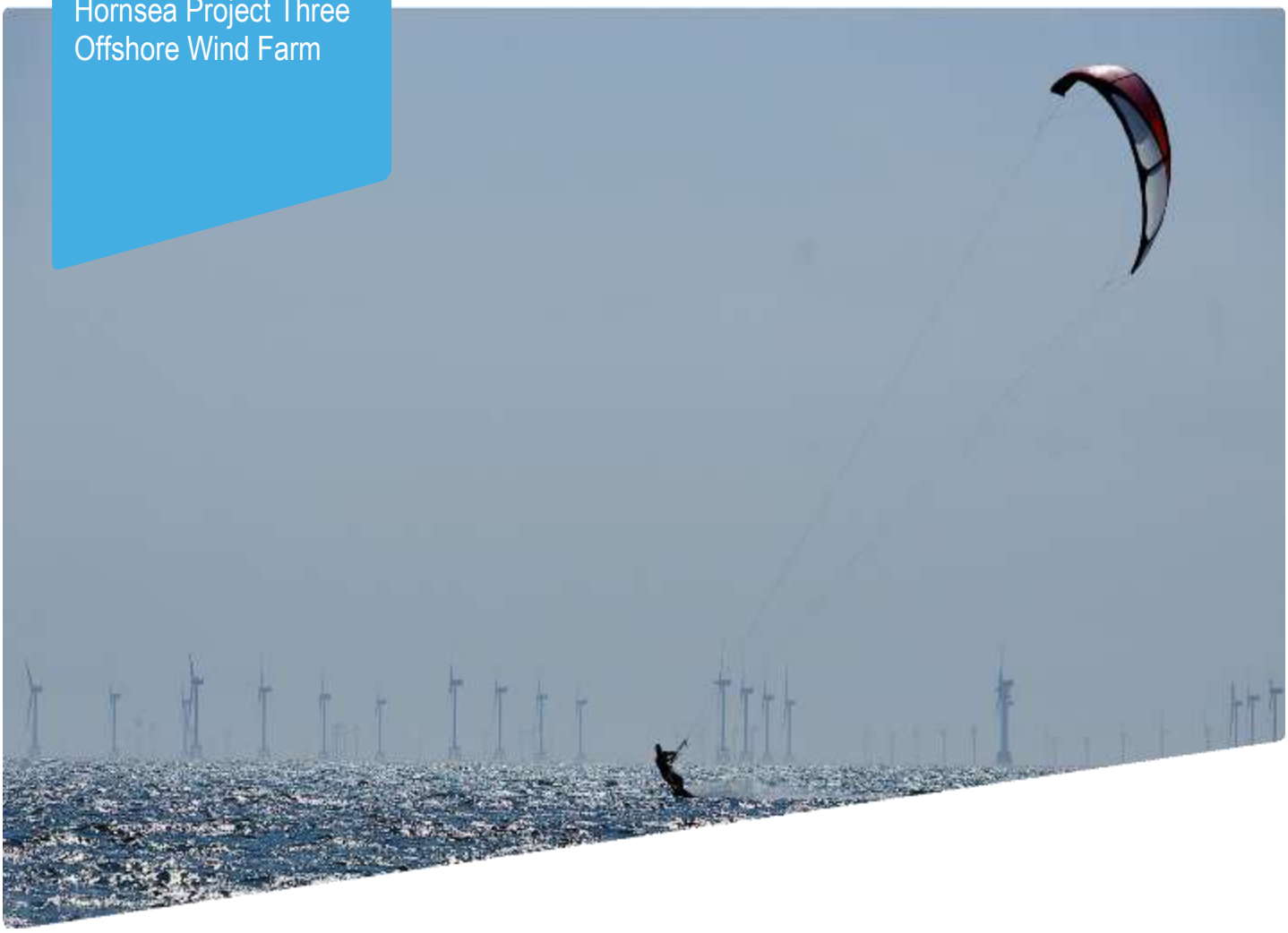
Hornsea Project Three
Offshore Wind Farm



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Offshore Wind Farm

Appendix 25 to Deadline I submission – Onshore HVAC Booster Station Infiltration Report

Date: 7th November 2018

Hornsea 3
Offshore Wind Farm

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Front cover picture: Kite surfer near a UK offshore wind farm © Ørsted Hornsea Project Three (UK) Ltd., 2018.

