The Sizewell C Project

6.3 Volume 2 Main Development Site

Chapter 18 Geology and Land Quality

Appendices 18B - 18E

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VOLUME 2, CHAPTER 18, APPENDIX 18B: CONCEPTUAL SITE MODELS

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1. Conceptual Site Models

Table 1.1: Construction phase conceptual site model.

Source	Receptor		Contaminant exposure/migration pathway.	Baseline			Construction with primary and tertiary mitigation.			Secondary mitigation measures.	Construction with primary, tertiary and secondary mitigation.		
				Probability	Consequence	Risk Category.	Probability	Consequence	Risk Category.		Probability	Consequence	Risk Category.
On-site: **Main platform** Former rifle range located in the centre of the main platform. Made Ground within the north-east of the main platform. Drainage and wind pumps in the north and centre of the main platform. Sewage treatment works located on the western boundary of the main platform. Made Ground and spoil disposal on the main platform associated with the construction of Sizewell B and former contractors' compound. Activities relating to the former contractors' compound on the main platform for Sizewell B including possible storage areas, fabrication areas, lagoons, stone washing / concrete batching area. Car park located on western edge of the main platform. Activities within the main platform associated with the	**Human health:** On-site	Pedestrians and road users using existing roads, footpaths and fields within the site (note that Sizewell C power station site will be secure).	Dermal contact with and ingestion of contaminants in soil, soil-derived dust and water. Inhalation of contaminants in soil, soil-derived dust, fibres and gas/vapours.	Low likelihood.	Minor	Very low risk.	Receptor not present.	--	--	Additional intrusive ground investigation undertaken post planning to inform the detailed design and confirm the ground conditions and contamination status of the site including soil and groundwater sampling and monitoring and testing of marine sediments. Remediation of soil and groundwater contamination prior to construction (e.g. source removal, treatment or capping) if deemed necessary.	Receptor not present.	--	--
		Farmers and workers on agricultural land.		Low likelihood.	Minor	Very low risk.	Receptor not present.	--	--		Receptor not present.	--	--
		Construction and maintenance workers.		Receptor not present.	--	--	Low likelihood.	Mild	Low risk.		Low likelihood.	Minor	Very low risk.
		Recreational site users of the Sizewell Marshes Site of Special Scientific Interest (SSSI), marshes and beach along the foreshore.		Low likelihood.	Minor	Very low risk.	Receptor not present.	--	--		Receptor not present.	--	--
		Current Sizewell B workers using areas of the main platform.		Low likelihood.	Minor	Very low risk.	Receptor not present.	--	--		Receptor not present.	--	--
		Future site workers and visitors.		Receptor not present.	--	--	Receptor not present.	--	--		Receptor not present.	--	--
	Human health: Off-site	Workers in adjacent Sizewell A and B power stations.	Dermal contact with and ingestion of contaminants in soil, soil-derived dust and water which may have migrated off-site. Inhalation of contaminants in soil, soil-derived dust, fibres and gas and/or vapours which may have migrated off-site.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.		Unlikely	Minor	Very low risk.
		Pedestrians accessing surrounding roads and footpaths.		Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.		Unlikely	Minor	Very low risk.
		Farmers and workers on agricultural land.		Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.		Unlikely	Minor	Very low risk.
		Recreational site users of the surrounding Sizewell Marshes SSSI and marshes.		Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.		Unlikely	Minor	Very low risk.
	Controlled Waters	Principal Bedrock and Superficial Secondary Aquifers (on-site and off-site).	Leaching / migration of contaminants in soil to groundwater in underlying aquifers.	Low likelihood.	Mild	Low risk.	Low likelihood.	Mild	Low risk.		Low likelihood.	Minor	Very low risk.

Source	**Receptor**		**Contaminant exposure/migration pathway.**	**Baseline**			**Construction with primary and tertiary mitigation.**			**Secondary mitigation measures.**	**Construction with primary, tertiary and secondary mitigation.**		
				Probability	**Consequence**	**Risk Category.**	**Probability**	**Consequence**	**Risk Category.**		**Probability**	**Consequence**	**Risk Category.**
operation of Sizewell B power station including radioactive materials. Former infilled sand pits located across the main platform. Peat and alluvial deposits indicated to be present within the eastern edge of the main platform. Farming activities across the entire site area including potential for unmarked farmers tips. Made Ground associated with the construction of existing roads crossing the various areas of the site as well as activities associated with their operation. Risk of inorganic and organic contamination including metals and hydrocarbons, biological contaminants, Polychlorinated Biphenyls (PCBs), asbestos, solvents, paints, fuels, oils, herbicides and pesticides. Ground gas generation.			Migration of contaminated water through preferential pathways such as underground services, pipes and granular material to groundwater in underlying aquifers.	Low likelihood.	Mild	Low risk.	Low likelihood.	Mild	Low risk.		Low likelihood.	Minor	Very low risk.
		Ponds and drains on site and within the study area.	Migration of contaminated water into underlying aquifers followed by lateral migration into nearby watercourses.	Unlikely	Medium	Low risk.	Unlikely	Medium	Low risk.		Unlikely	Mild	Very low risk.
			Discharge of contaminants entrained in groundwater and/or surface water run-off followed by overland flow and discharge.	Unlikely	Medium	Low risk.	Unlikely	Medium	Low risk.		Unlikely	Mild	Very low risk.
		North Sea (on-site and off-site).	Migration of contaminated water into underlying aquifers followed by lateral migration into nearby watercourses.	Unlikely	Medium	Low risk.	Unlikely	Medium	Low risk.		Unlikely	Mild	Very low risk.
			Discharge of contaminants entrained in surface water run-off followed by overland flow and discharge.	Unlikely	Medium	Low risk.	Unlikely	Medium	Low risk.		Unlikely	Mild	Very low risk.
	Property / services	Existing on-site and off-site services and structures including listed buildings.	Direct contact of contaminants in soil and/or groundwater with buried service.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.		Unlikely	Minor	Very low risk.

Source	Receptor		Contaminant exposure/migration pathway.	Baseline			Construction with primary and tertiary mitigation.			Secondary mitigation measures.	Construction with primary, tertiary and secondary mitigation.		
				Probability	**Consequence**	**Risk Category.**	**Probability**	**Consequence**	**Risk Category.**		**Probability**	**Consequence**	**Risk Category.**
			Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.		Unlikely	Minor	Very low risk.
		Proposed on-site services and structures.	Direct contact of contaminants in soil and/or groundwater with existing buried service.	Receptor not present.	--	--	Receptor not present.	--	--		Receptor not present.	--	--
			Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Receptor not present.	--	--	Receptor not present.	--	--		Receptor not present.	--	--
		Crops and livestock (on-site).	Direct contact, ingestion, inhalation and uptake of soil and water contamination by crops and/or livestock.	Unlikely	Minor	Very low risk.	Receptor not present.	--	--		Receptor not present.	--	--
		Crops and livestock (off-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by crops or ingestion/inhalation/dermal contact by livestock.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.		Unlikely	Minor	Very low risk.
	Ecological	Sizewell Marshes SSSI (on-site and off-site).	Direct contact, ingestion, inhalation and uptake of soil and water contamination by flora and/or fauna.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.		Unlikely	Minor	Very low risk.
			Migration of contaminated waters/dust/fibres and	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.		Unlikely	Minor	Very low risk.

Source	Receptor		Contaminant exposure/migration pathway.	Baseline			Construction with primary and tertiary mitigation.			Secondary mitigation measures.	Construction with primary, tertiary and secondary mitigation.		
				Probability	Consequence	Risk Category.	Probability	Consequence	Risk Category.		Probability	Consequence	Risk Category.
			subsequent uptake by flora or ingestion/inhalation/dermal contact by fauna.										
		Minsmere-Walberswick Heaths and Marshes SSSI, Ramsar, Special Area of Conservation (SAC) and Special Protection Area (SPA) and Suffolk Coast and Heaths Area of Outstanding Natural Beauty (AONB) (off-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by flora or ingestion/inhalation/dermal contact by fauna.	Unlikely	Minor	Very low risk	Unlikely	Minor	Very low risk.		Unlikely	Minor	Very low risk.
On-site: **Temporary construction area** Former infilled sand pits located across the temporary construction area. Grass covered mounds (suspected Made Ground) located in the north-east of the temporary construction area. Peat and alluvial deposits indicated to be present within the eastern edge of the temporary construction area. Farming activities across the entire site area including potential for unmarked farmers tips. Made Ground associated with the construction of existing roads	**Human health:** On-site	Pedestrians and road users using existing roads, footpaths and fields within the site.	Dermal contact with and ingestion of contaminants in soil, soil-derived dust and water. Inhalation of contaminants in soil, soil-derived dust and gas/vapours.	Unlikely	Mild	Very low risk.	Low likelihood.	Mild	Low risk.		Unlikely	Mild	Very low risk.
		Farmers and workers on agricultural land.		Unlikely	Mild	Very low risk.	Receptor not present.	--	--		Receptor not present.	--	--
		Construction and maintenance workers.		Receptor not present.	--	--	Low likelihood.	Mild	Low risk.		Unlikely	Mild	Very low risk.
		Residents within the temporary construction area.		Unlikely	Mild	Very low risk.	Low likelihood.	Mild	Low risk.		Unlikely	Mild	Very low risk.
	Human health: Off-site	Occupants of nearby residential, recreational and commercial properties.	Dermal contact with and ingestion of contaminants in soil, soil-derived dust and water which may have migrated off-site. Inhalation of contaminants in soil, soil-derived dust, fibres and gas/vapours which may have migrated off-site.	Unlikely	Mild	Very low risk.	Low likelihood.	Mild	Low risk.		Unlikely	Mild	Very low risk.
		Pedestrians accessing surrounding roads and footpaths.		Unlikely	Mild	Very low risk.	Low likelihood.	Mild	Low risk.		Unlikely	Mild	Very low risk.
		Farmers and workers on agricultural land.		Unlikely	Mild	Very low risk.	Low likelihood.	Mild	Low risk.		Unlikely	Mild	Very low risk.
		Recreational site users of the Sizewell Marshes SSSI and marshes.		Unlikely	Mild	Very low risk.	Low likelihood.	Mild	Low risk.		Unlikely	Mild	Very low risk.
	Controlled Waters	Principal Bedrock and Superficial Secondary A Aquifers (on-site and off-site).	Leaching / migration of contaminants in soil to groundwater in underlying aquifers.	Unlikely	Medium	Low risk.	Low likelihood.	Medium	Moderate/low risk.		Unlikely	Mild	Very low risk.

Source	Receptor		Contaminant exposure/migration pathway.	Baseline			Construction with primary and tertiary mitigation.			Secondary mitigation measures.	Construction with primary, tertiary and secondary mitigation.		
				Probability	Consequence	Risk Category.	Probability	Consequence	Risk Category.		Probability	Consequence	Risk Category.
crossing the various areas of the site as well as activities associated with their operation. Risk of inorganic and organic contamination including metals and hydrocarbons, asbestos, fuels, oils, herbicides and pesticides.			Migration of contaminated water through preferential pathways such as underground services, pipes and granular material to groundwater in underlying aquifers.	Unlikely	Medium	Low risk.	Low likelihood.	Medium	Moderate/low risk.		Unlikely	Mild	Very low risk.
		Ponds and drains on site and within study area.	Migration of contaminated water into underlying aquifers followed by lateral migration into nearby watercourses.	Unlikely	Medium	Low risk.	Low likelihood.	Medium	Moderate/low risk.		Unlikely	Mild	Very low risk.
			Discharge of contaminants entrained in groundwater and/or surface water run-off followed by overland flow and discharge.	Unlikely	Medium	Low risk.	Low likelihood.	Medium	Moderate/low risk		Unlikely	Mild	Very low risk.
		North Sea (off-site).	Migration of contaminated water into underlying aquifers followed by lateral migration into nearby watercourses.	Unlikely	Mild	Very low risk.	Low likelihood.	Mild	Low risk		Unlikely	Mild	Very low risk.
			Discharge of contaminants entrained in surface water run-off followed by overland flow and discharge.	Unlikely	Mild	Very low risk.	Low likelihood.	Mild	Low risk		Unlikely	Mild	Very low risk.
	Property / services	Existing on-site and off-site services and structures including Leiston Abbey	Direct contact of contaminants in soil and/or groundwater with existing buried service.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.		Unlikely	Minor	Very low risk.

Source	Receptor		Contaminant exposure/migration pathway.	Baseline			Construction with primary and tertiary mitigation.			Secondary mitigation measures.	Construction with primary, tertiary and secondary mitigation.		
				Probability	Consequence	Risk Category.	Probability	Consequence	Risk Category.		Probability	Consequence	Risk Category.
		Scheduled Monument and listed buildings.	Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Unlikely	Mild	Very low risk.	Unlikely.	Mild	Very low risk.		Unlikely	Mild	Very low risk.
		Proposed on-site services and structures.	Direct contact of contaminants in soil and/or groundwater with existing buried service.	Receptor not present.	--	--	Receptor not present.	--	--		Receptor not present.	--	--
			Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Receptor not present.	--	--	Receptor not present.	--	--		Receptor not present.	--	--
		Crops and livestock (on-site).	Direct contact, ingestion, inhalation and uptake of soil and water contamination by crops and/or livestock.	Unlikely	Mild	Very low risk.	Receptor not present.	--	--		Receptor not present.	--	--
		Crops and livestock (off-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by crops or ingestion/inhalation/dermal contact by livestock.	Unlikely	Mild	Very low risk.	Low likelihood.	Mild	Low risk.		Unlikely	Mild	Very low risk.
	Ecological	Sizewell Marshes SSSI (off-site).	Direct contact, ingestion, inhalation and uptake of soil and water contamination by flora and/or fauna.	Unlikely	Mild	Very low risk.	Low likelihood.	Mild	Low risk.		Unlikely	Mild	Very low risk.
			Migration of contaminated waters/dust/fibres and	Unlikely	Mild	Very low risk.	Low likelihood.	Mild	Low risk.		Unlikely	Mild	Very low risk.

Source	Receptor		Contaminant exposure/migration pathway.	Baseline			Construction with primary and tertiary mitigation.			Secondary mitigation measures.	Construction with primary, tertiary and secondary mitigation.		
				Probability	Consequence	Risk Category.	Probability	Consequence	Risk Category.		Probability	Consequence	Risk Category.
			subsequent uptake by flora or ingestion/inhalation/dermal contact by fauna.										
		Minsmere-Walberswick Heaths and Marshes SSSI, Ramsar, SAC and SPA and Suffolk Coast and Heaths AONB (off-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by flora or ingestion/inhalation/dermal contact by fauna.	Unlikely	Mild	Very low risk.	Low likelihood.	Mild	Low risk.		Unlikely	Mild	Very low risk.
On-site: Land to the East of Eastlands Industrial Estate **(LEEIE)** Fly tipping in the north-west of the (LEEIE. Railway line running through the western extent of the LEEIE. Farming activities across the entire site area including potential for unmarked farmers tips. Made Ground present within the southern section of the LEEIE associated with the railway line and in the northern section associated with an infilled reservoir. Electricity substation at the eastern extent of the proposed construction corridor for the electrical supply connection to the east of the LEEIE.	Human health: On-site	Pedestrians and road users using existing roads, railway, footpaths and fields within the site.	Dermal contact with and ingestion of contaminants in soil, soil-derived dust and water.	Low likelihood.	Mild	Low risk.	Receptor not present.	--	--		Receptor not present.	--	--
		Farmers and workers on agricultural land.	Inhalation of contaminants in soil, soil-derived dust and vapours.	Unlikely	Mild	Very low risk.	Receptor not present.	--	--		Receptor not present.	--	--
		Construction and maintenance workers.		Receptor not present.	--	--	Low likelihood.	Mild	Low risk.		Unlikely	Mild	Very low risk.
	Human health: Off-site	Occupants of nearby residential, recreational and commercial properties.	Dermal contact with and/or ingestion of contaminants in windblown soil-derived dusts and water that may have migrated off site.	Unlikely	Mild	Very low risk.	Low likelihood.	Mild	Low risk.		Unlikely	Mild	Very low risk.
		Pedestrians accessing surrounding roads and footpaths.		Unlikely	Mild	Very low risk.	Low likelihood.	Mild	Low risk.		Unlikely	Mild	Very low risk.
		Farmers and workers on agricultural land.	Inhalation of windblown soil derived dust, fibres and gas/vapours which may have migrated off site.	Unlikely	Mild	Very low risk.	Low likelihood.	Mild	Low risk.		Unlikely	Mild	Very low risk.
	Controlled Waters	Principal Bedrock and Superficial Secondary A aquifers (on-site and off-site).	Leaching / migration of contaminants in soil to groundwater in underlying aquifers.	Unlikely	Medium	Low risk.	Low likelihood.	Medium	Moderate / low risk.		Unlikely	Mild	Very low risk.
			Migration of contaminated water through preferential pathways such as underground services, pipes and	Unlikely	Medium	Low risk.	Low likelihood.	Medium	Moderate/low risk.		Unlikely	Mild	Very low risk.

