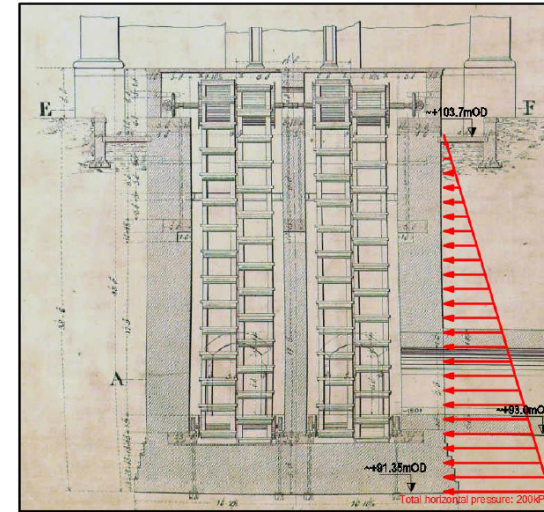
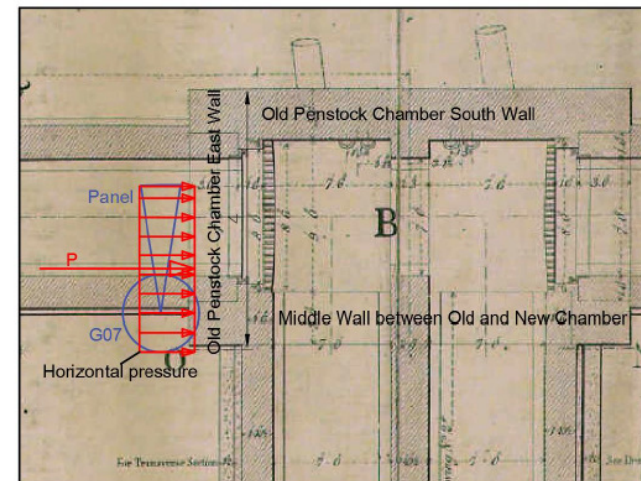
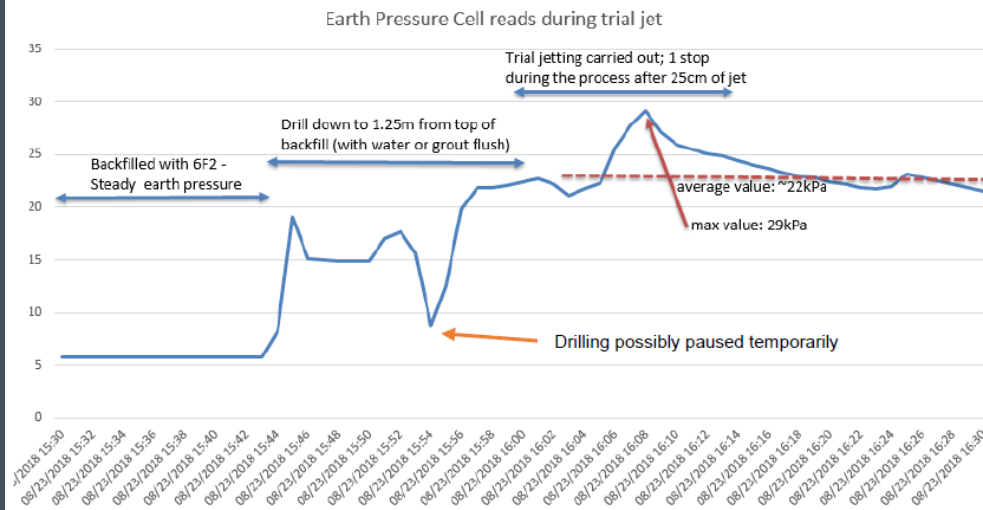


Figure 8.9 - Horizontal pressures from G07 and adjacent panel



Greenwich Pumping Station

Lengthy approvals process with TWUL for the works but excellent industry progress on understanding impact effects through works undertaken in conjunction with Wentworth House.

Grade II listed building very close – Rig 3D laser scan to review clashes.