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Acronyms

Acronym	Description
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
LLFA	Lead Local Flood Authority
M bgl	Metres below ground level

1. Introduction

Background

1.1 RPS was commissioned by Ørsted Hornsea Project Three (UK) Ltd (the Applicant) to undertake soil infiltration testing at the onshore HVAC booster station area. The onshore HVAC booster station forms part of the onshore infrastructure for the Hornsea Project Three Offshore Wind Farm (hereafter referred to as Hornsea Three).

1.2 In their Section 42 response, Norfolk County Council (as the Lead Local Flood Authority (LLFA)) requested an outline drainage strategy as part of the final application and further ground investigation work, including infiltration testing. A conceptual surface water drainage strategy for the onshore HVAC booster station was submitted as part of the Development Consent Order (DCO) application (Volume 6, Annex 2.1: Onshore Infrastructure Flood Risk Assessment of the Environmental Statement (Document Reference A6.6.2.1)) and included the option to discharge surface water run-off into ground via soakaways. Storage will be provided within the onshore HVAC booster station area for up to 1 in 100 year plus 40 % climate change event. Infiltration testing and ground investigations are typically undertaken post consent during the detailed design stage. However, to assist in discussions on the principles of the drainage strategy with the LLFA and to inform detailed drainage design for the onshore HVAC booster station, preliminary infiltration testing has been undertaken, the results of which are reported in this document.

Site description

1.3 The onshore HVAC booster station area is located approximately 2.5 km east of Edgefield, Norwich, at National Grid Reference TG 11336, 33206. The onshore HVAC booster station and associated permanent infrastructure will occupy an area up 3.04 ha.

1.4 The onshore HVAC booster station area comprises arable agricultural land and at the time of the infiltration testing it was occupied by crop stubble. The onshore HVAC booster station area is bounded by low hedgerows with occasional mature oak trees to the south, west and north. A farm track and steep slope bounds the north east of the onshore HVAC booster station area and the east is bounded by mixed woodland.

1.5 The onshore HVAC booster station area has an average slope of 8% with a steady fall towards the north east. The north eastern boundary of the onshore HVAC booster station area is the lowest point in the immediate area. No drainage ditches or watercourses were observed at the north east boundary of the onshore HVAC booster station area or within the immediate vicinity.

2. Infiltration Testing Methodology

Best Practice Guidance

2.1 The infiltration testing was undertaken in accordance with BRE Digest 365 Soakaway design (Garvin, 2016). The guidance recommends that test pits for infiltration testing are excavated in the locations where soakaways are proposed and that the pits should have vertical sides. The guidance does not specify the depth of the test pit but suggests that the depth should be in-line with the depth of the proposed soakaway and should also take into account the character of the underlying strata.

2.2 Test pits are then filled with water and allowed to drain three times and the lowest infiltration value is used to calculate the infiltration rate.

2.3 Infiltration is calculated by using the time taken for water to drain from 75% fill level to 25% fill level, based on equations in BRE Digest 365. The calculation assumes that the volume of the test pits remains consistent throughout the test, therefore, when sudden or catastrophic collapse of the pits occurs (i.e. due to the instability of the pits) the test is terminated.

2.4 In some cases, it may not be possible to undertake three tests as the water in the test pit does not drain away. This occurs where there is limited or no infiltration and repeated testing will not change the outcome. Equally if the test pit is found to be unstable then repeating the tests may not be practical.

Fieldwork

2.5 A total of four pits were excavated for the purpose of undertaking infiltration testing between the 23 August 2018 and 24 August 2018. The location of the infiltration test pits was based on the indicative layout of the onshore HVAC booster station (as shown in Appendix A of Volume 6, Annex 2.1: Onshore Infrastructure Flood Risk Assessments (Document Reference A6.6.2.1)) and the potential location of soakaways.

2.6 Infiltration test pits were excavated to a maximum depth of 2.6 m bgl: two pits were excavated to 2.6 m bgl, one pit was 2.5 m bgl deep and the remaining pit was excavated to 1.3 m bgl. A shallower depth had been selected in this location (SA3) to assess the feasibility of shallower infiltration. This was based on the strata encountered with the shallower soils containing a lower percentage of fines (indicating a high infiltration potential), compared to the deeper soils which became increasingly cohesive in nature (i.e. indicating a low infiltration potential). In addition, a single trial pit was excavated to a depth of 3.6 m bgl to confirm the geological sequence.