Source	Receptor		Contaminant exposure/migration pathway.	Baseline			Construction with primary and tertiary mitigation.			Secondary mitigation measures.	Construction with primary, tertiary and secondary mitigation.		
				Probability	Consequence	Risk Category.	Probability	Consequence	Risk Category.		Probability	Consequence	Risk Category.
Made Ground associated with the construction of existing roads crossing the various areas of the site as well as activities associated with their operation. Risk of inorganic and organic contamination including metals and hydrocarbons, asbestos, fuels, oils, PCBs, Polycyclic Aromatic Hydrocarbons (PAHs), herbicides and pesticides.			granular material to groundwater in underlying aquifers.										
		Ponds and drains on site and within study area.	Migration of contaminated water into underlying aquifers followed by lateral migration into nearby watercourses.	Unlikely	Medium	Low risk.	Low likelihood.	Medium	Moderate/low risk.		Unlikely	Mild	Very low risk.
			Discharge of contaminants entrained in groundwater and/or surface water run-off followed by overland flow and discharge.	Unlikely	Medium	Low risk.	Low likelihood.	Medium	Moderate/low risk.		Unlikely	Mild	Very low risk.
	Property/services	Existing on-site and off-site services and structures including listed buildings.	Direct contact of contaminants in soil and/or groundwater with existing buried service.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.		Unlikely	Mild	Very low risk.
			Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.		Unlikely	Mild	Very low risk.
		Proposed on-site services and structures.	Direct contact of contaminants in soil and/or groundwater with existing buried service.	Receptor not present.	--	--	Receptor not present.	--	--		Receptor not present.	--	--
			Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Receptor not present.	--	--	Receptor not present.	--	--		Receptor not present.	--	--

Source	Receptor		Contaminant exposure/migration pathway.	Baseline			Construction with primary and tertiary mitigation.			Secondary mitigation measures.	Construction with primary, tertiary and secondary mitigation.		
				Probability	Consequence	Risk Category.	Probability	Consequence	Risk Category.		Probability	Consequence	Risk Category.
		Crops and livestock (on-site).	Direct contact, ingestion, inhalation and uptake of soil and water contamination by crops and/or livestock.	Unlikely	Mild	Very low risk.	Receptor not present.	--	--		Receptor not present.	--	--
		Crops and livestock (off-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by crops or ingestion/inhalation/dermal contact by livestock.	Unlikely	Mild	Very low risk.	Low likelihood.	Mild	Low risk.		Unlikely	Mild	Very low risk.
	Ecological	Sizewell Marshes SSSI (off-site).	Direct contact, ingestion, inhalation and uptake of soil and water contamination by flora and/or fauna.	Unlikely	Mild	Very low risk.	Low likelihood.	Mild	Low risk.		Unlikely	Mild	Very low risk.
			Migration of contaminated waters/dust/fibres and subsequent uptake by flora or ingestion/inhalation/dermal contact by fauna.	Unlikely	Mild	Very low risk.	Low likelihood.	Mild	Low risk.		Unlikely	Mild	Very low risk.
Off-site: Activities associated with the operation of Sizewell A and B power stations including former asbestos lined tanks and their infill, the atmospheric deposition of radioactive materials on the main platform. Former sand pits located 250 metres (m) north-west and south-east of the main platform and	Human health: On-site	Pedestrians and road users using existing roads, footpaths, railway and fields within the site.	Dermal contact with and ingestion of contaminants in soil, soil-derived dust and water. Inhalation of contaminants in soil, soil-derived dust and vapours.	Low likelihood.	Mild	Low risk.	Low likelihood.	Mild	Low risk.		Low likelihood.	Mild	Low risk.
		Farmers and workers on agricultural land.		Unlikely	Mild	Very low risk.	Receptor not present.	--	--		Receptor not present.	--	--
		Construction and maintenance workers.		Receptor not present.	--	--	Low likelihood.	Mild	Low risk.		Unlikely	Mild	Very low risk.
		Recreational site users of the Sizewell Marshes SSSI, marshes and beach along the foreshore.		Low likelihood.	Mild	Low risk.	Receptor not present.	--	--		Receptor not present.	--	--
		Current Sizewell A and B site workers.		Low likelihood.	Mild	Low risk.	Receptor not present.	--	--		Receptor not present.	--	--

Source	Receptor		Contaminant exposure/migration pathway.	Baseline			Construction with primary and tertiary mitigation.			Secondary mitigation measures.	Construction with primary, tertiary and secondary mitigation.		
				Probability	Consequence	Risk Category.	Probability	Consequence	Risk Category.		Probability	Consequence	Risk Category.
250m to the south of the temporary construction area which have been infilled. Former brick works, brick field and clay pit located 300m to the west of the LEEIE which have been infilled. Smithy located approximately 450m south-east of the LEEIE. Tank and sewage works located 500m to the south-west of the LEEIE. Historical landfills within 500m of the site including refuse tip, Ogilvie at Home Farm, Leiston Landfill, Carrs Pit, Abbey Pit and Aldhurst Farm. Gas works, coal yard and tanks located 40m to the west of the LEEIE. Electrical substation located 100m south-west of the LEEIE. Farming activities in surrounding areas including potential for unmarked farmers tips. Allotments adjacent to the south of the LEEIE. Made Ground associated with the construction of roads surrounding the site		Future site workers and visitors.		Receptor not present.	--	--	Receptor not present.	--	--		Receptor not present.	--	--
		Residents within the temporary construction area.		Unlikely	Mild	Very low risk.	Low likelihood.	Mild	Low risk.		Unlikely	Mild	Very low risk.
	Controlled Waters	Principal Bedrock and Superficial Secondary A Aquifers (on-site).	Leaching / migration of contaminants in soil to groundwater in underlying aquifers.	Low likelihood.	Medium	Moderate/low risk.	Low likelihood.	Medium	Moderate / low risk.		Low likelihood.	Medium	Moderate/low risk.
			Migration of contaminated water through preferential pathways such as underground services, pipes and granular material to groundwater in underlying aquifers.	Unlikely	Medium	Low risk.	Unlikely	Medium	Low risk.		Unlikely	Mild	Very low risk.
		Ponds and drains on site.	Migration of contaminated water into underlying aquifers followed by lateral migration into nearby watercourses.	Low likelihood.	Medium	Moderate / low risk.	Low likelihood.	Medium	Moderate/low risk.		Low likelihood.	Medium	Moderate/low risk.
			Discharge of contaminants entrained in groundwater and/or surface water run-off followed by overland flow and discharge.	Unlikely	Medium	Low risk.	Unlikely	Medium	Low risk.		Unlikely	Medium	Low risk.
	Property/services	Existing on-site services and structures.	Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.		Unlikely	Mild	Very low risk.
		Proposed on-site services and structures associated with the site.	Migration of contaminated groundwater, ground gas and/or vapours along strata and	Receptor not present.	--	--	Receptor not present.	--	--		Receptor not present.	--	--

Source	Receptor		Contaminant exposure/migration pathway.	Baseline			Construction with primary and tertiary mitigation.			Secondary mitigation measures.	Construction with primary, tertiary and secondary mitigation.		
				Probability	Consequence	Risk Category.	Probability	Consequence	Risk Category.		Probability	Consequence	Risk Category.
as well as activities associated with their operation. Works and factories within Eastlands Industrial Estate. Risk of inorganic and organic contamination including metals and hydrocarbons, asbestos, solvents, fuels, oils, PCBs, radioactive materials, coal tar, acids and alkalis, herbicides and pesticides. Ground gas generation.			preferential pathways such as service routes or differentially permeable strata.										
		Crops and livestock (on-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by crops or ingestion/inhalation/dermal contact by livestock.	Unlikely	Mild	Very low risk.	Receptor not present.	--	--		Receptor not present.	--	--
		Sizewell Marshes SSSI (on-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by flora or ingestion/inhalation/ dermal contact by fauna.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.		Unlikely	Mild	Very low risk.

Table 1.2: Operation phase conceptual site model.

Source	Receptor		Contaminant exposure/migration pathway.	Baseline			Operation with primary and tertiary mitigation (assumed all mitigation proposed during construction is undertaken).			Operation with primary, tertiary and secondary mitigation.		
				Probability	Consequence	Risk Category.	Probability	Consequence	Risk Category.	Probability	Consequence	Risk Category.
On-site: main platform Former rifle range located in the centre of the main platform. Made Ground within the north-east of the main platform. Drainage and wind pumps in the north and centre of the main platform. Sewage treatment works located on the western boundary of the main platform. Made Ground and spoil disposal on the main platform associated with the construction of Sizewell B and former contractors' compound. Activities relating to the former contractors' compound on the main platform for Sizewell B including possible storage areas, fabrication areas, lagoons, stone washing and/or concrete batching area. Car park located on western edge of the main platform. Activities within the main platform associated with the operation of Sizewell B power station including radioactive materials. Former infilled sand pits located across the main platform. Peat and Alluvial deposits indicated to be present within the eastern edge of the main platform. Farming activities across the entire site area including potential for unmarked farmers tips. Made Ground associated with the construction of existing roads crossing the various areas of the	**Human health:** On-site	Pedestrians and road users using existing roads, footpaths and fields within the site (note that Sizewell C power station site will be secure).	Dermal contact with and ingestion of contaminants in soil, soil-derived dust and water. Inhalation of contaminants in soil, soil-derived dust, fibres and gas/vapours.	Low likelihood.	Minor	Very low risk.	Receptor not present.	--	--	Receptor not present.	--	--
		Farmers and workers on agricultural land.		Low likelihood.	Minor	Very low risk.	Receptor not present.	--	--	Receptor not present.	--	--
		Construction and maintenance workers.		Receptor not present.	--	--	Low likelihood.	Minor	Very low risk.	Low likelihood.	Minor	Very low risk.
		Recreational site users of the Sizewell Marshes SSSI, marshes and beach along the foreshore.		Low likelihood.	Minor	Very low risk.	Low likelihood.	Minor	Very low risk.	Low likelihood.	Minor	Very low risk.
		Current Sizewell B workers using areas of the main platform.		Low likelihood.	Minor	Very low risk.	Low likelihood.	Minor	Very low risk.	Low likelihood.	Minor	Very low risk.
		Future site workers and visitors.		Receptor not present.	--	--	Low likelihood.	Minor	Very low risk.	Low likelihood.	Minor	Very low risk.
	Human health: Off-site	Workers in adjacent Sizewell A and B power stations.	Dermal contact with and ingestion of contaminants in soil, soil-derived dust and water which may have migrated off-site. Inhalation of contaminants in soil, soil-derived dust, fibres and gas/vapours which may have migrated off-site.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.
		Pedestrians accessing surrounding roads and footpaths.		Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.
		Farmers and workers on agricultural land.		Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.
		Recreational site users of the surrounding Sizewell Marshes SSSI and marshes.		Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.
	Controlled Waters.	Principal Bedrock and Superficial Secondary A aquifers (on-site and off-site).	Leaching / migration of contaminants in soil to groundwater in underlying aquifers.	Low likelihood.	Mild	Low risk.	Low likelihood.	Mild	Low risk.	Low likelihood.	Minor	Very low risk.
			Migration of contaminated water through preferential pathways such as underground services, pipes	Low likelihood.	Mild	Low risk.	Low likelihood.	Mild	Low risk.	Low likelihood.	Minor	Very low risk.

Source	Receptor		Contaminant exposure/migration pathway.	Baseline			Operation with primary and tertiary mitigation (assumed all mitigation proposed during construction is undertaken).			Operation with primary, tertiary and secondary mitigation.		
				Probability	Consequence	Risk Category.	Probability	Consequence	Risk Category.	Probability	Consequence	Risk Category.
site as well as activities associated with their operation. Risk of inorganic and organic contamination including metals and hydrocarbons, biological contaminants, PCBs, asbestos, solvents, paints, fuels, oils, herbicides and pesticides. Ground gas generation.			and granular material to groundwater in underlying aquifers.									
		Ponds and drains on-site and within the study area.	Migration of contaminated water into underlying aquifers followed by lateral migration into nearby watercourses.	Unlikely	Medium	Low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
			Discharge of contaminants entrained in groundwater and/or surface water run-off followed by overland flow and discharge.	Unlikely	Medium	Low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
		North Sea (on-site and off-site).	Migration of contaminated water into underlying aquifers followed by lateral migration into nearby watercourses.	Unlikely	Medium	Low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
			Discharge of contaminants entrained in surface water run-off followed by overland flow and discharge.	Unlikely	Medium	Low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
	Property/services	Existing on-site and off-site services and structures including listed buildings.	Direct contact contaminants in soil and/or groundwater with buried service.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.
			Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Unlikely	Mild	Very low risk.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.
		Proposed on-site services and structures.	Direct contact contaminants in soil and/or groundwater with existing buried service.	Receptor not present.	--	--	Low likelihood.	Minor	Very low risk.	Low likelihood.	Minor	Very low risk.

Source	**Receptor**		**Contaminant exposure/migration pathway.**	**Baseline**			**Operation with primary and tertiary mitigation (assumed all mitigation proposed during construction is undertaken).**			**Operation with primary, tertiary and secondary mitigation.**		
				Probability	**Consequence**	**Risk Category.**	**Probability**	**Consequence**	**Risk Category.**	**Probability**	**Consequence**	**Risk Category.**
			Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Receptor not present.	--	--	Low likelihood.	Minor	Very low risk.	Low likelihood.	Minor	Very low risk.
		Crops and livestock (on-site).	Direct contact, ingestion, inhalation and uptake of soil and water contamination by crops and/or livestock.	Unlikely	Minor	Very low risk.	Receptor not present.	--	--	Receptor not present.	--	--
		Crops and livestock (off-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by crops or ingestion/inhalation/dermal contact by livestock.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.
	Ecological	Sizewell Marshes SSSI (on-site and off-site).	Direct contact, ingestion, inhalation and uptake of soil and water contamination by flora and/or fauna.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.
			Migration of contaminated waters/dust/fibres and subsequent uptake by flora or ingestion/inhalation/dermal contact by fauna.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.
		Minsmere-Walberswick Heaths and Marshes SSSI, Ramsar, SAC and SPA and Suffolk Coast and Heaths AONB (off-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by flora or ingestion/inhalation/dermal contact by fauna.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.
On-site: temporary construction area Former infilled sand pits located across the temporary construction area.	Human health: On-site	Pedestrians and road users using existing roads, footpaths and fields within the site.	Dermal contact with and ingestion of contaminants in soil, soil-derived dust and water.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
		Farmers and workers on agricultural land.		Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.

Source	Receptor		Contaminant exposure/migration pathway.	Baseline			Operation with primary and tertiary mitigation (assumed all mitigation proposed during construction is undertaken).			Operation with primary, tertiary and secondary mitigation.		
				Probability	Consequence	Risk Category.	Probability	Consequence	Risk Category.	Probability	Consequence	Risk Category.
Grass covered mounds (suspected Made Ground) located in the north east of the temporary construction area. Peat and alluvial deposits indicated to be present within the eastern edge of the temporary construction area. Farming activities across the entire site area including potential for unmarked farmers tips. Made Ground associated with the construction of roads crossing the various areas of the site as well as activities associated with their operation. Risk of inorganic and organic contamination including metals and hydrocarbons, asbestos, fuels, oils, herbicides and pesticides.		Construction and maintenance workers.	Inhalation of contaminants in soil, soil-derived dust and gas/vapours.	Receptor not present.	--	--	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
		Residents within the temporary construction area.		Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
	Human health: Off-site	Occupants of nearby residential, recreational and commercial properties.	Dermal contact with and ingestion of contaminants in soil, soil-derived dust and water which may have migrated off-site. Inhalation of contaminants in soil, soil-derived dust, fibres and gas/vapours which may have migrated off-site.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
		Pedestrians accessing surrounding roads and footpaths.		Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
		Farmers and workers on agricultural land.		Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
		Recreational site users of the Sizewell Marshes SSSI and marshes.		Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
	Controlled Waters	Principal Bedrock and Superficial Secondary A aquifers (on-site and off-site).	Leaching / migration of contaminants in soil to groundwater in underlying aquifers.	Unlikely	Medium	Low risk.	Low likelihood.	Mild	Low risk.	Unlikely	Mild	Very low risk.
			Migration of contaminated water through preferential pathways such as underground services, pipes and granular material to groundwater in underlying aquifers.	Unlikely	Medium	Low risk.	Low likelihood.	Mild	Low risk.	Unlikely	Mild	Very low risk.
		Ponds and drains on-site and within study area.	Migration of contaminated water into underlying aquifers followed by lateral migration into nearby watercourses.	Unlikely	Medium	Low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
			Discharge of contaminants entrained in groundwater and/or surface water run-off followed by overland flow and discharge.	Unlikely	Medium	Low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
		North Sea (off-site).	Migration of contaminated water into underlying aquifers followed by lateral	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.

Source	Receptor		Contaminant exposure/migration pathway.	Baseline			Operation with primary and tertiary mitigation (assumed all mitigation proposed during construction is undertaken).			Operation with primary, tertiary and secondary mitigation.		
				Probability	Consequence	Risk Category.	Probability	Consequence	Risk Category.	Probability	Consequence	Risk Category.
			migration into nearby watercourses.									
			Discharge of contaminants entrained in surface water run-off followed by overland flow and discharge.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
	Property/ services.	Existing on-site and off-site services and structures including Leiston Abbey Scheduled Monument and listed buildings.	Direct contact of contaminants in soil and/or groundwater with existing buried service.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.
			Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
		Proposed on-site services and structures.	Direct contact of contaminants in soil and/or groundwater with existing buried service.	Receptor not present.	--	--	Unlikely	Minor	Very low risk.	Unlikely	Mild	Very low risk.
			Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Receptor not present.	--	--	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
		Crops and livestock (on-site).	Direct contact, ingestion, inhalation and uptake of soil and water contamination by crops and/or livestock.	Unlikely	Mild	Very low risk.	Receptor not present.	--	--	Receptor not present.	--	--
		Crops and livestock (off-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by crops or ingestion/inhalation/ dermal contact by livestock.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.

Source	Receptor		Contaminant exposure/migration pathway.	Baseline			Operation with primary and tertiary mitigation (assumed all mitigation proposed during construction is undertaken).			Operation with primary, tertiary and secondary mitigation.		
				Probability	Consequence	Risk Category.	Probability	Consequence	Risk Category.	Probability	Consequence	Risk Category.
	Ecological	Sizewell Marshes SSSI (off-site).	Direct contact, ingestion, inhalation and uptake of soil and water contamination by flora and/or fauna.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
			Migration of contaminated waters/dust/fibres and subsequent uptake by flora or ingestion/inhalation/dermal contact by fauna.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
		Minsmere-Walberswick Heaths and Marshes SSSI, Ramsar, SAC and SPA and Suffolk Coast and Heaths AONB (off-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by flora or ingestion/inhalation/dermal contact by fauna.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
On-site: LEEIE Fly tipping in the north west of the LEEIE. Railway line running through the western extent of the LEEIE. Farming activities across the entire site area including potential for unmarked farmers tips. Made Ground present within the southern section of the LEEIE associated with the railway line and in the northern section associated with an infilled reservoir. Electricity substation at the eastern extent of the proposed construction corridor for the electrical supply connection to the east of the LEEIE E. Made Ground associated with the construction of existing roads crossing the various areas of the site as well as activities associated with their operation. Risk of inorganic and organic contamination including metals and	**Human health:** On-site	Pedestrians and road users using existing roads, railway, footpaths and fields within the site.	Dermal contact with and ingestion of contaminants in soil, soil-derived dust and water.	Low likelihood.	Mild	Low risk.	Receptor not present.	--	--	Receptor not present.	--	--
		Farmers and workers on agricultural land.	Inhalation of contaminants in soil, soil-derived dust and vapours.	Unlikely	Mild	Very low risk.	Receptor not present.	--	--	Receptor not present.	--	--
		Construction and maintenance workers.		Receptor not present.	--	--	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
	Human health: Off-site	Occupants of nearby residential, recreational and commercial properties.	Dermal contact with and/or ingestion of contaminants in windblown soil-derived dusts and water that may have migrated off site. Inhalation of windblown soil derived dust, fibres and gas/vapours which may have migrated off site.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
		Pedestrians accessing surrounding roads and footpaths.		Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
		Farmers and workers on agricultural land.		Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
	Controlled Waters	Principal Bedrock and Superficial Secondary A aquifers (on-site and off-site).	Leaching / migration of contaminants in soil to groundwater in underlying aquifers.	Unlikely	Medium	Low risk.	Low likelihood	Mild	Low risk.	Unlikely	Mild	Very low risk.
			Migration of contaminated water through preferential pathways such as	Unlikely	Medium	Low risk.	Low likelihood	Mild	Low risk.	Unlikely	Mild	Very low risk.