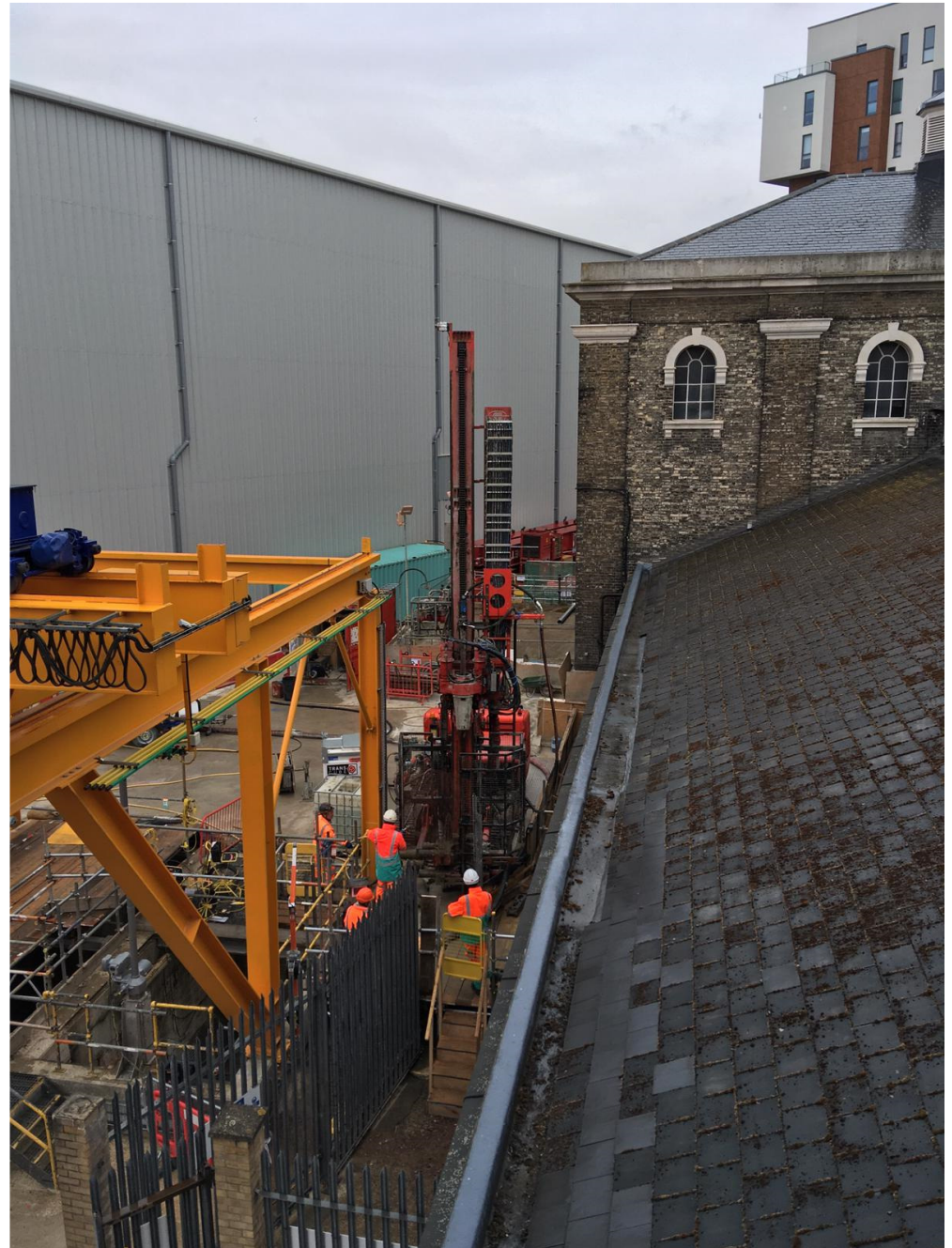
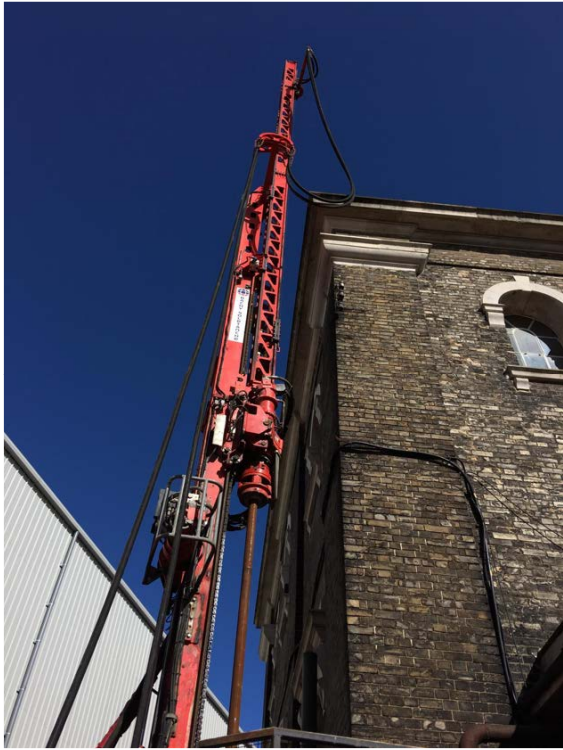
Live CCTV monitoring of sewer as part of LONO conditions.

Ongoing liaison throughout the works. Credit to site team during COVID.

Challenges around flush loss and spoil return next to adjacent assets due to high permeability ground and voids from old pipes and infrastructure. Site team “stop and consult” attitude built trust.

Jet grouting is not the destructive process some perceived.







 **hank You**