2.7 On completion of the testing, the pits were backfilled with the excavation arisings.

2.8 The location of the onshore HVAC booster station area, and the infiltration test pits/trial pit are shown in Figure 2.1 and Figure 2.2 respectively. Test and trial pit logs are included in Appendix A.

3. Results

Ground conditions

3.1 The ground conditions encountered were consistent with the anticipated geology based on the online mapping from British Geological Survey (BGS) and as outlined in Volume 3, Chapter 1: Geology and Ground Conditions of the Environmental Statement (Document Reference A6.3.1). Ground conditions encountered during the infiltration testing comprised:

- Topsoil – encountered beneath the vegetation to a depth of 0.2 and 0.4 m below existing ground level (bgl). This generally comprised soft dark brown very sandy slightly gravelly organic rich SILT. Gravel size constituents comprised flint; and
- Superficial Deposits – encountered in all trial pits beneath the topsoil but not fully penetrated in any location. This was generally a loose yellow brown slightly silty locally slightly gravelly, sand with localised pockets of silt. In SA2 an orange brown mottle grey very sandy clay was encountered beneath the sand.

3.2 No groundwater was encountered during the infiltration testing.

Infiltration testing

3.3 Test pit SA1 located in the centre of the onshore HVAC booster station area, failed to drain below 25% fill level during the test run, therefore limited infiltration is recorded in this pit.

3.4 Test pit SA2 located in north east of the onshore HVAC booster station area failed to drain below the 25% fill level during the test run, however small collapses in the side walls changed the surface area and caused a rise in the water level recorded. Therefore, the test was terminated.

3.5 Test pit SA3 is located in between SA2 and SA4. Three complete test runs were undertaken in SA3 with infiltration rates ranging from $3.61x10^{-05}$ ms to $2.76x10^{-05}$ ms.

3.6 Test pit SA4 located in the north west of the onshore HVAC booster station area achieved infiltration between the 75% and 25% fill level, however the second run of the test recorded significantly reduced drainage with the test draining to the 75% level over the course of four hours, whereas the first test run had completely drained within three and a half hours. A third test was not undertaken due to the limited the infiltration rate recorded during the second run. The results of the testing undertaken indicates that limited infiltration is likely in this area.

3.7 BRE365 suggests an approach whereby the lowest infiltration rate calculated for each test location is used to inform drainage design.

3.8 The findings of the fieldwork are presented in Appendix B.

4. Conclusions

4.1 As reported in paragraph 3.1, variable amounts of silt and clay were encountered within the sand superficial deposits across the onshore HVAC booster station area. Limited infiltration was recorded in the majority of test pits at depths 2.5 – 2.6 m bgl, however the infiltration rate calculated within the shallower sands at test pit SA3 indicates that soakaways maybe feasible on the onshore HVAC booster station area at shallow depths.