Source	Receptor		Contaminant exposure/migration pathway.	Baseline			Operation with primary and tertiary mitigation (assumed all mitigation proposed during construction is undertaken).			Operation with primary, tertiary and secondary mitigation.		
				Probability	Consequence	Risk Category.	Probability	Consequence	Risk Category.	Probability	Consequence	Risk Category.
hydrocarbons, asbestos, fuels, oils, PCBs, PAHs, herbicides and pesticides.			underground services, pipes and granular material to groundwater in underlying aquifers.									
		Ponds and drains on-site and within study area.	Migration of contaminated water into underlying aquifers followed by lateral migration into nearby watercourses.	Unlikely	Medium	Low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
			Discharge of contaminants entrained in groundwater and/or surface water run-off followed by overland flow and discharge.	Unlikely	Medium	Low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
	Property/ services	Existing on-site and off-site services and structures including listed buildings.	Direct contact of contaminants in soil and/or groundwater with existing buried service.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.
			Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
		Proposed on-site services and structures.	Direct contact of contaminants in soil and/or groundwater with existing buried service.	Receptor not present.	--	--	Unlikely	Minor	Very low risk.	Unlikely	Minor	Very low risk.
			Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Receptor not present.	--	--	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
		Crops and livestock (on-site).	Direct contact, ingestion, inhalation and uptake of soil and water contamination by crops and/or livestock.	Unlikely	Mild	Very low risk.	Receptor not present.	--	--	Receptor not present.	--	--

Source	Receptor		Contaminant exposure/migration pathway.	Baseline			Operation with primary and tertiary mitigation (assumed all mitigation proposed during construction is undertaken).			Operation with primary, tertiary and secondary mitigation.		
				Probability	**Consequence**	**Risk Category.**	**Probability**	**Consequence**	**Risk Category.**	**Probability**	**Consequence**	**Risk Category.**
		Crops and livestock (off-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by crops or ingestion/inhalation/ dermal contact by livestock.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
	Ecological	Sizewell Marshes SSSI (off-site).	Direct contact, ingestion, inhalation and uptake of soil and water contamination by flora and/or fauna.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
			Migration of contaminated waters/dust/fibres and subsequent uptake by flora or ingestion/inhalation/ dermal contact by fauna.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
Off-site: Activities associated with the operation of Sizewell A and B power stations including former asbestos lined tanks and their infill, the atmospheric deposition of radioactive materials on the main platform. Former sand pits located 250m north-west and south-east of the main platform and 250m to the south of the temporary construction area which have been infilled. Former brick works, brick field and clay pit located 300m to the west of the LEEIE which have been infilled. Smithy located approximately 450m south-east of the LEEIE. Tank and sewage works located 500m to the south-west of the LEEIE. Historical landfills within 500m of the site including refuse tip, Ogilvie at Home Farm, Leiston Landfill,	**Human health:** On-site	Pedestrians and road users using existing roads, footpaths, railway and fields within the site.	Dermal contact with and ingestion of contaminants in soil, soil-derived dust and water.	Low likelihood.	Mild	Low risk.	Low likelihood.	Mild	Low risk.	Low likelihood.	Mild	Low risk.
		Farmers and workers on agricultural land.	Inhalation of contaminants in soil, soil-derived dust and vapours.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
		Construction maintenance workers.		Receptor not present.	--	--	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
		Recreational site users of the Sizewell Marshes SSSI, marshes and beach along the foreshore.		Low likelihood.	Mild	Low risk.	Low likelihood.	Mild	Low risk.	Low likelihood.	Mild	Low risk.
		Current Sizewell B site workers using the main platform.		Low likelihood.	Mild	Low risk.	Low likelihood.	Mild	Low risk.	Low likelihood.	Mild	Low risk.
		Future site workers and visitors.		Receptor not present.	--	--	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
		Residents within the temporary construction area.		Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
	Controlled Waters	Principal Bedrock and Superficial Secondary A aquifers (on-site).	Leaching / migration of contaminants in soil to groundwater in underlying aquifers.	Low likelihood.	Medium	Moderate/ low risk.	Low likelihood.	Medium	Moderate/ low risk.	Low likelihood.	Medium	Moderate/ low risk.

Source	**Receptor**		**Contaminant exposure/migration pathway.**	**Baseline**			**Operation with primary and tertiary mitigation (assumed all mitigation proposed during construction is undertaken).**			**Operation with primary, tertiary and secondary mitigation.**		
				Probability	**Consequence**	**Risk Category.**	**Probability**	**Consequence**	**Risk Category.**	**Probability**	**Consequence**	**Risk Category.**
Carrs Pit, Abbey Pit and Aldhurst Farm. Gas works, coal yard and tanks located 40m to the west of the LEEIE. Electrical substation located 100m south-west of the LEEIE. Farming activities in surrounding areas including potential for unmarked farmers tips. Allotments adjacent to the south of the LEEIE. Made Ground associated with the construction of roads surrounding the site as well as activities associated with their operation. Works and factories within Eastlands Industrial Estate. Risk of inorganic and organic contamination including metals and hydrocarbons, asbestos, solvents, fuels, oils, PCBs, radioactive materials, coal tar, acids and alkalis, herbicides and pesticides. Ground gas generation.			Migration of contaminated water through preferential pathways such as underground services, pipes and granular material to groundwater in underlying aquifers.	Unlikely	Medium	Low risk.	Unlikely	Medium	Low risk.	Unlikely	Mild	Very low risk.
		Ponds and drains on-site.	Migration of contaminated water into underlying aquifers followed by lateral migration into nearby watercourses.	Low likelihood.	Medium	Moderate/ low risk.	Low likelihood.	Medium	Moderate/ low risk.	Low likelihood.	Medium	Moderate/ low risk.
			Discharge of contaminants entrained in groundwater and/or surface water run-off followed by overland flow and discharge.	Unlikely	Medium	Low risk.	Unlikely	Medium	Low risk.	Unlikely	Medium	Low risk.
	Property /services	Existing on-site services and structures.	Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
		Proposed on-site services and structures associated with the site.	Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Receptor not present.	--	--	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
		Crops and livestock (on-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by crops or ingestion/inhalation/ dermal contact by livestock.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.
		Sizewell Marshes SSSI (on-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by flora or ingestion/inhalation/ dermal contact by fauna.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.	Unlikely	Mild	Very low risk.

VOLUME 2, CHAPTER 18, APPENDIX 18C: IMPACT ASSESSMENT TABLES

Contents

Tables

Plates

None provided.

Figures

None provided.

1. Impact Assessment Tables

Table 1.1: Construction phase impact assessment.

Source	Receptor		Contaminant Exposure / Migration Pathway.	Baseline (Current) Risk Assessment.	Construction Phase Risk Assessment (with Primary and Tertiary Mitigation Measures).	Classification of Effect.	Secondary Mitigation Measures.	Construction Phase Risk Assessment (with Primary, Tertiary and Secondary Mitigation Measures).	Residual Effects.
On-site: Main platform. Former rifle range located in the centre of the main platform. Made Ground within the north-east of the main platform. Drainage and wind pumps in the north and centre of the main platform. Sewage treatment works located on the western boundary of the main platform. Made Ground and spoil disposal on the main platform associated with the construction of Sizewell B and former contractors' compound. Activities relating to the former contractors' compound on the main platform for Sizewell B including possible storage areas, fabrication areas, lagoons, stone washing/concrete batching area. Car park located on western edge of the main platform. Activities within the main platform associated with the operation of Sizewell B	**Human health:** On-site.	Pedestrians and road users using existing roads, footpaths and fields within the site (noted that Sizewell C power station site will be secure).	Dermal contact with and ingestion of contaminants in soil, soil-derived dust and water. Inhalation of contaminants in soil, soil-derived dust, fibres and gas/vapours.	Very low risk.	Receptor not present.	Negligible[1]	Additional intrusive ground investigation undertaken post planning to inform the detailed design and confirm the ground conditions and contamination status of the site including soil and groundwater sampling and monitoring and testing of marine sediments. Remediation of soil and groundwater contamination prior to construction (e.g. source removal, treatment or capping) if deemed necessary.	Receptor not present.	Negligible[1]
		Farmers and workers on agricultural land.		Very low risk.	Receptor not present.	Negligible[1]		Receptor not present.	Negligible[1]
		Construction and maintenance workers.		Receptor not present.	Low risk.	Minor adverse.		Very low risk.	Negligible[1]
		Recreational site users of the Sizewell Marshes Site of Special Scientific Interest (SSSI), marshes and beach along the foreshore.		Very low risk.	Receptor not present.	Negligible[1]		Receptor not present.	Negligible[1]
		Current Sizewell B workers using areas of the main platform.		Very low risk.	Receptor not present.	Negligible[1]		Receptor not present.	Negligible[1]
		Future site workers and visitors.		Receptor not present.	Receptor not present.	Negligible		Receptor not present.	Negligible
	Human health: Off-site.	Workers in adjacent Sizewell A and B power stations.	Dermal contact with and ingestion of contaminants in soil, soil-derived dust and water which may have migrated off-site. Inhalation of contaminants in soil, soil-derived dust, fibres and gas/vapours which may have migrated off-site.	Very low risk.	Very low risk.	Negligible		Very low risk.	Negligible
		Pedestrians accessing surrounding roads and footpaths.		Very low risk.	Very low risk.	Negligible		Very low risk.	Negligible
		Farmers and workers on agricultural land.		Very low risk.	Very low risk.	Negligible		Very low risk.	Negligible
		Recreational site users of the surrounding Sizewell Marshes SSSI and marshes.		Very low risk.	Very low risk.	Negligible		Very low risk.	Negligible
	Controlled Waters.	Principal Bedrock and Superficial Secondary A aquifers (on-site and off-site).	Leaching/migration of contaminants in soil to groundwater in underlying aquifers.	Low risk.	Low risk.	Negligible		Very low risk.	Minor beneficial.

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[1] Removal of this receptor at construction automatically triggers a minor beneficial effect. However, professional judgement has been exercised and this effect has been reduced to negligible.

Source	Receptor		Contaminant Exposure / Migration Pathway.	Baseline (Current) Risk Assessment.	Construction Phase Risk Assessment (with Primary and Tertiary Mitigation Measures).	Classification of Effect.	Secondary Mitigation Measures.	Construction Phase Risk Assessment (with Primary, Tertiary and Secondary Mitigation Measures).	Residual Effects.
power station including radioactive materials. Former infilled sand pits located across the main platform. Peat and Alluvial deposits indicated to be present within the eastern edge of the main platform. Farming activities across the entire site area including potential for unmarked farmers tips. Made Ground associated with the construction of roads crossing the various areas of the site as well as activities associated with their operation. Risk of inorganic and organic contamination including metals and hydrocarbons, biological contaminants, Polychlorinated Biphenyls (PCBs), asbestos, solvents, paints, fuels, oils, herbicides and pesticides. Ground gas generation.			Migration of contaminated water through preferential pathways such as underground services, pipes and granular material to groundwater in underlying aquifers.	Low risk.	Low risk.	Negligible		Very low risk.	Minor beneficial.
		Ponds and drains on-site and within the study area.	Migration of contaminated water into underlying aquifers followed by lateral migration into nearby watercourses.	Low risk.	Low risk.	Negligible		Very low risk.	Minor beneficial.
			Discharge of contaminants entrained in groundwater and/or surface water run-off followed by overland flow and discharge.	Low risk.	Low risk.	Negligible		Very low risk.	Minor beneficial.
		North Sea (on-site and off-site).	Migration of contaminated water into underlying aquifers followed by lateral migration into nearby watercourses.	Low risk.	Low risk.	Negligible		Very low risk.	Minor beneficial.
			Discharge of contaminants entrained in surface water run-off followed by overland flow and discharge.	Low risk.	Low risk.	Negligible		Very low risk.	Minor beneficial.
	Property / services	Existing on-site and off-site services and structures including listed buildings.	Direct contact of contaminants in soil and/or groundwater with buried service.	Very low risk.	Very low risk.	Negligible		Very low risk.	Negligible
			Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Very low risk.	Very low risk.	Negligible		Very low risk.	Negligible
		Proposed on-site services and structures.	Direct contact of contaminants in soil and/or groundwater with existing buried service.	Receptor not present.	Receptor not present.	Negligible		Receptor not present.	Negligible

Source	Receptor		Contaminant Exposure / Migration Pathway.	Baseline (Current) Risk Assessment.	Construction Phase Risk Assessment (with Primary and Tertiary Mitigation Measures).	Classification of Effect.	Secondary Mitigation Measures.	Construction Phase Risk Assessment (with Primary, Tertiary and Secondary Mitigation Measures).	Residual Effects.
			Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Receptor not present.	Receptor not present.	Negligible		Receptor not present.	Negligible
		Crops and livestock (on-site).	Direct contact, ingestion, inhalation and uptake of soil and water contamination by crops and/or livestock.	Very low risk.	Receptor not present.	Negligible[1]		Receptor not present.	Negligible[1]
		Crops and livestock (off-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by crops or ingestion/inhalation/dermal contact by livestock.	Very low risk.	Very low risk.	Negligible		Very low risk.	Negligible
	Ecological	Sizewell Marshes SSSI (on-site and off-site).	Direct contact, ingestion, inhalation and uptake of soil and water contamination by flora and/or fauna.	Very low risk.	Very low risk.	Negligible		Very low risk.	Negligible
			Migration of contaminated waters/dust/fibres and subsequent uptake by flora or ingestion/inhalation/dermal contact by fauna.	Very low risk.	Very low risk.	Negligible		Very low risk.	Negligible
		Minsmere-Walberswick Heaths and Marshes SSSI, Ramsar, Special Area of Conservation (SAC) and Special Protection Area (SPA) and Suffolk Coast and Heaths Area of Outstanding Natural Beauty (AONB) (off-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by flora or ingestion/inhalation/dermal contact by fauna.	Very low risk.	Very low risk.	Negligible		Very low risk.	Negligible
On-site: **Temporary Construction Area.** Former infilled sand pits located across the temporary construction area.	**Human health:** On-site.	Pedestrians and road users using existing roads, footpaths and fields within the site.	Dermal contact with and ingestion of contaminants in soil, soil-derived dust and water.	Very low risk.	Low risk.	Minor adverse.		Very low risk.	Negligible
		Farmers and workers on agricultural land.		Very low risk.	Receptor not present.	Negligible[1]		Receptor not present.	Negligible[1]

Source	Receptor		Contaminant Exposure / Migration Pathway.	Baseline (Current) Risk Assessment.	Construction Phase Risk Assessment (with Primary and Tertiary Mitigation Measures).	Classification of Effect.	Secondary Mitigation Measures.	Construction Phase Risk Assessment (with Primary, Tertiary and Secondary Mitigation Measures).	Residual Effects.
Grass covered mounds (suspected Made Ground) located in the north-east of the temporary construction area. Peat and Alluvial deposits indicated to be present within the eastern edge of the temporary construction area. Farming activities across the entire site area including potential for unmarked farmers tips. Made Ground associated with the construction of existing roads crossing the various areas of the site as well as activities associated with their operation. Risk of inorganic and organic contamination including metals and hydrocarbons, asbestos, fuels, oils, herbicides and pesticides.		Construction and maintenance workers.	Inhalation of contaminants in soil, soil-derived dust and gas/vapours.	Receptor not present.	Low risk.	Minor adverse.		Very low risk.	Negligible[2]
		Residents within the temporary construction area.		Very low risk.	Low risk.	Minor adverse.		Very low risk.	Negligible
	Human health: Off-site.	Occupants of nearby residential, recreational and commercial properties.	Dermal contact with and ingestion of contaminants in soil, soil-derived dust and water which may have migrated off-site. Inhalation of contaminants in soil, soil-derived dust, fibres and gas/vapours which may have migrated off-site.	Very low risk.	Low risk.	Minor adverse.		Very low risk.	Negligible
		Pedestrians accessing surrounding roads and footpaths.		Very low risk.	Low risk.	Minor adverse.		Very low risk.	Negligible
		Farmers and workers on agricultural land.		Very low risk.	Low risk.	Minor adverse.		Very low risk.	Negligible
		Recreational site users of the Sizewell Marshes SSSI and marshes.		Very low risk.	Low risk.	Minor adverse.		Very low risk.	Negligible
	Controlled Waters.	Principal Bedrock and Superficial Secondary A aquifers (on-site and off-site).	Leaching/migration of contaminants in soil to groundwater in underlying aquifers.	Low risk.	Moderate/low risk.	Minor adverse.		Very low risk.	Minor beneficial.
			Migration of contaminated water through preferential pathways such as underground services, pipes and granular material to groundwater in underlying aquifers.	Low risk.	Moderate/low risk.	Minor adverse.		Very low risk.	Minor beneficial.
		Ponds and drains on-site and within study area.	Migration of contaminated water into underlying aquifers followed by lateral migration into nearby watercourses.	Low risk.	Moderate/low risk.	Minor adverse.		Very low risk.	Minor beneficial.
			Discharge of contaminants entrained in groundwater and/or surface water run-off followed by overland flow and discharge.	Low risk.	Moderate/low risk.	Minor adverse.		Very low risk.	Minor beneficial.

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[2] Introduction of this receptor at construction automatically triggers a minor adverse effect. However, professional judgement has been exercised and this effect has been reduced to negligible.

Source	Receptor		Contaminant Exposure / Migration Pathway.	Baseline (Current) Risk Assessment.	Construction Phase Risk Assessment (with Primary and Tertiary Mitigation Measures).	Classification of Effect.	Secondary Mitigation Measures.	Construction Phase Risk Assessment (with Primary, Tertiary and Secondary Mitigation Measures).	Residual Effects.
		North Sea (off-site).	Migration of contaminated water into underlying aquifers followed by lateral migration into nearby watercourses.	Very low risk.	Low risk.	Minor adverse.		Very low risk.	Negligible
			Discharge of contaminants entrained in surface water run-off followed by overland flow and discharge.	Very low risk.	Low risk.	Minor adverse.		Very low risk.	Negligible
	Property / services	Existing on-site and off-site services and structures including Leiston Abbey Scheduled Monument and listed buildings.	Direct contact of contaminants in soil and/or groundwater with existing buried service.	Very low risk.	Very low risk.	Negligible		Very low risk.	Negligible
			Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Very low risk.	Very low risk.	Negligible		Very low risk.	Negligible
		Proposed on-site services and structure.	Direct contact of contaminants in soil and/or groundwater with existing buried service.	Receptor not present.	Receptor not present.	Negligible		Receptor not present.	Negligible
			Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Receptor not present.	Receptor not present.	Negligible		Receptor not present.	Negligible
		Crops and livestock (on-site).	Direct contact, ingestion, inhalation and uptake of soil and water contamination by crops and/or livestock.	Very low risk.	Receptor not present.	Negligible[1]		Receptor not present.	Negligible[1]
		Crops and livestock (off-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by crops or ingestion/inhalation/dermal contact by livestock.	Very low risk.	Low risk.	Minor adverse.		Very low risk.	Negligible
	Ecological	Sizewell Marshes SSSI (off-site).	Direct contact, ingestion, inhalation and uptake of soil and water contamination by flora and/or fauna.	Very low risk.	Low risk.	Minor adverse.		Very low risk.	Negligible

Source	Receptor		Contaminant Exposure / Migration Pathway.	Baseline (Current) Risk Assessment.	Construction Phase Risk Assessment (with Primary and Tertiary Mitigation Measures).	Classification of Effect.	Secondary Mitigation Measures.	Construction Phase Risk Assessment (with Primary, Tertiary and Secondary Mitigation Measures).	Residual Effects.
			Migration of contaminated waters/dust/fibres and subsequent uptake by flora or ingestion/inhalation/dermal contact by fauna.	Very low risk.	Low risk.	Minor adverse.		Very low risk.	Minor beneficial.
		Minsmere-Walberswick Heaths and Marshes SSSI, Ramsar, SAC and SPA and Suffolk Coast and Heaths AONB (off-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by flora or ingestion / inhalation/ dermal contact by fauna.	Very low risk.	Low risk.	Minor adverse.		Very low risk.	Minor beneficial.
On-site: Land east of Eastlands Industrial Estate (LEEIE). Fly tipping in the north-west of the LEEIE. Railway line running through the western extent of the LEEIE. Farming activities across the entire site area including potential for unmarked farmers tips. Made Ground present within the western section of the LEEIE associated with the railway line and in the northern section associated with an infilled reservoir. Electricity substation at the eastern extent of the proposed construction corridor for the electrical supply connection to the east of the LEEIE. Made Ground associated with the construction of roads crossing the various areas of the site as well as	**Human health:** On-site.	Pedestrians and road users using existing roads, railway, footpaths and fields within the site.	Dermal contact with and ingestion of contaminants in soil, soil-derived dust and water. Inhalation of contaminants in soil, soil-derived dust and vapours.	Low risk.	Receptor not present.	Negligible[1]		Receptor not present.	Negligible[1]
		Farmers and workers on agricultural land.		Very low risk.	Receptor not present.	Negligible[1]		Receptor not present.	Negligible[1]
		Construction and maintenance workers.		Receptor not present.	Low risk.	Minor adverse.		Very low risk.	Negligible[3]
	Human health: Off-site.	Occupants of nearby residential, recreational and commercial properties.	Dermal contact with and/or ingestion of contaminants in windblown soil-derived dusts and water that may have migrated off-site. Inhalation of windblown soil derived dust, fibres and gas/vapours which may have migrated off-site.	Very low risk.	Low risk.	Minor adverse.		Very low risk.	Negligible[1]
		Pedestrians accessing surrounding roads and footpaths.		Very low risk.	Low risk.	Minor adverse.		Very low risk.	Negligible[1]
		Farmers and workers on agricultural land.		Very low risk.	Low risk.	Minor adverse.		Very low risk.	Negligible[1]
	Controlled Waters.	Principal Bedrock and Superficial Secondary A aquifers (on-site and off-site).	Leaching/migration of contaminants in soil to groundwater in underlying aquifers.	Low risk.	Moderate/low risk.	Minor adverse.		Very low risk.	Minor beneficial.
			Migration of contaminated water through preferential pathways such as underground services, pipes and granular material to groundwater in underlying aquifers.	Low risk.	Moderate/low risk.	Minor adverse.		Very low risk.	Minor beneficial.

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[3] Introduction of this receptor at construction automatically triggers a minor adverse effect. However, professional judgement has been exercised and this effect has been reduced to negligible.

Source	Receptor		Contaminant Exposure / Migration Pathway.	Baseline (Current) Risk Assessment.	Construction Phase Risk Assessment (with Primary and Tertiary Mitigation Measures).	Classification of Effect.	Secondary Mitigation Measures.	Construction Phase Risk Assessment (with Primary, Tertiary and Secondary Mitigation Measures).	Residual Effects.
activities associated with their operation. Risk of inorganic and organic contamination including metals and hydrocarbons, asbestos, fuels, oils, Polychlorinated Biphenyls (PCBs), Polycyclic Aromatic Hydrocarbons (PAHs), herbicides and pesticides.		Ponds and drains on-site and within study area.	Migration of contaminated water into underlying aquifers followed by lateral migration into nearby watercourses.	Low risk.	Moderate/low risk.	Minor adverse.		Very low risk.	Minor beneficial.
			Discharge of contaminants entrained in groundwater and/or surface water run-off followed by overland flow and discharge.	Low risk.	Moderate/low risk.	Minor adverse.		Very low risk.	Minor beneficial.
	Property / services	Existing on-site and off-site services and structures including listed buildings.	Direct contact of contaminants in soil and/or groundwater with existing buried service.	Very low risk.	Very low risk.	Negligible		Very low risk.	Negligible
			Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Very low risk.	Very low risk.	Negligible		Very low risk.	Negligible
		Proposed on-site services and structures.	Direct contact of contaminants in soil and/or groundwater with existing buried service.	Receptor not present.	Receptor not present.	Negligible		Receptor not present.	Negligible
			Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Receptor not present.	Receptor not present.	Negligible		Receptor not present.	Negligible
		Crops and livestock (on-site).	Direct contact, ingestion, inhalation and uptake of soil and water contamination by crops and/or livestock.	Very low risk.	Receptor not present.	Negligible[1]		Receptor not present.	Negligible[1]
		Crops and livestock (off-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by crops or ingestion/inhalation/dermal contact by livestock.	Very low risk.	Low risk.	Minor adverse.		Very low risk.	Negligible

Source	Receptor		Contaminant Exposure / Migration Pathway.	Baseline (Current) Risk Assessment.	Construction Phase Risk Assessment (with Primary and Tertiary Mitigation Measures).	Classification of Effect.	Secondary Mitigation Measures.	Construction Phase Risk Assessment (with Primary, Tertiary and Secondary Mitigation Measures).	Residual Effects.
	Ecological	Sizewell Marshes SSSI (off-site).	Direct contact, ingestion, inhalation and uptake of soil and water contamination by flora and/or fauna.	Very low risk.	Low risk.	Minor adverse.		Very low risk.	Negligible
			Migration of contaminated waters/dust/fibres and subsequent uptake by flora or ingestion/inhalation/dermal contact by fauna.	Very low risk.	Low risk.	Minor adverse.		Very low risk.	Negligible
Off-site: Activities associated with the operation of Sizewell A and B power stations including former asbestos lined tanks and their infill, the atmospheric deposition of radioactive materials on the main platform main platform. Former sand pits located 250 metres (m) north-west and south-east of the main platform and 250m to the south of the temporary construction area which have been infilled. Former brick works, brick field and clay pit located 300m to the west of the LEEIE which have been infilled. Smithy located approximately 450m south-east of the LEEIE. Tank and sewage works located 500m to the south-west of the LEEIE. Historical landfills within 500m of the site including refuse tip, Ogilvie at Home Farm, Leiston Landfill, Carrs Pit, Abbey Pit and Aldhurst Farm.	**Human health:** On-site.	Pedestrians and road users using existing roads, footpaths, railway and fields within the site.	Dermal contact with and ingestion of contaminants in soil, soil-derived dust and water. Inhalation of contaminants in soil, soil-derived dust and vapours.	Low risk.	Low risk.	Negligible		Low risk.	Negligible
		Farmers and workers on agricultural land.		Very low risk.	Receptor not present.	Negligible[1]		Receptor not present.	Negligible[1]
		Construction and maintenance workers.		Receptor not present.	Low risk.	Minor adverse.		Very low risk.	Negligible[3]
		Recreational site users of the SSSI, marshes and beach along the foreshore.		Low risk.	Receptor not present.	Negligible[1]		Receptor not present.	Negligible[1]
		Current Sizewell B site workers using the main platform.		Low risk.	Receptor not present.	Negligible[1]		Receptor not present.	Negligible[1]
		Future site workers and visitors.		Receptor not present.	Receptor not present.	Negligible		Receptor not present.	Negligible
		Residents within the temporary construction area.		Very low risk.	Low risk.	Minor adverse.		Very low risk.	Negligible
	Controlled Waters.	Principal Bedrock and Superficial Secondary A Aquifers (on-site).	Leaching/migration of contaminants in soil to groundwater in underlying aquifers.	Moderate/low risk.	Moderate/low risk.	Negligible		Moderate/low risk.	Negligible
			Migration of contaminated water through preferential pathways such as underground services, pipes and granular material to groundwater in underlying aquifers.	Low risk.	Low risk.	Negligible		Very low risk.	Minor beneficial.
		Ponds and drains on-site.	Migration of contaminated water into underlying aquifers followed by lateral migration into nearby watercourses.	Moderate/low risk.	Moderate/low risk.	Negligible		Moderate/low risk.	Negligible

Source	Receptor		Contaminant Exposure / Migration Pathway.	Baseline (Current) Risk Assessment.	Construction Phase Risk Assessment (with Primary and Tertiary Mitigation Measures).	Classification of Effect.	Secondary Mitigation Measures.	Construction Phase Risk Assessment (with Primary, Tertiary and Secondary Mitigation Measures).	Residual Effects.
Gas works, coal yard and tanks located 40m to the west of the LEEIE. Electrical substation located 100m south-west of the LEEIE. Farming activities in surrounding areas including potential for unmarked farmers tips. Allotments adjacent to the south of the LEEIE. Made Ground associated with the construction of existing roads surrounding the site as well as activities associated with their operation. Works and factories within Eastlands Industrial Estate. Risk of inorganic and organic contamination including metals and hydrocarbons, asbestos, solvents, fuels, oils, PCBs, radioactive materials, coal tar, acids and alkalis, herbicides and pesticides. Ground gas generation.			Discharge of contaminants entrained in groundwater and/or surface water run-off followed by overland flow and discharge.	Low risk.	Low risk.	Negligible		Low risk.	Negligible
	Property / services	Existing on-site services and structures.	Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Very low risk.	Very low risk.	Negligible		Very low risk.	Negligible
		Proposed on-site services and structures associated with the site.	Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Receptor not present.	Receptor not present.	Negligible		Receptor not present.	Negligible
		Crops and livestock (on-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by crops or ingestion/inhalation/dermal contact by livestock.	Very low risk.	Receptor not present.	Negligible[1]		Receptor not present.	Negligible[1]
		Sizewell Marshes SSSI (on-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by flora or ingestion/inhalation/ dermal contact by fauna.	Very low risk.	Very low risk.	Negligible		Very low risk.	Negligible

Table 1.2: Operational phase impact assessment.

Source	Receptor		Contaminant Exposure / Migration Pathway.	Baseline (Current) Risk Assessment.	Operation Phase Risk Assessment (with primary and Tertiary Mitigation Measures Assuming All Mitigation Proposed During Construction is Undertaken).	Classification of Effect.	Operational Phase Risk Assessment (with Primary, Tertiary and Secondary Mitigation Measures).	Residual Effects.
On-site: Main platform. Former rifle range located in the centre of the main platform. Made Ground within the north-east of the main platform. Drainage and wind pumps in the north and centre of the main platform. Sewage treatment works located on the western boundary of the main platform. Made Ground and spoil disposal on the main platform associated with the construction of Sizewell B and former contractors' compound. Activities relating to the former contractors' compound on the main platform for Sizewell B including possible storage areas, fabrication areas, lagoons, stone washing / concrete batching area. Car park located on western edge of the main platform. Activities within the main platform associated with the operation of Sizewell B power station including radioactive materials. Former infilled sand pits located across the main platform.	**Human health:** On-site.	Pedestrians and road users using existing roads, footpaths and fields within the site (note that Sizewell C power station site will be secure).	Dermal contact with and ingestion of contaminants in soil, soil-derived dust and water. Inhalation of contaminants in soil, soil-derived dust, fibres and gas/vapours.	Very low risk.	Receptor not present.	Negligible[4]	Receptor not present.	Negligible[4]
		Farmers and workers on agricultural land.		Very low risk.	Receptor not present.	Negligible[4]	Receptor not present.	Negligible[4]
		Construction and maintenance workers.		Receptor not present.	Very low risk.	Negligible[5]	Very low risk.	Negligible[5]
		Recreational site users of the Sizewell Marshes SSSI, marshes and beach along the foreshore.		Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
		Current Sizewell B workers using areas of the main platform.		Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
		Future site workers and visitors.		Receptor not present.	Very low risk.	Negligible[5]	Very low risk.	Negligible[5]
	Human health: Off-site.	Workers in adjacent Sizewell B power station.	Dermal contact with and ingestion of contaminants in soil, soil-derived dust and water which may have migrated off-site. Inhalation of contaminants in soil, soil-derived dust, fibres and gas/vapours which may have migrated off-site.	Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
		Pedestrians accessing surrounding roads and footpaths.		Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
		Farmers and workers on agricultural land.		Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
		Recreational site users of the surrounding Sizewell Marshes SSSI and marshes.		Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
	Controlled Waters.		Leaching/migration of contaminants in soil to groundwater in underlying aquifers.	Low risk.	Low risk.	Negligible	Very low risk.	Minor beneficial.

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[4] Removal of this receptor at operation automatically triggers a minor beneficial effect. However, professional judgement has been exercised and this effect has been reduced to negligible.

[5] Introduction of this receptor at operation automatically triggers a minor adverse effect. However, professional judgement has been exercised and this effect has been reduced to negligible.

Source	Receptor		Contaminant Exposure / Migration Pathway.	Baseline (Current) Risk Assessment.	Operation Phase Risk Assessment (with primary and Tertiary Mitigation Measures Assuming All Mitigation Proposed During Construction is Undertaken).	Classification of Effect.	Operational Phase Risk Assessment (with Primary, Tertiary and Secondary Mitigation Measures).	Residual Effects.
Peat and Alluvial deposits indicated to be present within the eastern edge of the main platform. Farming activities across the entire site area including potential for unmarked farmers tips. Made Ground associated with the construction of roads crossing the various areas of the site as well as activities associated with their operation. Risk of inorganic and organic contamination including metals and hydrocarbons, biological contaminants, PCBs, asbestos, solvents, paints, fuels, oils, herbicides and pesticides. Ground gas generation.		Principal Bedrock and Superficial Secondary A Aquifers (on-site and off-site).	Migration of contaminated water through preferential pathways such as underground services, pipes and granular material to groundwater in underlying aquifers.	Low risk.	Low risk.	Negligible	Very low risk.	Minor beneficial.
		Ponds and drains on-site and within the study area.	Migration of contaminated water into underlying aquifers followed by lateral migration into nearby watercourses.	Low risk.	Very low risk.	Minor beneficial.	Very low risk.	Minor beneficial.
			Discharge of contaminants entrained in groundwater and/or surface water run-off followed by overland flow and discharge.	Low risk.	Very low risk.	Minor beneficial.	Very low risk.	Minor beneficial.
		North Sea (on-site and off-site).	Migration of contaminated water into underlying aquifers followed by lateral migration into nearby watercourses.	Low risk.	Very low risk.	Minor beneficial.	Very low risk.	Minor beneficial.
			Discharge of contaminants entrained in surface water run-off followed by overland flow and discharge.	Low risk.	Very low risk.	Minor beneficial.	Very low risk.	Minor beneficial.
	Property / services	Existing on-site and off-site services and structures including listed buildings.	Direct contact of contaminants in soil and/or groundwater with buried service.	Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
			Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
		Proposed on-site services and structures.	Direct contact of contaminants in soil and/or groundwater with existing buried service.	Receptor not present.	Very low risk.	Negligible[5]	Very low risk.	Negligible[5]
			Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Receptor not present.	Very low risk.	Negligible[5]	Very low risk.	Negligible[5]
		Crops and livestock (on-site).	Direct contact, ingestion, inhalation and uptake of soil and water contamination by crops and/or livestock.	Very low risk.	Receptor not present.	Negligible[4]	Receptor not present.	Negligible[4]

Source	Receptor		Contaminant Exposure / Migration Pathway.	Baseline (Current) Risk Assessment.	Operation Phase Risk Assessment (with primary and Tertiary Mitigation Measures Assuming All Mitigation Proposed During Construction is Undertaken).	Classification of Effect.	Operational Phase Risk Assessment (with Primary, Tertiary and Secondary Mitigation Measures).	Residual Effects.
		Crops and livestock (off-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by crops or ingestion/inhalation /dermal contact by livestock.	Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
	Ecological	Sizewell Marshes SSSI (on-site and off-site).	Direct contact, ingestion, inhalation and uptake of soil and water contamination by flora and/or fauna.	Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
			Migration of contaminated waters/dust/fibres and subsequent uptake by flora or ingestion/inhalation /dermal contact by fauna.	Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
		Minsmere-Walberswick Heaths and Marshes SSSI, Ramsar, SAC and SPA and Suffolk Coast and Heaths AONB (off-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by flora or ingestion/inhalation/ dermal contact by fauna.	Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
On-site: Temporary Construction Area. Former infilled sand pits located across the temporary construction area. Grass covered mounds (suspected Made Ground) located in the north-east of the temporary construction area. Peat and Alluvial deposits indicated to be present within the eastern edge of the temporary construction area. Farming activities across the entire site area including potential for unmarked farmers tips. Made Ground associated with the construction of roads crossing the various areas of the site as well as activities associated with their operation.	**Human health:** On-site.	Pedestrians and road users using existing roads, footpaths and fields within the site.	Dermal contact with and ingestion of contaminants in soil, soil-derived dust and water. Inhalation of contaminants in soil, soil-derived dust and gas/vapours.	Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
		Farmers and workers on agricultural land.		Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
		Construction and maintenance workers.		Receptor not present.	Very low risk.	Negligible[5]	Very low risk.	Negligible[5]
		Residents within the temporary construction area.		Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
	Human health: Off-site.	Occupants of nearby residential, recreational and commercial properties.	Dermal contact with and ingestion of contaminants in soil, soil-derived dust and water which may have migrated off-site. Inhalation of contaminants in soil, soil-derived dust, fibres and gas/vapours which may have migrated off-site.	Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
		Pedestrians accessing surrounding roads and footpaths.		Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
		Farmers and workers on agricultural land.		Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
		Recreational site users of the Sizewell Marshes SSSI and marshes.		Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
	Controlled Waters.		Leaching/migration of contaminants in soil to groundwater in underlying aquifers.	Low risk.	Low risk.	Negligible	Very low risk.	Minor beneficial.

Source	Receptor		Contaminant Exposure / Migration Pathway.	Baseline (Current) Risk Assessment.	Operation Phase Risk Assessment (with primary and Tertiary Mitigation Measures Assuming All Mitigation Proposed During Construction is Undertaken).	Classification of Effect.	Operational Phase Risk Assessment (with Primary, Tertiary and Secondary Mitigation Measures).	Residual Effects.
Risk of inorganic and organic contamination including metals and hydrocarbons, asbestos, fuels, oils, herbicides and pesticides.		Principal Bedrock and Superficial Secondary A Aquifers (on-site and off-site).	Migration of contaminated water through preferential pathways such as underground services, pipes and granular material to groundwater in underlying aquifers.	Low risk.	Low risk.	Negligible	Very low risk.	Minor beneficial.
		Ponds and drains on-site and within study area.	Migration of contaminated water into underlying aquifers followed by lateral migration into nearby watercourses.	Low risk.	Very low risk.	Minor beneficial.	Very low risk.	Minor beneficial.
			Discharge of contaminants entrained in groundwater and/or surface water run-off followed by overland flow and discharge.	Low risk.	Very low risk.	Minor beneficial.	Very low risk.	Minor beneficial.
		North Sea (off-site).	Migration of contaminated water into underlying aquifers followed by lateral migration into nearby watercourses.	Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
			Discharge of contaminants entrained in surface water run-off followed by overland flow and discharge.	Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
	Property / services	Existing on-site and off-site services and structures including Leiston Abbey Scheduled Monument and listed buildings.	Direct contact of contaminants in soil and/or groundwater with existing buried service.	Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
			Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
		Proposed on-site services and structures.	Direct contact of contaminants in soil and/or groundwater with existing buried service.	Receptor not present.	Very low risk.	Negligible[5]	Very low risk.	Negligible[5]
			Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Receptor not present.	Very low risk.	Negligible[5]	Very low risk.	Negligible[5]
		Crops and livestock (on-site).	Direct contact, ingestion, inhalation and uptake of soil and water contamination by crops and/or livestock.	Very low risk.	Receptor not present.	Negligible[4]	Receptor not present.	Negligible[4]

Source	Receptor		Contaminant Exposure / Migration Pathway.	Baseline (Current) Risk Assessment.	Operation Phase Risk Assessment (with primary and Tertiary Mitigation Measures Assuming All Mitigation Proposed During Construction is Undertaken).	Classification of Effect.	Operational Phase Risk Assessment (with Primary, Tertiary and Secondary Mitigation Measures).	Residual Effects.
		Crops and livestock (off-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by crops or ingestion/ inhalation/ dermal contact by livestock.	Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
	Ecological	Sizewell Marshes SSSI (off-site).	Direct contact, ingestion, inhalation and uptake of soil and water contamination by flora and/or fauna.	Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
			Migration of contaminated waters/dust/fibres and subsequent uptake by flora or ingestion /inhalation/ dermal contact by fauna.	Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
		Minsmere-Walberswick Heaths and Marshes SSSI, Ramsar, SAC and SPA and Suffolk Coast and Heaths AONB (off-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by flora or ingestion /inhalation/ dermal contact by fauna.	Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
On-site: Land east of Eastlands Industrial Estate (LEEIE). Fly tipping in the north-west of the LEEIE. Railway line running through the western extent of the LEEIE and associated buildings. Farming activities across the entire site area including potential for unmarked farmers tips. Made Ground present within the western section of the LEEIE associated with the railway line and in the northern section associated with an infilled reservoir. Electricity substation at the eastern extent of the proposed construction corridor for the electrical supply connection to the east of the LEEIE. Made Ground associated with the construction of roads crossing the various areas of the site as well as activities associated with their operation.	**Human health:** On-site.	Pedestrians and road users using existing roads, railway, footpaths and fields within the site.	Dermal contact with and ingestion of contaminants in soil, soil-derived dust and water. Inhalation of contaminants in soil, soil-derived dust and vapours.	Low risk.	Receptor not present.	Negligible[4]	Receptor not present.	Negligible[4]
		Farmers and workers on agricultural land.		Very low risk.	Receptor not present.	Negligible[4]	Receptor not present.	Negligible[4]
		Construction and maintenance workers.		Receptor not present.	Very low risk.	Negligible[5]	Very low risk.	Negligible[5]
	Human health: Off-site.	Occupants of nearby residential, recreational and commercial properties.	Dermal contact with and/or ingestion of contaminants in windblown soil-derived dusts and water that may have migrated off-site. Inhalation of windblown soil derived dust, fibres and gas/vapours which may have migrated off-site.	Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
		Pedestrians accessing surrounding roads and footpaths.		Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
		Farmers and workers on agricultural land.		Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
	Controlled Waters.	Principal Bedrock and Superficial Secondary A Aquifers (on-site and off-site).	Leaching/migration of contaminants in soil to groundwater in underlying aquifers.	Low risk.	Low risk.	Negligible	Very low risk.	Minor beneficial.
			Migration of contaminated water through preferential pathways such as underground services, pipes and granular material to groundwater in underlying aquifers.	Low risk.	Low risk.	Negligible	Very low risk.	Minor beneficial.