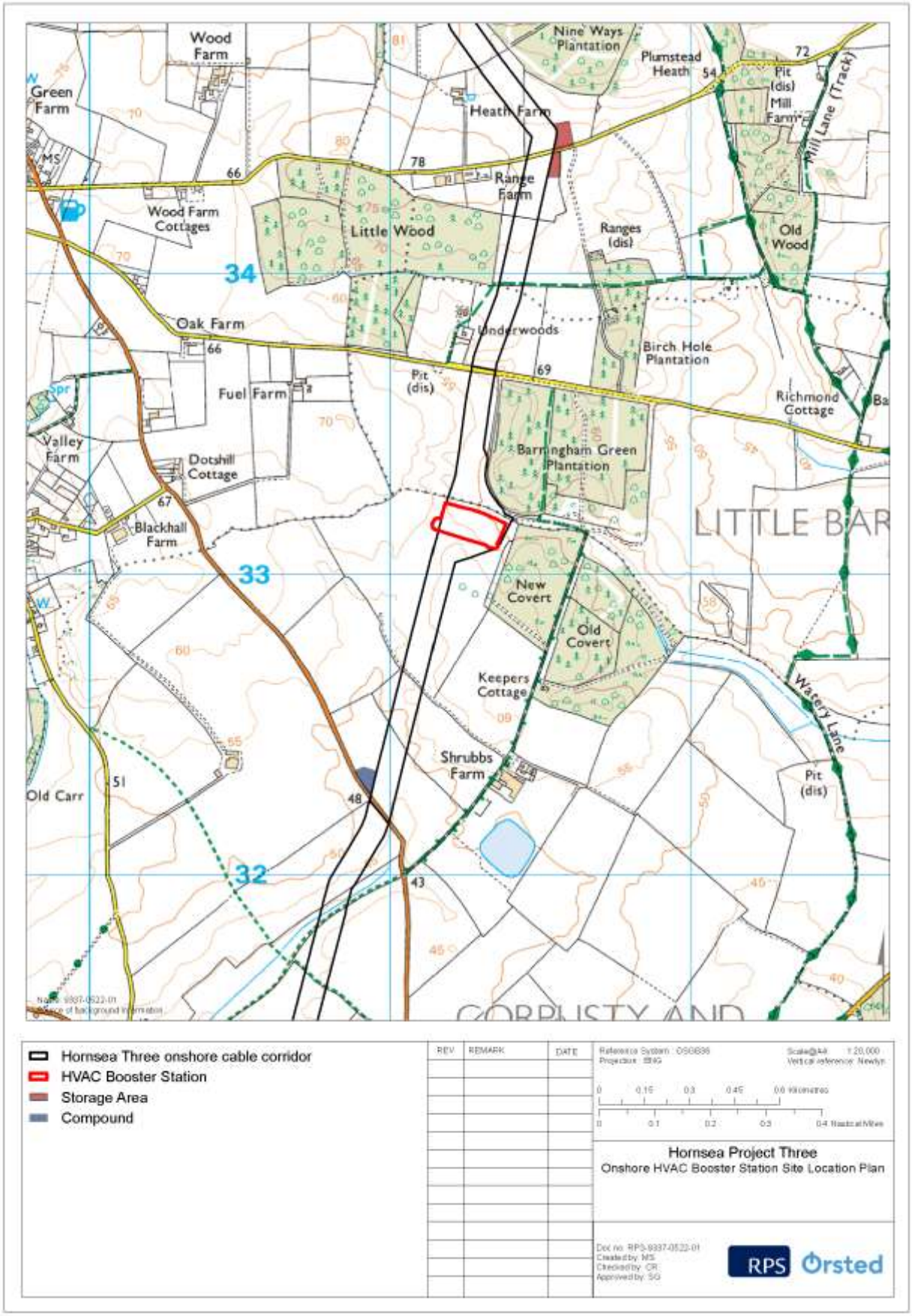


Figure 2.1: Site Location Plan.

Figure 2.2: Onshore HVAC Booster Station Infiltration Testing Location Plan.

Appendix A Test/Trial Pit Logs

TRIAL PIT LOG

Pit No. **SA1**

Sheet 1 of 1

Project Name:	Hornsea 3 Edgefield	Co-ordinates:		Date(s): 24/09/2018	Hole Type:
Project No:	RCEI64177b	Easting:	611262	Equipment:	TP
Location:	Norfolk	Northing:	333166	JCB 3CX	Pit Length: 2.00 m / Scale:
Client:	Orsted	Ground Level (mAOD):		Logged By: TF	Pit Width: 0.45 m / 1:50

Backfill	Water Strike(s)	Samples & In Situ Testing: Depth (m)	Type	Results	Depth (mbGL)	Thickness (m)	Level (mAOD)	Legend	Stratum Description	Scale
					0.00	(0.40)			Dark brown very sandy slightly gravelly organic rich SILT including rootlets. Gravel is fine to coarse, sub-angular to well rounded flint. (TOPSOIL)	
					0.40	(0.80)			Soft brown sandy gravelly SILT. Gravel is fine to coarse, sub-angular to rounded of flint and quartzite. (SUPERFICIAL DEPOSITS)	
					1.20	(1.30)			Loose orangey brown gravelly fine to medium SAND including pockets of soft silt. Gravel is fine to coarse, sub-angular to rounded of flint. (SUPERFICIAL DEPOSITS)	
									End of Pit at 2.50m	

Remarks: 1) Trial pit terminated at 2.5m bgl. 2) Infiltration test undertaken. 3) Backfilled with arisings upon completion of test.

Groundwater: None encountered.

Stability: Stable

TRIAL PIT LOG

Pit No. **SA2**

Sheet 1 of 1

Project Name:	Hornsea 3 Edgefield	Co-ordinates:		Date(s): 23/08/2018	Hole Type:
Project No:	RCEI64177b	Easting:	611337	Equipment:	TP
Location:	Norfolk	Northing:	333195	JCB 3CX	Pit Length: 2.00 m / Scale:
Client:	Orsted	Ground Level (mAOD):		Logged By: TF	Pit Width: 0.45 m / 1:50

Backfill	Water Strike(s)	Samples & In Situ Testing: Depth (m)	Type	Results	Depth (mbGL)	Thickness (m)	Level (mAOD)	Legend	Stratum Description	Scale
					0.00	(0.30)			Dark brown very sandy slightly gravelly organic rich SILT including rootlets. Gravel is fine to coarse, sub-angular to well rounded flint. (TOPSOIL)	
					0.30	(2.10)			Loose orangey brown gravelly fine to medium SAND. Gravel is fine to coarse, sub-angular to well rounded of flint and quartzite. (SUPERFICIAL DEPOSITS)	1
									From 2.3m becoming slightly clayey	2
					2.40	(0.20)			Soft orangey brown mottled grey very sandy CLAY. (SUPERFICIAL DEPOSITS)	
									End of Pit at 2.60m	3 4 5 6 7 8 9 10

Remarks: 1) Trial pit terminated at 2.6m bgl. 2) Infiltration test undertaken. 3) Backfilled with arisings upon completion of test.

Groundwater: None encountered.

Stability: Slightly unstable

AGS

TRIAL PIT LOG

Pit No. **SA3**

Sheet 1 of 1

Project Name:	Hornsea 3 Edgefield	Co-ordinates:		Date(s): 23/08/2018	Hole Type:
Project No:	RCEI64177b	Easting:	611292	Equipment:	TP
Location:	Norfolk	Northing:	333211	JCB 3CX	Pit Length: 2.00 m
Client:	Orsted	Ground Level (mAOD):		Logged By: TF	Pit Width: 0.45 m

Backfill	Water Strike(s)	Samples & In Situ Testing: Depth (m)	Type	Results	Depth (mbGL)	Thickness (m)	Level (mAOD)	Legend	Stratum Description	Scale
					0.00	(0.20)			Dark brown very sandy slightly gravelly organic rich SILT including rootlets. Gravel is fine to coarse, sub-angular to well rounded flint. (TOPSOIL)	
					0.20	(1.10)			Loose orangey brown gravelly fine to medium SAND. Gravel is fine to coarse, sub-angular to well rounded of flint and quartzite. (SUPERFICIAL DEPOSITS)	
									End of Pit at 1.30m	

Remarks: 1) Trial pit terminated at 1.3m bgl. 2) Infiltration test undertaken. 3) Backfilled with arisings upon completion of test.

Groundwater: None encountered.

Stability: Stable

TRIAL PIT LOG

Pit No. **SA4**

Sheet 1 of 1

Project Name:	Hornsea 3 Edgefield	Co-ordinates:		Date(s): 23/08/2018	Hole Type:
Project No:	RCEI64177b	Easting:	611226	Equipment:	TP
Location:	Norfolk	Northing:	333229	JCB 3CX	Pit Length: 2.00 m
Client:	Orsted	Ground Level (mAOD):		Logged By: TF	Pit Width: 0.45 m

Scale: 1:50

Backfill	Water Strike(s)	Samples & In Situ Testing: Depth (m)	Type	Results	Depth (mbGL)	Thickness (m)	Level (mAOD)	Legend	Stratum Description	Scale
					0.00	(0.20)			Dark brown very sandy slightly gravelly organic rich SILT including rootlets. Gravel is fine to coarse, sub-angular to well rounded flint. (TOPSOIL)	
					0.20	(2.40)			Loose yellow brown fine to medium SAND including pockets of fine orange sandy silt. (SUPERFICIAL DEPOSITS)	
									End of Pit at 2.60m	

Remarks: 1) Trial pit terminated at 2.6m bgl. 2) Infiltration test undertaken. 3) Backfilled with arisings upon completion of test.

Groundwater: None encountered.