Source	Receptor		Contaminant Exposure / Migration Pathway.	Baseline (Current) Risk Assessment.	Operation Phase Risk Assessment (with primary and Tertiary Mitigation Measures Assuming All Mitigation Proposed During Construction is Undertaken).	Classification of Effect.	Operational Phase Risk Assessment (with Primary, Tertiary and Secondary Mitigation Measures).	Residual Effects.
Risk of inorganic and organic contamination including metals and hydrocarbons, asbestos, fuels, oils, PCBs, PAHs, herbicides and pesticides.		Ponds and drains on-site and within study area.	Migration of contaminated water into underlying aquifers followed by lateral migration into nearby watercourses.	Low risk.	Very low risk.	Minor beneficial.	Very low risk.	Minor beneficial.
			Discharge of contaminants entrained in groundwater and/or surface water run-off followed by overland flow and discharge.	Low risk.	Very low risk.	Minor beneficial.	Very low risk.	Minor beneficial.
	Property / services	Existing on-site and off-site services and structures including listed buildings.	Direct contact of contaminants in soil and/or groundwater with existing buried service.	Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
			Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
		Proposed on-site services and structures.	Direct contact of contaminants in soil and/or groundwater with existing buried service.	Receptor not present.	Very low risk.	Negligible[5]	Very low risk.	Negligible[5]
			Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Receptor not present.	Very low risk.	Negligible[5]	Very low risk.	Negligible[5]
		Crops and livestock (on-site).	Direct contact, ingestion, inhalation and uptake of soil and water contamination by crops and/or livestock.	Very low risk.	Receptor not present.	Negligible[1]	Receptor not present.	Negligible[1]
		Crops and livestock (off-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by crops or ingestion/ inhalation/ dermal contact by livestock.	Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
	Ecological	Sizewell Marshes SSSI (off-site).	Direct contact, ingestion, inhalation and uptake of soil and water contamination by flora and/or fauna.	Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
			Migration of contaminated waters/ dust/fibres and subsequent uptake by flora or ingestion/inhalation/ dermal contact by fauna.	Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible

Source	Receptor		Contaminant Exposure / Migration Pathway.	Baseline (Current) Risk Assessment.	Operation Phase Risk Assessment (with primary and Tertiary Mitigation Measures Assuming All Mitigation Proposed During Construction is Undertaken).	Classification of Effect.	Operational Phase Risk Assessment (with Primary, Tertiary and Secondary Mitigation Measures).	Residual Effects.
Off-site: Activities associated with the operation of Sizewell A and B power stations including former asbestos lined tanks and their infill, the atmospheric deposition of radioactive materials on the main platform main platform. Former sand pits located 250m north-west and south-east of the main platform and 250m to the south of the temporary construction area which have been infilled. Former brick works, brick field and clay pit located 300m to the west of the LEEIE which have been infilled. Smithy located approximately 450m south-east of the LEEIE. Tank and sewage works located 500m to the south-west of the LEEIE. Historical landfills within 500m of the site including refuse tip, Ogilvie at Home Farm, Leiston Landfill, Carrs Pit, Abbey Pit and Aldhurst Farm. Gas works, coal yard and tanks located 40m to the west of the LEEIE. Electrical substation located 100m south-west of the LEEIE. Farming activities in surrounding areas including potential for unmarked farmers tips. Allotments adjacent to the south of the LEEIE. Made Ground associated with the construction of roads surrounding	**Human health:** On-site.	Pedestrians and road users using existing roads, footpaths, railway and fields within the site.	Dermal contact with and ingestion of contaminants in soil, soil-derived dust and water. Inhalation of contaminants in soil, soil-derived dust and vapours.	Low risk.	Low risk.	Negligible	Low risk.	Negligible
		Farmers and workers on agricultural land.		Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
		Construction and maintenance workers.		Receptor not present.	Very low risk.	Negligible[5]	Very low risk.	Negligible[5]
		Recreational site users of the Sizewell Marshes SSSI, marshes and beach along the foreshore.		Low risk.	Low risk.	Negligible	Low risk.	Negligible
		Current Sizewell B site workers using the main platform.		Low risk.	Low risk.	Negligible	Low risk.	Negligible
		Future site workers and visitors.		Receptor not present.	Very low risk.	Negligible[5]	Very low risk.	Negligible[55]
		Residents within the temporary construction area.		Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible
	Controlled Waters.	Principal Bedrock and Superficial Secondary A aquifers (on-site).	Leaching/migration of contaminants in soil to groundwater in underlying aquifers.	Moderate/low risk.	Moderate/low risk.	Negligible	Moderate/low risk.	Negligible
			Migration of contaminated water through preferential pathways such as underground services, pipes and granular material to groundwater in underlying aquifers.	Low risk.	Low risk.	Negligible	Very low risk.	Minor beneficial.
		Ponds and drains on-site.	Migration of contaminated water into underlying aquifers followed by lateral migration into nearby watercourses.	Moderate/low risk.	Moderate/low risk.	Negligible	Moderate/low risk.	Negligible
			Discharge of contaminants entrained in groundwater and/or surface water run-off followed by overland flow and discharge.	Low risk.	Low risk.	Negligible	Low risk.	Negligible
	Property / services.	Existing on-site services and structures.	Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible

Source	Receptor		Contaminant Exposure / Migration Pathway.	Baseline (Current) Risk Assessment.	Operation Phase Risk Assessment (with primary and Tertiary Mitigation Measures Assuming All Mitigation Proposed During Construction is Undertaken).	Classification of Effect.	Operational Phase Risk Assessment (with Primary, Tertiary and Secondary Mitigation Measures).	Residual Effects.
the site as well as activities associated with their operation. Works and factories within Eastlands Industrial Estate. Risk of inorganic and organic contamination including metals and hydrocarbons, asbestos, solvents, fuels, oils, PCBs, radioactive materials, coal tar, acids and alkalis, herbicides and pesticides. Ground gas generation.		Proposed on-site services and structures associated with the site.	Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.	Receptor not present.	Very low risk.	Negligible[5]	Very low risk.	Negligible[5]
		Crops and livestock (on-site).	Migration of contaminated waters /dust/fibres and subsequent uptake by crops or ingestion/ inhalation/ dermal contact by livestock.	Very low risk.	Receptor not present.	Negligible[4]	Receptor not present.	Negligible[4]
		Sizewell Marshes SSSI (on-site).	Migration of contaminated waters/dust/fibres and subsequent uptake by flora or ingestion/inhalation/ dermal contact by fauna.	Very low risk.	Very low risk.	Negligible	Very low risk.	Negligible

VOLUME 2, CHAPTER 18, APPENDIX 18D: MAIN DEVELOPMENT SITE OFF-SITE DEVELOPMENTS ASSESSMENT

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Plates

None provided.

Annexes

Annex 18D.1: Envirocheck Reports and Zetica UXO risk maps

Annex 18D.2: Conceptual Site Models

Annex 18D.3: Impact Assessment Tables

1. Off-site Developments Geology and Land Quality Assessment

1.1 Introduction

1.1.1 This appendix of **Volume 2** of the **Environmental Statement** (**ES**) presents an assessment of the potential effects on geology and land quality arising from the construction and operation of the proposed off-site developments, including the off-site sports facilities at Leiston, fen meadow compensation sites south of Benhall and east of Halesworth and, if required, the marsh harrier habitat improvement area (Westleton). This includes an assessment of potential impacts, the significance of effects, the requirements for mitigation, and the residual effects.

1.1.2 Detailed descriptions of the proposed development sites (referred to throughout this volume as the 'site' as relevant to the location of the works), the proposed off-site development works and different construction and operational phases are provided in **Chapters 2** to **4** of this volume of the **ES**. A glossary of terms and list of abbreviations used in this chapter is provided in **Volume 1, Appendix 1A** of the **ES**.

1.1.3 The Government's Good Practice Guide for Environmental Impact Assessment[1] (EIA) (Ref. 1.1) outlines the potential environmental effects that should be considered for geology and land quality e.g. physical effects of the development, effects on geology and effects on contamination. Further information on these potential environmental effects and those which have been scoped into the geology and land quality assessment can be found in **Volume 1, Appendix 6N**.

1.1.4 This assessment has been informed by data from other assessments as follows:

- **Chapter 17**: Soils and agriculture; and
- **Chapter 19**: Groundwater and surface water.

1.1.5 This assessment has been informed by data presented in the following technical appendices:

- **Annex 18D.2**: Conceptual site models; and
- **Annex 18D.3**: Impact assessment tables.

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[1] It should be noted that this document has been withdrawn; however, it still constitutes good advice and should be referred to in the absence of alternative guidance documents.

1.2 Legislation, policy and guidance

1.2.1 **Volume 1, Appendix 6N** identifies and describes legislation, policy and guidance of relevance to the assessment of the potential geology and land quality impacts associated with the Sizewell C Project across all ES volumes. Furthermore, **Chapter 18** of this volume provides a description of legislation, policy and guidance relevant to the assessment of effects for the main development site of the Sizewell C Project.

1.2.2 There is no further legislation, policy and guidance over and above that described in **Volume 1**, **Appendix 6N** and **Chapter 18** of this volume that is deemed relevant to the assessment of effects associated with the off-site development works.

1.3 Methodology

a) Scope of the assessment

1.3.2 The generic EIA methodology is detailed in **Volume 1, Chapter 6** of the ES. The full method of assessment for geology and land quality that has been applied for the Sizewell C Project is included as an appendix in **Volume 1**, **Appendix 6N**.

1.3.3 The scope of this assessment has been established through a formal EIA scoping process undertaken with the Planning Inspectorate. A request for an EIA Scoping Opinion was initially issued to the Planning Inspectorate in 2014, with an updated request issued in 2019, see **Volume 1, Appendix 6A**.

1.3.4 Comments raised in the EIA Scoping Opinion received in 2014 and 2019 have been taken into account in the development of the assessment methodology. These are detailed in **Volume 1**, **Appendices 6A to 6C**.

1.3.5 This section provides specific details of the geology and land quality screening exercise, as detailed below, methodology applied to the assessment of the proposed off-site development works screened in, and a summary of the general approach to provide appropriate context for the assessment that follows.

1.3.6 Where the proposed off-site development works are considered to have the potential for likely significant effects, these have been screened in for further assessment. The scope of assessment considers the impacts of the construction and operational use of the proposed off-site developments.

1.3.7 The Government's Good Practice Guide[2] for EIA states that the following potential environmental effects should be considered for geology and land quality:

- physical effects of the development: such as changes in topography, soil compaction, soil erosion, ground stability, etc.;
- effects on geology as a valuable resource: such as mineral resource sterilisation, loss or damage to regionally important geology sites, geological Sites of Special Scientific Interest (SSSIs) etc.;
- effects on soil as a valuable resource: such as loss or damage to soil of good agricultural quality;
- effects associated with ground contamination that may already exist on site: such as introducing or changing pathways and receptors;
- effects associated with the potential for polluting substances used (during the various phase) to cause new ground contamination issues on site, such as introducing or changing the source of contamination and, or pathways; and
- effects associated with re-use of soils and waste soils: such as re-use of site-sourced materials on-site or off-site, disposal of site-sourced materials off-site, importation of materials to the site etc.

1.3.8 The proposed development is considered unlikely to have an impact on important geological sites as no geological SSSIs or Local Geological Sites have been identified within the study area (described below in **section 18D.3d**). However, given the comments in revised Scoping Opinion received in 2019 in relation to the effects on geology as a valuable resource, an assessment of the effects on mineral resources has been included.

1.3.9 The proposed development will involve minor earthworks and is therefore considered unlikely to have an impact on soil compaction. Physical effects in relation to changes in topography are discussed in **Chapter 13** of this volume. The effects on soil as a valuable resource are discussed in **Chapter 17** of this volume. Management of site-sourced waste materials, other than site soils (i.e. general waste materials from construction and operational phases) is summarised in **Chapter 8** of this volume, with further details provided in the **Waste Management Strategy** (**Appendix 8A** of this volume).

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[2] It should be noted that this document has been withdrawn; however, it still constitutes good advice and should be referred to in the absence of alternative guidance documents.

1.3.10 Therefore, the following remaining environmental effects have been considered and form part of the assessment:

- physical effects including soil erosion and ground stability;
- mineral resource loss, damage or sterilisation;
- effects associated with existing ground contamination and potential new ground contamination issues; and
- effects associated with the re-use or disposal of site sourced soils and waste soils.

1.3.11 Potential impacts from existing and new contamination sources on controlled waters have been considered as part of the geology and land quality assessment to determine and classify potential effects associated with ground contamination. Further description of the effects from contamination to groundwater and surface water is provided in **Chapter 19** of this volume.

1.3.12 This chapter provides an initial indication of chronic long-term risks to construction and maintenance workers. In accordance with the **Code of Construction Practice** (**CoCP**) (**Doc Ref. 8.11**), short-term acute risks should be assessed, managed and mitigated by the Contractor with appropriate risk assessments and methods statements, and subsequent control measures.

b) Consultation

1.3.13 The scope of the assessment has also been informed by ongoing project-wide consultation and engagement with statutory consultees throughout the design and assessment process as outlined in **Volume 1, Appendix 6N**.

c) Environmental screening

1.3.14 An environmental screening exercise was undertaken to identify which of the off-site development works may give rise to environmental effects that could potentially be significant. This concluded that the off-site sports facilities at Leiston should be taken forward to the assessment of likely effects on land quality and geology.

1.3.15 The fen meadow compensation sites south of Benhall and east of Halesworth and the marsh harrier habitat improvement area west of Westleton have been screened out of the land quality and geology assessment as they are not likely to give rise to significant environmental effects.

1.3.16 **Table 1.1** provides a summary of the environmental screening exercise.

Table 1.1: Summary of environmental screening exercise.

Proposed Off-site Developments.	Summary of Potential Effects.	Screened In or Out of the Assessment.
Off-site sports facilities at Leiston.	The proposed works would involve the construction of a 3G pitch and two Multi-Use Games Areas (MUGAs) which are likely to include a topsoil strip and minor earthworks. Physical effects including changes in soil erosion associated with stripping of topsoil, minor earthworks and associated machine movements are anticipated. The proposed works may also disturb and mobilise existing sources of contamination and introduce new pathways for migration of existing contamination. Potential historical sources of contamination have been identified in close proximity to the site including a brick works and isolation hospital which require further assessment. The works would be completed in accordance with current best practice and potential geology and land quality impacts during the construction and operation phases would be managed through primary and tertiary mitigation methods. However, given the potential for effects on geology and land quality, the sports facilities have been taken forward for further assessment.	Screened in.
Fen meadow compensation site south of Benhall.	The proposed works would involve minor modifications to topography and landforms to raise water levels. Physical effects including changes in soil erosion and soil compaction associated with stripping of topsoil, vegetation clearance, stockpiling, earthworks and associated machine movements are anticipated to be minimal. The proposed works may also disturb and mobilise existing sources of contamination and introduce new pathways for migration of existing contamination. The site has been used as agricultural land since the 1880s and therefore contamination impacts are likely to be minimal. The works would also be completed in accordance with current best practice and potential geology and land quality impacts during the construction and operation phases would be managed through primary and tertiary mitigation methods. Therefore, no significant effects on geology and land quality are anticipated.	Screened out.

Proposed Off-site Developments.	Summary of Potential Effects.	Screened In or Out of the Assessment.
Fen meadow habitat compensation site east of Halesworth.	The proposed works would involve minor modifications to topography and landforms to raise water levels. Physical effects including changes in soil erosion and soil compaction associated with stripping of topsoil, vegetation clearance, stockpiling, earthworks and associated machine movements are anticipated to be minimal. The proposed works may also disturb and mobilise existing sources of contamination and introduce new pathways for migration of existing contamination. The site has been used as agricultural land since the 1880s and therefore contamination impacts are likely to be minimal. The works would also be completed in accordance with current best practice and potential geology and land quality impacts during the construction and operation phases would be managed through primary and tertiary mitigation methods. Therefore, no significant effects on geology and land quality are anticipated.	Screened out.
Marsh harrier habitat improvement area - west of Westleton.	The proposed works would involve standard farming practices to create rough grassland, game strips, hedgerow and scrub to enhance the landscape and will involve minimal disturbance of the ground. The site has been used as agricultural land since the 1880s and therefore contamination impacts are likely to be minimal. The works would also be completed in accordance with current best practice and potential geology and land quality impacts during the construction and operation phases would be managed through primary and tertiary mitigation methods. Therefore, no significant effects on geology and land quality are anticipated.	Screened out.

1.3.17 The following assessment therefore relates to the proposed off-site sports facilities at Leiston only.

d) Study area

1.3.18 To consider the physical effects of the proposed off-site sports facilities at Leiston and the effects associated with mineral resources, the re-use of soils and waste soils, the study area is defined as the site boundary. The site boundary of the proposed development is presented in **Chapter 1** of this volume.

1.3.19 The study area for the consideration of effects on human receptors, controlled waters, ecological receptors and property receptors includes the site and land immediately beyond it to a distance of 500 metres (m).

1.3.20 The study area takes into account the transport and final destination of potential contaminants of concern in the environment and the connectivity of these contaminants via pathways of migration or exposure to the receptors identified.

1.3.21 This buffer zone was considered sufficient for the assessment of the potential contaminant linkages (PCL)[3] risks for the site, where the land has undergone limited development and as such contamination is likely to be limited or have a limited lateral mobility, if present.

e) Assessment scenarios

1.3.22 The assessment of effects on geology and land quality includes the assessment of the construction and operational phases of the proposed development, rather than specific assessment years.

f) Assessment criteria

1.3.23 As described in **Volume 1**, **Chapter 6**, the EIA methodology considers whether impacts of the proposed off-site developments would have an effect on any identified resources or receptors. For physical effects, the assessments broadly consider the magnitude of impacts and value/sensitivity of resources/receptors that could be affected in order to classify effects. For land contamination the assessment considers the change in the level of contaminative risks to the relevant receptors in order to classify effects.

1.3.24 A summary of the two assessment methods and assessment criteria used in the geology and land quality assessment is presented in **Chapter 18** of this volume.

1.4 Baseline environment

1.4.1 This section presents a description of the baseline environmental characteristics within the study area.

a) Current baseline

i. Site history

1.4.2 **Table 1.2** summarises the key historical land use information for the study area. This has been compiled using an Envirocheck report (**Annex 18D.1**) which covers the study area.

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[3] Where a linkage exists or is considered likely to be present between a potential contamination hazard/source, pathway and receptor relevant to the site.

Table 1.2: Historical development of the site.