Stability: Stable

TRIAL PIT LOG

Pit No. **TP1** Sheet 1 of 1

Project Name:	Hornsea 3 Edgefield	Co-ordinates:		Date(s): 24/08/2018	Hole Type:
Project No:	RCEI64177b	Easting:	611294	Equipment:	TP
Location:	Norfolk	Northing:	333213	JCB 3CX	Pit Length: 2.00 m / Scale:
Client:	Orsted	Ground Level (mAOD):		Logged By: TF	Pit Width: 0.45 m / 1:50

Backfill	Water Strike(s)	Samples & In Situ Testing: Depth (m)	Type	Results	Depth (mbGL)	Thickness (m)	Level (mAOD)	Legend	Stratum Description	Scale
					0.00	(0.30)			Dark brown very sandy slightly gravelly organic rich SILT including rootlets. Gravel is fine to coarse, sub-angular to well rounded flint. (MADE GROUND)	
					0.30				*At 0.3m small square of plastic membrane*	
						(0.80)			Loose brown slightly silty slightly gravelly SAND. Gravel is fine to coarse, sub-angular to well rounded of flint and quartzite. (SUPERFICIAL DEPOSITS)	
					1.10				Loose orangey brown gravelly medium SAND including low cobble content of flint. Gravel is fine to coarse, angular to well rounded of flint and quartzite. (SUPERFICIAL DEPOSITS)	
						(2.50)			*From 2.5m becoming slightly silty and slightly gravelly.*	
									From 2.8m becoming silty	
									From 3.0m becoming slightly silty	
									End of Pit at 3.60m	

Remarks: 1) Trial pit terminated at 3.6m bgl. 2) Backfilled with arisings upon completion of test.

Groundwater:

Stability: Stable

Appendix B Infiltration Test Results

RPS Group
8 Exchange Quay
Salfrod
M5 3Ej

Soil Infiltration Test (BRE Digest 365)

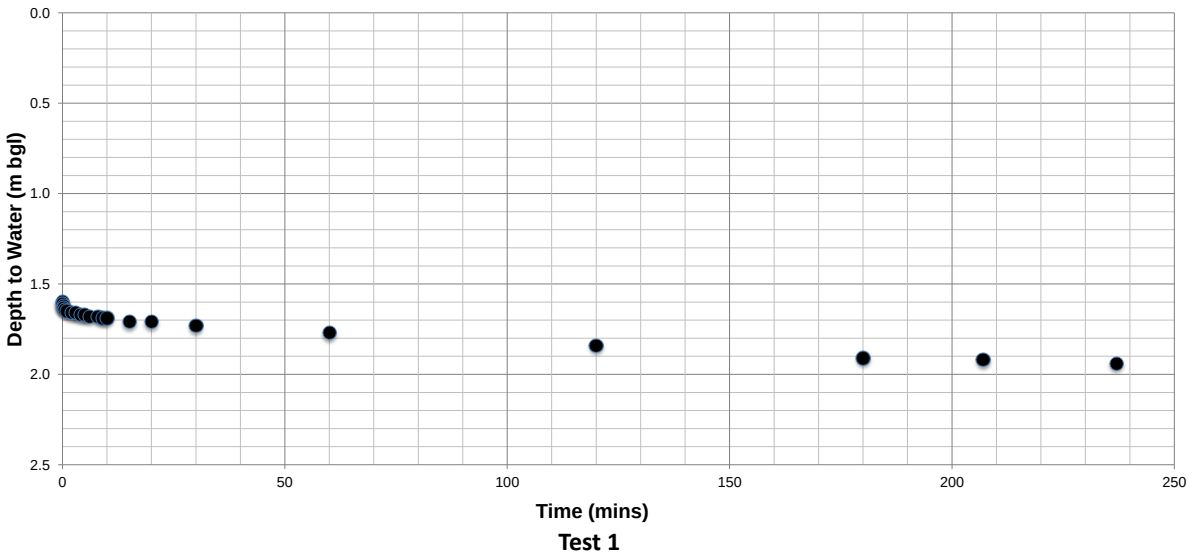
Client:	Orsted	Report Ref:	RCEI64177.003	**SA1**
Site:	Hornsea 3 HVAC Booster Station	Date:	30 August 2018	

Soil Type: Superficial Deposits
Groundwater: Not encountered
Drain Invert Level: Not Known
Sidewall Stability: Stable
Remarks: 25% effective depth not reach at termination of test.