Map Date.	Key Contamination Sources On-site.	Key Contamination Sources in Study Area.
1883–1884 (1:10,560).	The site is shown as undeveloped agricultural land.	Agricultural land is present surrounding the site in all directions. A lane is present adjacent to the south of the site. Mawsell's Farm and Red House are located at approximately 200m to the south-east and west of site.
1905 (1:10,560).	No substantial changes.	A brick works is present adjacent to the east of the site. Residential properties are present approximately 300m to the north-west.
1928 (1:10,560).	No substantial changes.	The brick works is no longer shown on the map and an isolation hospital is indicated to be present in the area of the former brick works. The lane adjacent to the south of the site is now labelled as Grimsey's Lane. Allotments gardens are present at approximately 100m to the north.
1938 (1:10,560).	No substantial changes.	No substantial changes.
1950–1951 (1:10,560).	No substantial changes.	No substantial changes.
1958 (1:10,000).	No substantial changes.	A school is present approximately 100m to the north of the site. The residential area to the north-west of the site has expanded.
1976–1977 (1:10,000).	The site is shown as a playing field.	Leiston High School is now present adjacent to the north of the site and a sport centre is located adjacent to the west of the site. The isolation hospital is no longer shown on the map and is now labelled as a playing field. The buildings associated with the hospital are still shown on the map. The allotments gardens to the north of the site are no longer shown. The residential area to the north-west of the site has expanded further and is present bounding the west and north of the site. A factory is located at approximately 300m to the north-east of the site.
2000 (1:10,000).	The site is no longer shown as a playing field.	The buildings associated with the former isolation hospital adjacent to the east of the site appear to have been redeveloped and are shown in a different layout. The factory located 300m to the north-east of the site is now labelled as an industrial estate. A caravan park is located at approximately 400m to the north of the site.

Map Date.	Key Contamination Sources On-site.	Key Contamination Sources in Study Area.
2006 (1:10,000).	No substantial changes.	No substantial changes.
2019 (1:10,000).	No substantial changes.	Leiston High School is now labelled as Alde Valley Academy.

ii. Geology

1.4.3 Made Ground is not indicated to be present underlying the site on the British Geological Society (BGS) online mapping (Ref. 1.2).

1.4.4 Available BGS records indicate that the site is underlain by Diamicton superficial deposits of the Lowestoft Formation, which consist of an extensive sheet of chalky till, together with outwash sands and gravels, silts and clays. The till is characterised by its chalk and flint content.

1.4.5 According to the BGS website, bedrock geology beneath the site comprises sand of the Crag Group, described as ‘coarse-grained, poorly sorted, cross-bedded, abundantly shelly sands’.

1.4.6 There are no BGS borehole logs located within the study area.

1.4.7 The Envirocheck report (**Annex 18D.1**) indicates that there is either no hazard or low potential for running sand, landslides, ground stability hazards, shrinking or swelling clay and ground dissolution stability hazards at the site. There are also no significant structural features located on or within the study area.

iii. Mineral extraction

1.4.8 The Envirocheck report (**Annex 18D.1**) and the Coal Authority Interactive Map indicate that the site is in an area unlikely to be affected by mining for coal or other mineral resources.

1.4.9 The Envirocheck report (**Annex 18D.1**) indicates that no historical extractive activities have been undertaken within the study area.

iv. Local geological sites

1.4.10 According to protected sites mapping on the Suffolk Biodiversity Information Service website (Ref. 1.3), the study area is not located within a geological SSSI or Local Geological Site.

v. Hydrogeology

1.4.11 According to the Multi-Agency Geographic Information for the Countryside (MAGIC) website (Ref. 1.4) the Lowestoft Formation superficial deposits are classified by the Environment Agency as a Secondary (undifferentiated)[4]. The Crag Group bedrock underlying the site is classed as a Principal Aquifer[5].

1.4.12 The site is located approximately 400m to the east of a groundwater Source Protection Zone 3 – Total Catchment[6].

1.4.13 The Environment Agency website indicates that there are no licensed groundwater abstractions within the study area. There is the potential for unknown Private Water Supplies (PWS) to be in use within the study area. Should any PWS exist, they would likely be associated with the farm buildings and residential properties in the study area.

vi. Hydrology

1.4.14 The MAGIC website indicates that there are no surface waters located within the study area.

1.4.15 The Envirocheck report (**Annex 18D.1**) indicates there are no water abstractions relating to surface water within the study area.

vii. Flood risk

1.4.16 The Environment Agency flood risk map contained within the Envirocheck report, and the Environment Agency website, indicate that the site is not located within an area known to be at risk from flooding from rivers or the sea. Two areas immediately to the north-west and east of the site are indicated to have a high risk of surface water flooding[7].

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[4] Secondary (undifferentiated) has been assigned in cases where it has not been possible to attribute either category A or B to a rock type. In most cases, this means that the layer in question has previously been designated as both minor and non-aquifer in different locations due to the variable characteristics of the rock type.

[5] Principal Aquifers are layers of rock or drift deposits that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale. In most cases, principal aquifers are aquifers previously designated as major aquifer.

[6] Source Protection Zones III – Total Catchment is defined as the area around a source within which all groundwater recharge is presumed to be discharged at the source. In confined aquifers, the source catchment may be displaced some distance from the source. For heavily exploited aquifers, the final Source Catchment Protection Zone can be defined as the whole aquifer recharge area where the ratio of groundwater abstraction to aquifer recharge (average recharge multiplied by outcrop area) is >0.75. There is still the need to define individual source protection areas to assist operators in catchment management.

[7] ‘High’ risk means that each year, this area has a chance of flooding of greater than 1 in 30 (3.3%).

viii. Historic and environmentally sensitive sites

1.4.17 There are no environmentally sensitive statutory or non-statutory designations indicated to be present within the study area.

1.4.18 A Grade II[8] listed building is present 400m to the west of the site.

ix. Waste management sites

1.4.19 The Envirocheck report (**Annex 18D.1**) confirms that there are none of the following facilities within the study area:

- historic landfill sites;
- authorised landfill sites;
- waste transfer sites;
- Control of Major Accident Hazards Sites (COMAH);
- explosive sites;
- Notification of Installations Handling Hazardous Substances (NIHHS);
- Planning Hazardous Substance Consents; and
- Planning Hazardous Substance Enforcements.

x. Service stations

1.4.20 There are no service stations located within the study area according to the Envirocheck report (**Annex 18D.1**) and the Yell website (Ref. 1.5).

xi. Industrial and other potentially contaminative land uses

1.4.21 The Envirocheck report (**Annex 18D.1**) indicates that there is a domestic cleaning service located 180m to the north-east of the site that has the potential to use contaminants of concern. Several farms are also present within the study area which have the potential to use contaminants of concern.

xii. Potential for unexploded ordnance

1.4.22 A Zetica UXO map was obtained to assess the risk of encountering UXO at the site (**Annex 18D.1**). The map indicates that the site is within an area with a moderate risk of encountering UXO.

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[8] Grade II Listed buildings are of special interest and the vast majority of listings.

xiii. Previous investigations

1.4.23 There have been no previous ground investigations undertaken at the site.

b) Future baseline

1.4.24 Committed developments within the study area have been considered as future receptors as part of the baseline. Further details are provided in **Chapter 18** of this volume.

c) Preliminary Conceptual Site Model

1.4.25 A Preliminary Conceptual Site Model (PCSM) identifies the potential or known sources of contamination, receptors and pathways between the two. Where all three are present or are considered likely to be present (source-pathway-receptor linkage), they are called a PCL.

1.4.26 Three PCSMs (baseline, construction and operational) have been produced for the proposed development using the information summarised above. A summary of potential contamination sources is provided in **Table 1.3** and potential pathways and receptors identified is provided in **Table 1.4**.

Table 1.3: Existing potential sources of contamination for the proposed development.

Potential Source of Contamination.	Potential Contamination.	Approximate Location.
Made Ground associated with the construction of the playing field.	A range of inorganic and organic contaminants including the potential for asbestos.	On-site
Historical farmland within site boundary. Potential for unmapped farmers tips.	Contamination risk from herbicides, pesticides, silage, effluent, and fuel oils. Risk of inorganic and organic contamination including metals and hydrocarbons, Polychlorinated Biphenyls (PCBs), asbestos, etc.	
Made Ground associated with the construction of local roads adjacent to the site, as well as activities associated with their operation.	A range of inorganic and organic contaminants including the potential for asbestos. Fuels and oils attributed to spills from vehicles on the roads included within the site boundary, plus exhaust particulates.	Off-site
Made Ground associated with the construction of the school, as well as activities associated with its operation.	A range of inorganic and organic contaminants inorganic and organic contaminants such as metals, hydrocarbons, fuel oils and asbestos.	

Potential Source of Contamination.	Potential Contamination.	Approximate Location.
Farmland surrounding the site. Potential for unmapped farmers tips.	Contamination risk from herbicides, pesticides, silage, effluent, and fuel oils. Risk of inorganic and organic contamination including metals, hydrocarbons, PCBs, and asbestos, etc.	
Made Ground associated with the adjacent former brickworks, including related activities.	A range of inorganic and organic contamination including metals and hydrocarbons, PCBs, asbestos, etc. Ground gas generation including carbon dioxide and methane.	
Made Ground associated with the adjacent former hospital, including related activities.	A range of inorganic and organic contaminants inorganic and organic contaminants such as metals, hydrocarbons, biological contaminants, PCBs, fuel oils and asbestos.	
Domestic cleaning service and works and factories within industrial estate (approx. 300m north).	A range of inorganic and organic contaminants including metals and hydrocarbons, asbestos, acids, solvents, etc.	
Allotments	A range of inorganic and organic contaminants including herbicides, pesticides and fuel oils.	

Table 1.4: Potential receptors and contaminant exposure and migration pathways at baseline and resulting from the proposed development.

Receptor Group.	Receptor	Principal Contaminant Migration Pathways.
Human health (on-site).	Current users of the site.	Dermal contact with and ingestion of contaminants in soils, soil-derived dusts and water; and Inhalation of contaminants in soil-derived dust, fibres, gas and vapours.
	Construction and maintenance workers.	
	Users of the new sport pitches.	
Human health (off-site).	Users of the adjacent Alde Valley Academy.	Dermal contact with and ingestion of contaminants in soil, soil-derived dust and water which may have migrated off-site. Inhalation of contaminants in soil, soil-derived dust, fibres and gas/vapours which may have migrated off-site.
	Residents in adjacent properties and users of commercial premises in the surrounding area.	
	Pedestrians accessing surrounding roads and footpaths.	
	Farmers and workers on agricultural land.	
Controlled waters:	Groundwater in principal bedrock aquifer.	Leaching/migration of contaminants in soil to groundwater in underlying aquifers; and

Receptor Group.	Receptor	Principal Contaminant Migration Pathways.
Groundwater (on-site and off-site).	Groundwater in Secondary (Undifferentiated) Superficial Aquifer.	Migration of contaminated water through preferential pathways such as underground services, pipes and granular material to groundwater in underlying aquifers.
Property (on-site and off-site).	Existing on-site and off-site services and structures (including listed buildings). Proposed on-site services and structures.	Direct contact of contaminants in soil and, or groundwater with existing and proposed structures and buried services; and Migration of contaminated groundwater, ground gas and, or vapours along strata and preferential pathways such as service routes or differentially permeable strata.
	Crops and livestock (off-site).	Migration of contaminated waters/dust /fibres and subsequent uptake by crops or ingestion /inhalation/dermal contact by livestock.

1.5 Environmental design and mitigation

1.5.1 As detailed in **Volume 1**, **Chapter 6**, a number of primary mitigation measures have been identified through the iterative EIA process and have been incorporated into the design and construction planning of the proposed development. Tertiary mitigation measures are legal requirements or are standard practices that would be implemented as part of the proposed development.

1.5.2 The assessment of likely significant effects of the proposed development assumes that primary and tertiary mitigation measures are in place. For geology and land quality, these measures are identified in the following sections, with a summary provided on how the measures contribute to the mitigation, and management of potentially significant environmental effects.

a) Primary mitigation

1.5.3 Primary mitigation is often referred to as ‘embedded mitigation’ and includes modifications to the location or design to mitigate impacts; these measures become an inherent part of the proposed development.

1.5.4 Primary mitigation for the proposed development would include:

- prior to earthworks, topsoil present would be removed and appropriately stored for potential re-use in landscaping areas, subject to demonstrating suitability for reuse criteria. This process would reduce the potential for buried topsoil to generate ground gas beneath the proposed development which may pose a risk to human health;

- the selection of materials for the off-site sports facilities at Leiston would be required to take into account the ground conditions including the potential for ground movement, compaction, ground gas and ground aggressivity;
- gas mitigation measures would be provided in relevant structures where required, the design of which would be dependent on the risk profile and the nature/usage of the structure; and
- the use of appropriate drainage systems in accordance with the Drainage Strategy (**Volume 2, Appendix 2B)** to reduce the potential for contamination to migrate and impact on the ground, groundwaters and surface waters.

b) Tertiary mitigation

1.5.5 Tertiary mitigation will be required regardless of any EIA assessment, as it is imposed, for example, as a result of legislative requirements and/or standard sectoral practices.

1.5.6 Tertiary mitigation measures to be incorporated into the proposed development during the construction as set out in the **CoCP (Doc Ref. 8.11**) phase include:

- development of health and safety risk assessments and method statements by the Contractor (including emergency response procedures), and provision of appropriate personal protective equipment (PPE) for the protection of construction workers;
- implementation of a contamination watching brief by suitably qualified and experienced personnel would be completed for the proposed development when excavating areas of potential contamination risk. If unidentified contamination is encountered, works will be temporarily suspended in the area and appropriate investigations and remediation will be discussed and agreed with stakeholders and completed in accordance with current best practice;
- implementation of appropriate dust suppression measures to reduce migration of contaminated dust, further details are provided in the air quality chapter (**Chapter 12**);
- minimising the area and duration of soil exposure and timely reinstatement of vegetation or hardstanding to reduce soil exposure/erosion and reduce temporary effects on soil compaction;

- clear segregation between stockpiled material including imported material, excavated material stockpiled for re-use and excavated waste material stockpiled for treatment and / or off-site disposal;
- stockpile management (such as water spraying and avoiding over stockpiling to reduce compaction of soil and loss of integrity) to reduce windblown dust and surface water run-off;
- covering / hydroseeding of temporary stockpiles to reduce soil erosion and dust generation;
- stockpiles would be located a minimum of 10m from the nearest watercourse;
- implementation of working methods during construction to ensure that surface water run-off from the stockpiles or working areas into adjacent surface watercourses or leaching into underlying groundwater is minimised and, where necessary, in accordance with best practice;
- implementation of appropriate pollution incident control e.g. plant drip trays and spill kits; and
- implementation of appropriate and safe storage of fuel, oils and equipment during construction in accordance with Control of Substances Hazardous to Human Health Regulations 2002 and oil storage regulations.

1.5.7 Additional tertiary mitigation that would be anticipated and is referenced in the **CoCP** (**Doc Ref. 8.11**) includes:

- implementation of an appropriate **Materials Management Strategy** to document how the excavated materials would be dealt with via Materials Management Plan(s) (MMP) and a verification report(s) to record the excavation and placement of materials at the site. Further details are provided in the **Materials Management Strategy (Appendix 3A** of this volume**)**;
- implementation of a site waste management plan in accordance with the **Waste Management Strategy** (**Appendix 8A** of this volume).; and
- implementation of an **Outline SMP**, (**Volume 2, Appendix 17C**).

1.5.8 For the operational phase storage and disposal of wastes and hazardous substances where required would be managed in accordance with current guidance and legislative requirements.

1.6 Assessment

a) Introduction

1.6.1 This section presents the findings of the geology and land quality assessment for the construction and operational phases of the proposed development.

1.6.2 This section identifies any likely significant effects that are predicted to occur and **section 18D.7** highlights the secondary mitigation and monitoring measures that are proposed to minimise any adverse significant effects (if required).

b) Construction

i. Physical effects

1.6.3 A qualitative approach has been undertaken to assess the likely physical effects of the proposed development. The effects have then been categorised in accordance with the methodology described in **Volume 1, Appendix 6N**, and summarised in **section 18D.3,** and confirmed as either temporary or permanent, adverse or beneficial and significant (moderate or major effects) or not significant (minor or negligible).

1.6.4 The construction phase of the proposed development may result in physical effects to soils and geological receptors, arising from changes in soil erosion and ground instability associated with stripping of topsoil, vegetation, earthworks and construction of the off-site sports facilities at Leiston and infrastructure. These are discussed in more detail below.

Soil erosion

1.6.5 Earthworks, including areas for temporary works, are anticipated for the construction of the proposed development. Topsoil and potentially subsoil may be stored in temporary stockpiles on the site during construction works for either off-site disposal or re-use.

1.6.6 There is the potential for increased soil erosion and run-off with a high sediment load which may impact local surface waters. Earthworks would be managed in accordance with the **CoCP** (**Doc Ref. 8.11**) to minimise soil exposure as far as practicable. Stockpiles would be managed in accordance within primary and tertiary measures set out in **section 18D.5** and the **CoCP** (**Doc Ref. 8.11**) to reduce soil erosion and dust generation by good management practices. The impacts on soil erosion are therefore considered to be temporary, short term and direct.

1.6.7 Given that there are limited soil erosion hazards at the site, the value/sensitivity of the receptor is classed as low. With the primary and tertiary mitigation measures, the magnitude of the impact is considered to be very low**.** The overall effect for soil erosion is therefore considered to be negligible and classed as **not significant**.

Ground stability

1.6.8 The site is located within an area with a moderate UXO risk assumed to be due to the local presence of RAF Leiston to the north of the site. The impact on ground stability during the construction phase is therefore considered to be temporary, short term and direct. However, the site and adjacent area were developed in the 1950s and 1970s, suggesting that WWII UXO strikes would likely have been dealt with post war.

1.6.9 Given the above, the value/sensitivity of the receptor is classed as medium and the magnitude of the impact is considered to be low**.** The effect for ground stability is therefore considered to be minor adverse and classed as **not significant**.

ii. Mineral resources

1.6.10 A qualitative approach has been undertaken to assess the likely effects of the proposed development on mineral resources in accordance with the methodology outlined in **Volume 1, Appendix 6N**.

1.6.11 The proposed development may cause impacts upon mineral resources and associated Mineral Safeguarding Areas including the loss, damage or sterilisation of an important mineral resource.

1.6.12 The site and study area are not located within a coal mining area, an area of historical or planned mineral extraction or a Minerals Safeguarding Area. Therefore, there would be a limited impact on the current regional mineral resources. The impacts on mineral resources during the construction phase are therefore considered to be temporary, short term and direct.

1.6.13 Given that there are limited valuable mineral resources located within the study area, the value/sensitivity of the receptor is classed as low. The magnitude of the impact is considered to be very low as there would be limited loss of regional mineral resources. The overall effect is therefore considered to be negligible and classed as **not significant**.

iii. Effects associated with ground contamination

1.6.14 The construction PCSM and risk assessment are presented in **Annex 18D.2** and the impact assessments in **Annex 18D.3**. The construction impact assessment is undertaken by comparing the baseline land contamination risks to those predicted during construction, while considering any new sources and pollution pathways introduced by construction activities.

1.6.15 The construction phase would potentially introduce new sources of contamination and disturb and mobilise existing sources of contamination. Construction activities, such as excavation may introduce new pathways for migration of existing contamination and exposure of contaminated soil, remobilisation of contaminants through soil disturbance and the creation of preferential pathways for surface water run-off and ground gas migration pathways. Potential changes to the baseline situation creating PCLs, which have been assessed within this chapter are:

- the potential for mobilising contaminants by excavation and stockpiling of material, increasing the risk to controlled water receptors through leaching and run-off. Earthworks could provide opportunities for run-off to contain suspended solids if not managed properly;
- the potential for introducing new sources of contamination i.e. from spillages and leaks;
- the potential for exposure of human receptors by generation of potentially contaminated dust and vapours released by the construction works; and
- the potential for creation of new pathways to groundwater during groundworks, through opening up ground temporarily and construction activities, such as earthworks, installation of drainage and other below-ground services.

1.6.16 The impacts on land contamination during the construction phase are considered to be permanent, and direct. Primary and tertiary mitigation measures would be incorporated into the construction process as outlined in **section 18D.5**. These would include the adoption of working methods during construction to manage groundwater appropriately, implementation of appropriate pollution incident control and implementation of appropriate and safe storage of fuel, oils and equipment.

1.6.17 A summary of the construction phase PCSM and impact assessment is provided in **Table 1.5** and includes the risks identified to the receptors. A more detailed assessment of construction risk and impact assessment is provided in **Annexes 18D.2** and **18D.3**.

1.6.18 It is considered that with the primary and tertiary mitigation measures in place, the risks to human health, controlled waters, ecological and property receptors during construction would range between very low to moderate/low risk. Compared to the existing baseline, the level of risk to receptors has generally remained the same or increased during the construction phase. An overall negligible to minor adverse effect has therefore been predicted which is classed as **not significant**.

Table 1.5: Construction phase effects for the proposed development.

Receptor	Value/ Sensitivity.	Baseline Risk.	Construction Risk.	Classification of Effect.
Human (on-site).	High	Very low risk.	Low risk.	Minor adverse (**not significant**).
Human (off-site).	High	Very low risk.	Very low risk.	Negligible (**not significant**).
Controlled waters: groundwater (on-site and off-site).	Medium	Very low risk.	Low risk.	Minor adverse (**not significant**).
Property: existing and future structures and services (on-site and off-site).	Medium	Very low risk.	Low risk.	Minor adverse (**not significant**).
Property: crops and livestock (on-site and off-site).	Medium	Very low risk.	Very low risk.	Negligible (**not significant**).

iv. Effects associated with waste soils and soil re-use

1.6.19 Excavated material for construction works is assumed to be primarily topsoil and possible some subsoil which may need to be removed from site given the proposal for artificial surfaces, although some maybe kept on-site and used in construction where possible. There is the potential that waste soil generated during construction is classified as geotechnically and/or chemically unsuitable for reuse on-site or hazardous, therefore requiring removal from site. Waste soils would be dealt with in accordance with the **Waste Management Strategy** presented in **Appendix 8A** of this volume.

1.6.20 A MMP in accordance with the **Materials Management Strategy (Appendix 3A** of this volume) would set out how material is managed on site during construction in accordance with appropriate guidance such as the Contaminated Land: Applications in Real Environments Development Industry Code of Practice (Ref. 1.6), to allow the re-use of suitable soils during the construction of the proposed development.

1.6.21 Additionally, the design would seek, as far as reasonably practicable, to reuse and recycle waste materials on site, to reduce the amount of materials of a hazardous nature where possible and to manage materials suitably including off-site disposal of waste, if required, in accordance with relevant legislation. Therefore, the impacts on waste soils and soil re-use are considered to be temporary, short-term and direct.

1.6.22 Given the proposals to re-use site won material as part of the development, the value/sensitivity of the receptor is classed as medium. With the primary and tertiary mitigation measures, the magnitude of the impact is considered to be low. The overall effect is therefore considered to be minor adverse and therefore **not significant**.

v. Inter-relationship effects

1.6.23 This section provides a description of the identified inter-relationship effects that are anticipated to occur on geology and land quality receptors between the individual environmental effects arising from construction of the proposed development.

1.6.24 There are not anticipated to be inter-relationship effects between geology and land quality, soils and agriculture and groundwater and surface water in relation to potential receptors which could be impacted by ground contamination during the construction of the proposed development.

c) Operation

i. Physical effects: soil erosion and ground stability

1.6.25 Physical effects are considered to be mainly related to the construction phase. During operation, there would be limited effects on soil erosion and ground stability through maintenance operations. The impact on ground stability due to the moderate UXO risk is also assumed to have reduced as secondary mitigation has been implemented. Suitable design and subsequent construction works would also minimise physical effects and the proposed development would be operated in accordance with the relevant regulations and best practicable measures. The impacts on soil erosion and ground stability during the operational phase are therefore considered to be temporary, short-term, and direct.

1.6.26 Given the likely limited disturbance of the proposed development through the operational phase, the value/sensitivity of the receptor is classed as low. With the primary and tertiary mitigation measures as set out in **section 18D.5** and secondary measures associated with the construction stage set out in **section 18D.7**, the magnitude of the impact is considered to be very low**.** The effect is therefore considered to be negligible and are classed as **not significant.**

ii. Mineral resources

1.6.27 Effects in relation to mineral resources during the operation phase relate to the permanent sterilisation/loss of minerals, preventing future extraction. The impacts on mineral resources during the operational phase are therefore considered to be permanent and direct.

1.6.28 Given that there are limited valuable mineral resources located within the to study area, the value/sensitivity of the receptor is classed as low. The magnitude of the impact is considered to be very low. Effects in relation to loss, damage or sterilisation of mineral resources would remain as negligible and are classed as **not significant**.

iii. Effects associated with ground contamination

1.6.29 The operational PCSM and risk assessment are presented in **Annex 18D.2** and the impact assessment in **Annex 18D.3**.

1.6.30 The operational impact assessment has been undertaken by comparing the baseline land contamination risks to those predicted during operation, while considering any new sources and pollution pathways introduced by operational activities.

1.6.31 The operation of the proposed development would potentially introduce new sources of contamination. Spillages and leaks may occur and below ground services could create additional potential pathways for the migration of potential contamination that were not present at baseline. The impacts on land contamination during the operational phase are considered to be permanent and direct

1.6.32 A summary of the operational phase contamination effects is provided in **Table 1.6**. A more detailed assessment of operational risk and impact assessment is provided in **Annexes 18D.2** and **18D.3**. It is considered that with proposed mitigation, risks identified to human health, controlled waters, ecological and property receptors during operation are assessed as very low. Compared to the existing baseline, the level of risk to receptors has generally remained the same. An overall negligible effect is therefore anticipated which is classed as **not significant**.

1.6.33 The assessment of land contamination effects during the operational phase is summarised in **Table 1.6.**

Table 1.6: Operational phase effects for the proposed development.

Receptor	Value/ Sensitivity.	Baseline Risk.	Operation Risk.	Classification of Effect.
Human (on-site).	High	Very low risk.	Very low risk.	Negligible (**not significant**).
Human (off-site).	High	Very low risk.	Very low risk.	Negligible (**not significant**).
Controlled waters: groundwater (on-site and off-site).	Medium	Very low risk to low risk.	Very low risk to low risk.	Negligible (**not significant**).
Property: existing and future structures and services (on-site and off-site).	Medium	Very low risk.	Very low risk.	Negligible (**not significant**).
Property: crops and livestock (on-site and off-site).	Medium	Very low risk.	Very low risk.	Negligible (**not significant**).

iv. Effects associated with waste soils and soil re-use

1.6.34 The proposed development may also generate limited waste soils during operation due to maintenance requirements which may include excavations for landscaping and for repairs or maintenance of services. The proposed development would also be operated in accordance with the relevant regulations and best practice pollution prevention guidance. Therefore, the impacts associated with waste soils are assessed to be temporary, short-term and indirect.

1.6.35 Given that there is less potential for soil reuse during the operation phase, the value/sensitivity of the receptor is classed as low**.** With the primary and tertiary mitigation measures, the magnitude of the impact is considered to be very low. The overall effect is therefore assessed to be negligible and classed as **not significant**.

v. Inter-relationship effects

1.6.36 This section provides a description of the identified inter-relationship effects that are anticipated to occur on geology and land quality receptors between the individual environmental effects arising from operation of the proposed development.

1.6.37 There are not anticipated to be inter-relationship effects between geology and land quality and groundwater and surface water in relation to potential receptors which could be impacted by ground contamination during the operation of the proposed development.

1.7 Mitigation and monitoring

a) Introduction

1.7.1 Primary and tertiary mitigation measures which have been accounted for as part of the assessment are summarised in **section 18D.5**. Where further mitigation is required, this is referred to as secondary mitigation and where reasonably practicable, secondary mitigation measures have been proposed.

1.7.2 This section describes the proposed secondary mitigation measures for geology and land quality as well as describes any monitoring required of specific receptors/resources or for the effectiveness of a mitigation measure.

b) Mitigation

1.7.3 The additional assessment of the moderate World War II UXO bomb risk identified across the proposed development would be undertaken in the form of a detailed UXO desk study and risk assessment. Where required, mitigation measures would then be implemented as appropriate.

1.7.4 A ground investigation would be undertaken to inform the detailed design of the proposed development and confirm ground conditions, contamination status and other ground related risks. This would be completed prior to construction works. Where the ground investigation and subsequent generic risk assessments identify unacceptable levels of contamination and ground related risks, further detailed quantitative risk assessment followed by, where necessary, the remediation of soil and groundwater contamination prior to construction may be required.

c) Monitoring

1.7.5 A programme of short-term gas and groundwater monitoring would be designed as part of the additional ground investigation for the site and would be required prior to construction works commencing. The results of this would determine the need for whether further long-term gas and groundwater monitoring is required during the construction and operational phases.

1.7.6 A contamination watching brief by suitably qualified and experienced personnel would be implemented when excavating areas of potential contamination risk.

1.8 Residual effects

1.8.1 The following tables present a summary of the geology and land quality assessment. They identify the receptor(s) likely to be impacted, the level of effect and, where the effect is deemed to be significant, the tables include the mitigation proposed and the resulting residual effect.

Table 1.7: Summary of effects for the construction phase.

Receptor	Impact	Primary or Tertiary Mitigation.	Assessment of Effects.	Additional Mitigation.	Residual Effects.
Geology	Soil erosion.	Health and safety risk assessments, method statements and appropriate PPE for the protection of construction workers. Implementation of measures in the CoCP (**Doc Ref. 8.11**) during construction works. Design and selection of construction materials in accordance with best practice.	Negligible	Additional assessment of the UXO risk on site with associated mitigation measures where required. Ground investigation and risk assessments completed prior to detailed design and construction work. Remediation of soil and groundwater if necessary. Longer term gas and groundwater monitoring if necessary.	Negligible (**not significant**).
Geology	Ground stability		Minor adverse.		Negligible (**not significant**).
Mineral resources.	Loss, damage or sterilisation.		Negligible		Negligible (**not significant**).
Human health.	Contamination from on-site sources.		Negligible to minor adverse.		Negligible (**not significant**).
Controlled waters (groundwater).	Contamination from on-site sources.		Minor adverse.		Negligible (**not significant**).
Property (existing and future structures and services).	Contamination from on-site sources.		Minor adverse.		Negligible (**not significant**).
Property (crops and livestock).	Contamination from on-site sources.		Negligible		Negligible (**not significant**).
Soils	Impacts from waste soils generated during construction works.		Minor adverse.		Minor adverse (**not significant**).

Table 1.8: Summary of effects for the operational phase.

Receptor	Impact	Primary or Tertiary Mitigation.	Assessment of Effects.	Additional Mitigation.	Residual Effects.
Geology	Soil erosion.	Use spill response kits and adequate staff training. Use of hardstanding to reduce impact	Negligible	Longer term gas and groundwater monitoring if necessary.	Negligible (**not significant**).
Geology	Ground stability		Negligible		Negligible (**not significant**).
Mineral resources.	Loss, damage or sterilisation.		Negligible		Negligible (**not significant**).

Receptor	Impact	Primary or Tertiary Mitigation.	Assessment of Effects.	Additional Mitigation.	Residual Effects.
Human health.	Contamination from on-site sources.	from spills and leaks. Incorporation of bypass separators within the drainage design where considered necessary. The use of grid connections for electricity rather than generators. Appropriate storage and disposal of chemicals, oils, fuels, materials and wastes in accordance with current guidance. Health and safety risk assessments, method statements and appropriate PPE for the protection of maintenance workers.	Negligible.		Negligible (**not significant**).
Controlled waters (groundwater).	Contamination from on-site sources.		Negligible.		Negligible (**not significant**).
Property (existing and future structures and services).	Contamination from on-site sources.		Negligible.		Negligible (**not significant**).
Property (crops and livestock).	Contamination from on-site sources.		Negligible		Negligible (**not significant**).
Soils	Impacts from waste soils generated during construction works.		Negligible		Negligible (**not significant**).

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VOLUME 2, CHAPTER 18, APPENDIX 18E: BORROW PIT RISK ASSESSMENT REPORT

EDF Energy

Borrow Pit Risk Assessment Report

Peat and Alluvium as Backfill for Borrow Pits: Groundwater, Surface Water & Ground Gas Risk Assessment

Wood Environment & Infrastructure Solutions UK Limited – February 2020

Report for

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Executive summary

The purpose of this report is to assess the feasibility of using peat and clay, excavated as part of the proposed Sizewell C (SZC) development, as backfill for borrow pits. This report is provided as an appendix to the **Environmental Statement** (**ES**) supporting the Development Consent Order (DCO) application for the construction, operation and decommissioning of SZC.

The excavation of the area within the cut-off wall of the SZC main development site may generate approximately 1.1 million m^3 (1.1 Mm^3) of recent deposits, comprising a mixture of peat, peaty clay and clay/silt (referred to collectively as alluvium). This material is not suitable as engineering fill around power station structures but may be suitable to provide backfill to borrow pits which may be excavated to win Crag Sand as engineering fill and for landscaping purposes. EDF Energy identified potential locations (Areas 2, 3 and 4) for the borrow pits (**Figure 1.1**), which would provide 846,391 m^3 of suitable engineering material, extending over a pit footprint area of 20 ha and an average excavation depth of 8 m. This excavation depth would give a base of excavation at least 2 m above the maximum recorded and predicted groundwater levels. EDF Energy propose to undertake lime stabilisation of the alluvium to improve the geotechnical properties of the material.

As part of the assessment of the feasibility of infilling the borrow pit void with alluvium, Wood prepared previous risk assessments (Wood, 2014a, 2014b, 2014c, 2015 and 2016). EDF Energy undertook further investigation of Areas 1 and 2 in 2017 and revised the potential locations for the borrow pits (Area 1 will not be taken forward and Area 4 has a larger footprint). As part of the management of construction materials that will be adopted for the SZC construction phase works, EDF Energy has re-considered the potential to use the infilled borrow pits as a temporary stockpile area and require the retention of this option to optimise land use. This report provides an update to the 2016 Risk Assessment to take account of: revised borrow pit footprint, data from a site investigation in 2017 and use of infilled borrow pits as a temporary stockpile area. The risk assessment assumes a worst-case scenario in which all three borrow pits (Area 2, 3 and 4) would be used for backfilling of alluvium. However, only the void volume required for backfilling would be excavated and the final dimensions of the pits will be confirmed following further ground investigation planned for 2020-2021.

The borrow pits are underlain by sand and gravels which overly the Crag Principal aquifer. Groundwater flow below the borrow pits is towards the Minsmere-Walberswick Heaths & Marshes Site of Special Scientific Interest (SSSI) with discharge to ditches and streams which feed the marsh. A review of licensed and private water supply sources has identified two private sources down gradient of the borrow pits (at distances of 250 m and 350 m from the potential pit locations). These properties are part of the managed EDF Energy Nuclear Generation Ltd Sizewell Estate.

No new chemical testing data is available for the alluvium since the 2016 Risk Assessment. The human health risk assessment reported herein has concluded that there are no unacceptable chronic risks to human health from use of extracted alluvium as backfill materials for the borrow pits. The conclusion applies to both on-site and off-site receptors. The final end-use of the borrow pits for agriculture is appropriate in this context. This finding is consistent with the previous risk assessment findings undertaken in 2016.

No new ground gas monitoring data is available since the 2016 Risk Assessment. The ground gas risk assessment reported herein has concluded that the risk from the peat and alluvial soils proposed to be used as backfill for Areas 2, 3 and 4 is very low to low. Available gas monitoring data indicates the proposed backfill materials correspond to Characteristic Situation 1 to 2 (very low to low risk sources).

The geotechnical characteristics of the alluvium have been reviewed. The material is characterised by high liquid and plastic limits which indicates that care will be required in handling and management of the material during excavation, placement and compaction of the material. The addition of lime will improve its handling properties and its mechanical strength. The geotechnical properties of the material are suitable for the intended final agricultural end use or heathland creation.

The backfill is likely to be characterised by low permeability which will restrict infiltration and drainage of the material. Excavation and placement of the material is likely to result in temporary exposure to the atmosphere and therefore as a worst case the initial drainage is assumed to be characterised by a high sulphate concentrations, but in the longer term conditions in the backfill would be expected to become anaerobic preventing further oxidation of pyrite and a decrease in sulphate concentrations in drainage.

The findings from the updated controlled waters risk assessment are:

- Base scenario (no lime treatment and no stockpiling on the borrow pits)
    - No breakthrough of phenanthrene at the water table below the borrow pits;
    - No breakthrough above or breakthrough marginally above background quality by ammoniacal-N and iron in groundwater;
    - Small increases in concentrations of chloride, sodium and sulphate in groundwater downgradient of the borrow pits but no exceedances of water quality standards (WQS);
    - No impact on surface water (and therefore on dependent habitats);
- Lime treatment scenario
    - The addition of lime will affect the rate and quality of the drainage from the borrow pits. The main effects will be: a reduction in permeability of the fill; a reduction in pore water due to hydration of the lime; a rise in pH (e.g. no acidic drainage) and a reduction in the mobility of most metals; and the precipitation of sodium and sulphate hydrates within the alluvium.
    - The addition of lime reduced predicted maximum concentrations of sulphate, chloride and sodium with no significant changes in ammoniacal-N and iron. No breakthrough of phenanthrene at the water table is predicted;
    - There is likely to be a short-term increase in groundwater alkalinity beneath and downgradient of the borrow pits due to the addition of lime. However, a qualitative assessment indicates that concentrations in groundwater are unlikely to rise significantly above the elevated baseline. It is therefore concluded that lime modification will not adversely affect surface water quality in the Minsmere & Walberswick Heath Marshes;
    - The sand and gravels which underly the borrow pits are characterised by a moderate calcium carbonate content and pH buffering calculations have shown that solution of this mineral would buffer any acidic drainage from the backfill and therefore no risk of a breakthrough of hazardous metals at the water table is predicted.
- Stockpiling scenario (5 m stockpile)
    - The impact on water quality from stockpiling over the borrow pits is mainly associated with the initial squeezing out of pore water over a relatively short time scale (about 5 years);
    - Assuming best and average case properties of the alluvium it is concluded that a stockpile of less than 5 m is unlikely to adversely affect water quality. Although sulphate and sodium concentrations are predicted to exceed marginally the relevant WQSs at the discharge point to surface water, the predictions overestimate settlement (and also water impact) because they take no account of the reduced settlement behavior of the infill following lime treatment.

Infilling the borrow pits would be supported by a groundwater monitoring programme. Water quality trigger levels at these monitoring points would be agreed with the Environment Agency. If required, a remediation plan would be developed which would be implemented if trigger levels were exceeded.

Contents

1. Introduction

1.1 Purpose of this Report

Wood Environment & Infrastructure Solutions UK Ltd has been appointed by EDF Energy to produce a risk assessment (ground gas, human health and controlled waters) for the use of peat and clay, excavated as part of the Sizewell C (SZC) development, as backfill for borrow pits. This report is provided as an appendix to the **Environmental Statement** (**ES**) supporting the Development Consent Order (DCO) application for the construction, operation and decommissioning of SZC.