Soil Infiltration Rate:

$$f = \frac{Vp75 - 25}{ap50 \times tp75 - 25}$$

		Test 1	Test 2	Test 3
Dimensions of Trial Pit:	Depth (m)	2.20	2.20	2.20
	Width (m)	0.45	0.45	0.45
	Length (m)	2.00	2.00	2.00
Effective Depth (m)		0.60	0.60	0.60
$V_{p75\text{-}25}$: volume of the trial pit between 75% and 25% of the effective depth (m^3)		0.27	0.27	0.27
a_{p50}: internal surface area of trial pit up to 50% effective depth (m^2)		2.37	2.37	2.37
$t_{p75\text{-}25}$: time for water to fall from 75% to 25% effective depth (secs)		Not achieved		
f: Soil Infitration Rate (ms^{-1})				



Test 1

RPS Group
8 Exchange Quay
Salfrod
M5 3EJ

Soil Infiltration Test (BRE Digest 365)

Client:	Orsted	Report Ref:	RCEI64177.003	**SA2**
Site:	Hornsea 3 HVAC Booster Station	Date:	30 August 2018	

Soil Type: Superficial Deposits

Groundwater: Not encountered

Drain Invert Level: Not Known

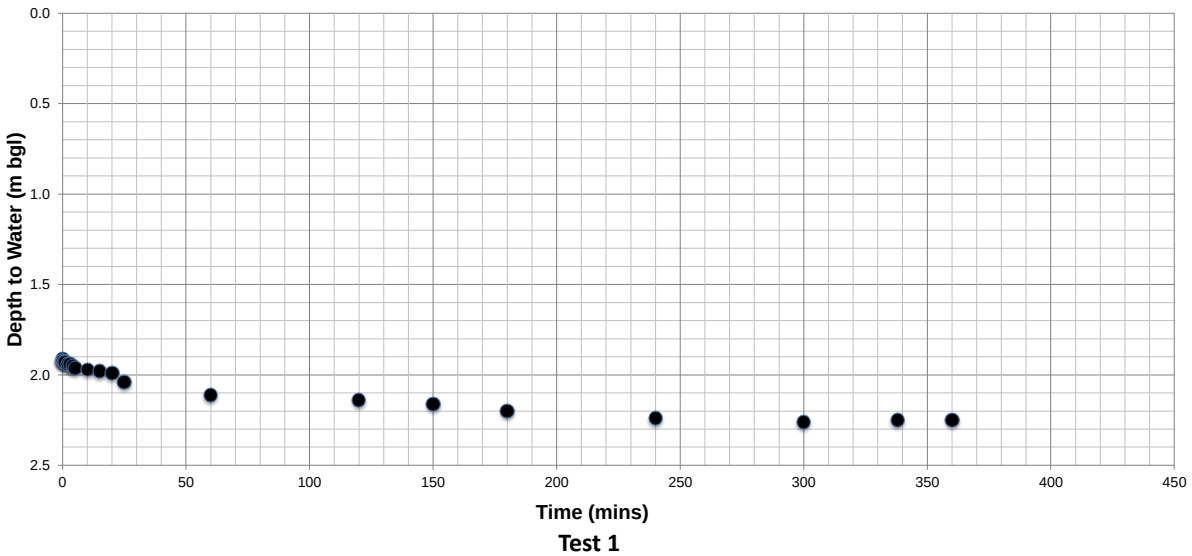
Sidewall Stability: Becoming unstable

Remarks: After 5.5hours sudden collapse in walls reducing pit depth and raising water level, no further infiltration recorded after this time

Soil Infiltration Rate:

$$f = \frac{Vp75 - 25}{ap50 \times tp75 - 25}$$

		Test 1	Test 2	Test 3
Dimensions of Trial Pit:	Depth (m)	2.40	2.40	2.40
	Width (m)	0.45	0.45	0.45
	Length (m)	2.00	2.00	2.00
Effective Depth (m)		0.50	0.50	0.50
$V_{p75\text{-}25}$: volume of the trial pit between 75% and 25% of the effective depth (m^3)		0.23	0.23	0.23
a_{p50}: internal surface area of trial pit up to 50% effective depth (m^2)		2.13	2.13	2.13
$t_{p75\text{-}25}$: time for water to fall from 75% to 25% effective depth (secs)		Not achieved		
f: Soil Infiltration Rate (ms^{-1})				



Test 1

RPS Group
8 Exchange Quay
Salfrod
M5 3EJ

Soil Infiltration Test (BRE Digest 365)

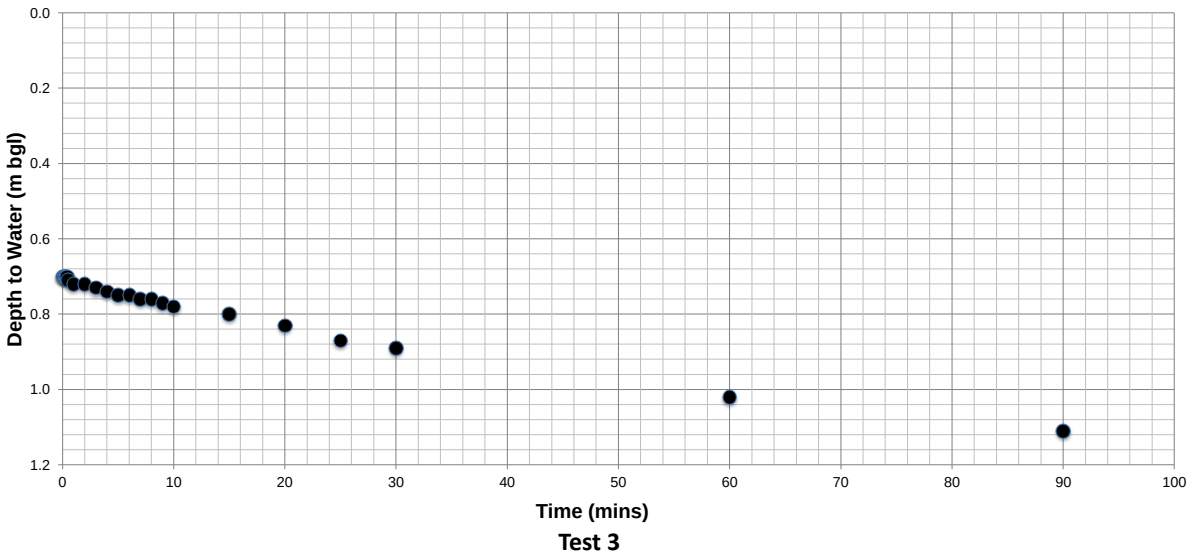
Client:	Orsted	Report Ref:	RCEI64177.003	**SA3**
Site:	Hornsea 3 HVAC Booster Station	Date:	30 August 2018	

Soil Type: Superficial Deposits
Groundwater: Not encountered
Drain Invert Level: Not Known
Sidewall Stability: Stable
Remarks: Three complete tests run.

Soil Infiltration Rate:

$$f = \frac{Vp75 - 25}{ap50 \times tp75 - 25}$$

		Test 1	Test 2	Test 3
Dimensions of Trial Pit:	Depth (m)	1.22	1.22	1.22
	Width (m)	0.45	0.45	0.45
	Length (m)	2.00	2.00	2.00
Effective Depth (m)		0.45	0.45	0.45
V_{p75-25}: volume of the trial pit between 75% and 25% of the effective depth (m^3)		0.20	0.20	0.20
a_{p50}: internal surface area of trial pit up to 50% effective depth (m^2)		2.00	2.00	2.00
t_{p75-25}: time for water to fall from 75% to 25% effective depth (secs)		2805	3250	3661
f: Soil Infitration Rate (ms^{-1})		3.61E-05	3.11E-05	2.76E-05



Test 3

RPS Group 8 Exchange Quay Salfrod M5 3EJ	**Soil Infiltration Test (BRE Digest 365)**		
Client:	Orsted	Report Ref:	RCEI64177.003
Site:	Hornsea 3 HVAC Booster Station	Date:	30 August 2018

SA4

Soil Type: Superficial Deposits

Groundwater: Not encountered

Drain Invert Level: Not Known

Sidewall Stability: Stable

Remarks: Test 1 recorded an infiltration rate, however, the second test failed to drain to a 25% effective depth over the period of the test

Soil Infiltration Rate:

$$f = \frac{Vp75 - 25}{ap50 \times tp75 - 25}$$

		Test 1	Test 2	Test 3
Dimensions of Trial Pit:	Depth (m)	2.60	2.60	2.60
	Width (m)	0.45	0.45	0.45
	Length (m)	2.00	2.00	2.00
Effective Depth (m)		0.92	0.92	0.92
V_{p75-25}: volume of the trial pit between 75% and 25% of the effective depth (m^3)		0.41	0.41	0.41
a_{p50}: internal surface area of trial pit up to 50% effective depth (m^2)		3.15	3.15	3.15
t_{p75-25}: time for water to fall from 75% to 25% effective depth (secs)		86625	Not achieved	
f: Soil Infiltration Rate (ms^{-1})		1.52E-06