1.2 Background

EDF Energy is undertaking studies into the feasibility of constructing a new nuclear power station at Sizewell in Suffolk, henceforth referred to SZC. Bulk excavations will be required to enable the foundations and underground structures of the power station to be constructed. The excavations will be undertaken primarily within a hydraulic cut-off wall. Ground conditions within the cut-off wall area comprise Made Ground (mainly sand with predominantly granular site clearance/demolition material, including concrete and brick, originating from the construction of the Sizewell B power station) overlying natural in-situ peat, peaty clays and clay/ silt (collectively referred to hereafter as alluvium) and Crag Sand.

The excavation of the area within the cut-off wall of the SZC power station footprint may generate approximately 1.1 million m^3 (1.1 Mm^3) of alluvium which EDF Energy considers will not be suitable as engineering fill around power station structures. EDF Energy is considering options for winning a similar replacement volume of material from the wider SZC development site for use as engineering fill and for landscaping and land forming purposes.

EDF Energy identified potential locations (Areas 2, 3 and 4) for the borrow pit area (**Figure 1.1**), which would provide 846,391 m^3 of suitable engineering material, extending over a pit footprint area of 20 ha and an average excavation depth of 8 m. Previous assessments also considered Area 1 which will no longer be taken forward as a potential location for the borrow pits. This excavation depth would give a base of excavation at least 2 m above the maximum recorded and predicted groundwater levels.

The option considered within this study is to backfill the void with alluvium excavated from the SZC power station development footprint. This study does not address the Made Ground to be excavated as part of the SZC development construction at this stage, because it is likely to have re-use potential within the development, although placement of this material within the borrow pits has not been discounted, subject to further assessment.

As part of the assessment of the feasibility of infilling the borrow pit void (Area 1 and 2) with alluvium, a controlled waters risk assessment was carried out by Wood (previously Amec Foster Wheeler Environment and Infrastructure UK Ltd) in order to determine the potential effects on groundwater and surface water resources and other relevant receptors. A preliminary assessment was undertaken in January 2014 (Wood, 2014a) the findings of which were presented to the Environment Agency at a meeting on the 3 February 2014 where it was agreed that the assessment should be updated to take account of a proposed initial site investigation that would provide specific information on the depth to groundwater and the physical and chemical characteristics of the strata within the footprint of the proposed borrow pit area.

The initial investigation was undertaken in March and April 2014 and the risk assessment was updated and reported to the Environment Agency at meetings on the 9 July and 16 September 2014 (Wood, 2014b and 2014c). At the July meeting, the use of the infilled borrow pit area as an interim materials stockpile storage location during the construction of SZC was also discussed, and in September 2014 the results of an assessment of the influence on settlement of the infill as a result of the placement of stockpiled material was presented. The Environment Agency has accepted the findings of the risk assessment in relation to controlled waters with respect to the proposals presented up to September 2014 subject to further information arising from: targeted borrow pit footprint site investigation, testing of the alluvium, an update of the risk assessment based on further investigation and development of a monitoring and contingency plan. Further assessment has also been requested with respect to a review of the risks from ground gas generation from the infill material.

The 2014 Risk Assessment was updated in March 2015 (Wood, 2015) considering alternative options for the borrow pit locations. This study concluded that predicted concentrations of contaminants in groundwater for Option 1 (Areas 2 and 3), Option 2 (Area 3) and Option 3 (Areas 3 and 4) are comparable (within 20%) of the Reference Case (Areas 1 and 2) and confirmed that there would not be an unacceptable impact on groundwater or surface water quality. The results of this study were presented and discussed with the Environment Agency on 18 April 2015. The findings were accepted subject to further investigation of Areas 1 to 4 and an updated risk assessment taking into account the investigation findings.

Following a constructability study for backfilling of the borrow pits undertaken in 2015, EDF Energy proposed to undertake lime stabilisation of the alluvium to improve the geotechnical properties of the material. In the period July to September 2015, EDF Energy also undertook an investigation of Areas 3 and 4. The 2015 Risk Assessment was updated in 2016 (Wood, 2016) to include the additional site investigation data and assess the benefits associated with lime stabilisation. This assessment concluded that Option 1 (Areas 2 and 3) results in the lowest impact on groundwater and Option 2 (Area 3) the highest and confirmed that there would not be an unacceptable impact on groundwater or surface water quality.

EDF Energy has undertaken further investigation of Areas 1 and 2 in 2017 and revised the potential locations for the borrow pits (Area 1 is no longer taken forward and Area 4 has larger footprint). As part of the management of construction materials that will be used in the SZC build, EDF Energy has re-considered the potential to use the infilled borrow pits as a temporary stockpile area and is keen to do so to optimise land use. This report provides an update to the 2016 Risk Assessment to take account of: revised borrow pit footprint, site investigation undertaken in 2015 and use of infilled borrow pits as a temporary stockpile. The preliminary results of the risk assessment were presented and discussed at a meeting with the Environment Agency, Suffolk County Council and East Suffolk Council on 12 September 2019. The updated risk assessment findings were discussed and it was agreed that further assessment of the potential increase in groundwater alkalinity due to the addition of lime would be included. It was also requested that a groundwater and surface water monitoring programme be proposed and additional details be provided of the methodology and calculations used to assess settlement of the infill as a result of the construction of stockpiles.

1.3 Objectives

The objective of this study presented herein is to understand the environmental risks associated with the use of the alluvium as backfill (taking account of the benefit of the addition of lime), the use of the infilled borrow pits as a temporary stockpile area, and also to assess geotechnical constraints regarding the reuse of the alluvium. The scope includes:

- Review additional site geological and hydrogeological information (including details of registered groundwater abstraction boreholes, groundwater and surface water monitoring data collected between 2015 and 2019; results of the 2017 site investigation);
- Update the human health, ground gas and controlled waters conceptual site model (CSM) presented in the 2016 Risk Assessment using the environmental data described above in order to identify and assess the key environmental risks to inform borrow pit site selection and design;

- Identify and summarise the key geotechnical issues associated with backfilling the borrow pits and assess the benefits associated with lime stabilisation;
- Update the 2016 human health risk assessment using current and appropriate human health Generic Assessment Criteria (GAC) for commercial and public open space use;
- Update the 2016 risk assessment for ground gas further considering the conceptual model in the context of ground gas;
- Updated the 2016 risk assessment for groundwater and surface water for the revised borrow pit footprint including the benefits of lime stabilisation and assessment of increased drainage due to stockpiling on the borrow pits; and
- A review of risk assessment findings to provide commentary as to whether the borrow pit locations are viable in terms of acceptable risks to environmental receptors.

1.4 Report Structure

The report is structured as follows:

- Section 2 provides a summary of the proposed operation for backfilling and restoration of the borrow pits;
- Section 3 provides a summary of the site investigations (including monitoring) undertaken in 2014, 2015 and 2017;
- Section 4 sets out the geological, hydrological and hydrogeological setting of the site together with the site conceptual model;
- Section 5 describes the physical and chemical properties of the backfill material;
- Section 6 describes the geotechnical properties of the alluvium and assesses the benefits from lime stabilisation;
- Section 7 describes the characteristics of the Crag aquifer underlying the borrow pits area;
- Section 8 describes the risk assessment approach and the results of the analysis; and
- Section 9 provides the conclusions and recommendations from the study.

1.5 Summary of Report Changes

The main changes to the 2016 Risk Assessment are:

- Section 2 (Proposed Development) has been updated to reflect the revised borrow pit footprint and proposals for temporary use of infilled borrow pits as a stockpile;
- Section 3 (Site Investigations) has been updated to account for the 2017 site investigation;
- Section 4 (Site Setting and Conceptual Site Model) has been updated to reflect the revised borrow pit footprint, additional groundwater and surface water monitoring data collected at the site between 2015 and 2019 and updated list of water abstractions near the borrow pits;
- Section 6 (Geotechnical Assessment) has been updated to account for the revised footprint of the borrow pits, and to include a geotechnical risk register;
- Section 7 (Characterisation of the Sands and Gravels and Crag) has been updated with data from the 2017 site investigation;

- Section 8.2 on human health risk assessment has been updated against current and appropriate human health GAC for commercial and public open space use;
- Section 8.3 on ground gas risk assessment has been updated to further consider the conceptual model in the context of ground gas;
- Section 8.4 on controlled waters risk assessment has been updated to account for the revised footprint of the borrow pits, benefits of lime stabilisation, assessment of increase in groundwater alkalinity due to the addition of lime and assessment of increased drainage due to stockpiling on the borrow pits; and
- Section 9 (Conclusions and recommendations) updated based on the results of the updated risk assessment.

Section 5 (Characterisation of backfill materials) has not been changed from the 2016 Risk Assessment.

1.6 Data Sources and Previous Investigations

The following information has been obtained and reviewed as part of this study:

- Chemical laboratory results of previous soils sampling (predominantly for human health risk assessment);
- Chemical laboratory results and field readings of routine groundwater level and quality and surface water quality monitoring;
- Previous geological and geotechnical investigations including the Structural Soils factual report (2009);
- 2014, 2015 and 2017 site investigations undertaken by Structural Soils;
- Previous investigations, including the ADAS study on heathland creation (ADAS, 2010);
- Environment Agency and British Geological Survey (BGS) reports on groundwater quality; and
- Details of licensed and private groundwater and surface water abstractions; and
- A Constructability Study undertaken by Costain in 2015.

2. Proposed Development

The location of the proposed SZC and the borrow pits is shown on **Figure 1.1**. The borrow pits extend over a footprint area of approximately 20 ha and comprise Areas 2, 3 and 4. The main change from the 2016 Risk Assessment is that Area 1 will not be taken forward and Area 4 has a larger footprint. The borrow pits will be excavated to an average depth of 8 m to provide 973,500 m^3 of sand and gravel that will be used as engineering fill material and for land forming and landscaping. The option considered within this study is to backfill the borrow pit void with alluvium excavated from the SZC power station development footprint.

There is the potential that subject to further design, only Areas 2 and 3 are used as borrow pits and Area 4 is used for stockpiling only. In assessing all three areas, this report considers the potential worst case.

Table 2.1 provides a summary of how the borrow pit areas could be used to provide the required volume of material for SZC construction. As previously agreed with the Environment Agency, the base of void excavation would be at least 2 m above maximum groundwater levels. The risk assessment assumes a worst-case scenario in which all three borrow pits (Area 2, 3 and 4) are used for backfilling of alluvium. However, only the void volume required would be excavated and the final dimensions will be confirmed following further ground investigation planned for 2020-2021.

Table 2.1 Summary of borrow pits dimensions

Area	Plan area (ha)	Ground level (m AOD) [average]	Average depth of excavation (m below ground level)	Minimum base of excavation (m AOD)
Area 2	4.53	10.0 to 15.8 [13]	7.8	5.2
Area 3	10.77	11.3 to 17.2 [14]	8.9	5.2
Area 4	4.60	15.5 to 17.5 [17]	8.0	9.0

Notes: a) See section 4.4 for definition of minimum base of excavation.

Prior to excavation of material from the proposed SZC development (**Figure 1.1**), a cut-off wall will be constructed around the power station development footprint. Groundwater levels within the cut-off wall will be lowered to the base of the alluvium by pumping from the underlying Crag deposits. Drains will be constructed through the Made Ground and alluvium to facilitate drainage prior to bulk excavation. Excavation is likely to commence some 3 months after the start of dewatering. Approximately 1.1 Mm^3 of alluvium will be excavated which is approximately equivalent to the borrow pit void volume. More detailed work will be required to determine whether excavation, subsequent placement and compaction of the alluvium in the proposed borrow pits will result in a net change in volume.

At present it has been assumed that the majority of the Made Ground deposits can be re-used within the SZC development site and therefore such materials are not considered as part of this study. It is estimated that bulk excavations within the proposed SZC power station footprint will extend over a 2-year period. Excavation, transport and placement of the alluvium within the borrow pits is planned to occur over two consecutive summers. The material will be placed in layers 200 to 300 mm thick, treated with lime and compacted. To minimise handling and exposure of the alluvium, it is not proposed to stockpile it unless weather conditions prevent immediate placement and compaction of the material in the borrow pits. Surface water which collects within the void will be routed to a sump and pumped out. Arrangements for management of this water will be determined in due course.

A previous study by Jacobs (Jacobs, 2010) indicates that the alluvium comprises 38% peat, 19% clay and 31% clay/peat mix, 12% silt/sand. The study also identified that it will be difficult to separate the different lithologies during bulk excavations and therefore the placed material will represent a composite mix of peat, peaty clay and clay/silt.

Following a constructability study for backfilling of the borrow pits, EDF Energy proposes to undertake lime treatment of the alluvium to improve the geotechnical properties and handling of the material. This treatment may also have the benefit of reducing the risk to controlled waters. This is discussed further in Section 6.1.

On completion of infilling of the borrow pits, EDF Energy also propose to place up to 3 m of granular material (principally Crag removed from the main excavation area) to allow for settlement of the alluvium and to facilitate reprofiling, drainage and restoration of the backfilled void. Topsoil and sub soil will be placed over the reprofiled area and the site returned to agriculture or heathland creation. As part of the management of construction materials that will be used in the SZC build, EDF Energy has also considered the potential to use the infilled borrow pits as a temporary stockpile area. Stockpiles of up to 5 m are estimated to remain in place for up to approximately 8 years (pending re-use within the construction site) or permanently as landscape bunds (subject to further risk assessment).

3. Site Investigations

This section has been updated from 2016 Risk Assessment to include the results of a site investigation undertaken in 2017. It provides a summary of the site investigations (including monitoring) undertaken in 2014, 2015 and 2017.

3.1 2014 Investigation

A site investigation has been undertaken in the area of the proposed borrow pit footprint. The investigation is described in Structural Soils (2014). The investigation comprised:

- Drilling of boreholes to determine the geology and to obtain soil samples for laboratory testing. Selected boreholes were completed as permanent groundwater monitoring points (Table 3.1);
- Permeability testing (Section 4.4.1);
- Groundwater level and quality monitoring implemented by EDF Energy in the last quarter of 2014 (Sections 4.6 and 4.7); and
- Laboratory analysis of soil samples (Section 7.2). Testing included measurement of the fraction or organic carbon, calcium carbonate content and leaching tests.

The locations of the boreholes are shown on **Figure 3.1** and details of the groundwater monitoring points are summarised in **Table 3.1**. The results from the investigation are presented and discussed in Sections 4 and 7 of this report.

Table 3.1 Summary of monitoring boreholes from 2014 site investigation

Borehole	Ground level (m AOD)	Borehole depth (m bgl)	Screen section (m bgl)	Depth to groundwater, m bgl (March 2014)	Geology
C3	17.05	10	7 to 10	Dry	Sand and gravels
C7	15.73	20	14 to 20	13.15	Crag
BP6	16.44	20	10 to 20	14.4	Sand and gravels/ Crag
BP7	16.41	20	12 to 20	14.58	Sand and gravels/ Crag
BP9	13.63	20	8 to 20	11.7	Sand and gravels/ Crag
BP12	12.01	20	12 to 20	10.11	Sand and gravels/ Crag
BP27	11.92	20	9 to 20	10.24	Sand and gravels/ Crag
BP28	10.31	20	8 to 20	8.52	Sand and gravels/ Crag

Note: m bgl indicates metres below ground level
Details of the other investigation boreholes shown on Figure 3.1 are given in Structural Soils 2014, 2015 and 2017.

3.2 2015 Investigation

A further site investigation has been undertaken in Areas 3 and 4. The investigation is described in Structural Soils (2015). The investigation comprised:

- Drilling of boreholes to determine the geology and to obtain soil samples for laboratory testing. Selected boreholes were completed as permanent groundwater monitoring points (Table 3.2);
- Permeability testing (Section 4.4.1);
- Groundwater level and quality monitoring (Section 4.6 and 4.7);
- Laboratory analysis of soil samples. Testing included measurement of fraction or organic carbon, calcium carbonate content and leaching tests (Sections 7.2 and 7.3).

The locations of the boreholes are shown on **Figure 3.1** and details of the monitoring points are summarised in **Table 3.2**. The results from the investigation are incorporated in Sections 4 and 7.

Table 3.2 Summary of monitoring boreholes from 2015 site investigation

Borehole	Ground level (m AOD)	Borehole depth (m bgl)	Screen section (m bgl)	Depth to groundwater, m bgl (October 2015)	Geology
SD_BP3	12.39	50	35 to 45	11.27	Crag to 45m
SD_BP5	15.47	20	8 to 20	14.18	Sand and gravels/ Crag
SD_BP6	14.14	20	8 to 20	13.21	Sand and gravels/ Crag
SD_BP7	17.23	20	8 to 20	15.15	Sand and gravels/ Crag
SD_BP8	15.66	20	8 to 20	14.24	Sand and gravels/ Crag
CPB BH11	17.37	20	8 to 20	16.04	Sand and gravels/ Crag
CPB BH13	12.07	20	8 to 20	11.07	Sand and gravels/ Crag
CPB BH14	13.93	20	8 to 20	12.89	Sand and gravels/ Crag

Note: m bgl indicates metres below ground level

3.3 2017 Site Investigation

A further site investigation was undertaken in Areas 1 and 2. The investigation is described in Structural Soils (2017). A number of trial pits were excavated at a further two locations outside the main investigation areas. These were on the northern outskirts of Leiston and another area approximately 400 m southwest of Ash Wood Cottages (location plan in Structural Soils, 2017). The investigation was completed between 30 January and 17 March 2017 and comprised:

- Drilling of boreholes to determine the geology and to obtain soil samples for laboratory testing. Standard Penetration Tests (SPT) were undertaken during percussion drilling. Selected boreholes were completed as permanent groundwater monitoring points (**Table 3.3**);
- Trial pits and some with infiltration tests;
- Permeability testing (Section 4.4.1);

- A limited post borehole installation groundwater level and quality monitoring programme (Section 3.3);
- Geotechnical laboratory testing of soil samples;
- Laboratory analysis of soil samples. Testing included measurement of fraction of organic carbon, calcium carbonate content, cation exchange capacity and leaching tests (Sections 7.2 and 7.3).

The locations of the boreholes are shown on **Figure 3.1** and details of the monitoring points are summarised in **Table 3.3.** The results from the investigation are incorporated in Sections 4 and 7.

Table 3.3 Summary of monitoring boreholes from 2017 site investigation

Borehole	Ground level (m AOD)	Borehole depth (m bgl)	Screen section (m bgl)	Depth to groundwater, m bgl (March 2017)	Geology
CPB-BP-2	12.88	20	8 to 20	11.45	Sand/ Silt
CPB-C-15	15.39	20	8 to 15	12.15	Clay/ silt and Sand
CPB-C-19	17.17	15.45	3 to 8	DRY	Clay/ Sand
SD-BP-1	13.10	51	9 to 20	11.18	Sand
SD-BP-2	14.31	25.5	9 to 20	12.78	Sand/ Crag
SD-BP-4	12.91	25.5	7 to 20	10.89	Silty fine Sand

Note: m bgl indicates metres below ground level

4. Site Setting and Conceptual Site Model

This section has been updated from the 2016 Risk Assessment to reflect the revised footprint of the borrow pits, additional groundwater and surface water monitoring data collected between 2015 and 2019 and updated water abstractions in the vicinity of the borrow pits. It sets out the geological, hydrological and hydrogeological setting together with the conceptual model for the borrow pits.

4.1 Site Description

The borrow pits are located to the north and northwest of Ash Wood in the northern part of the EDF Energy Nuclear Generation Ltd Estate (**Figure 1.1**). The current land use in the area is arable agriculture. The nearest occupied properties are the Round House (southern boundary of Area 2), Plantation Cottages (approximately 160 m north of Area 2) and Ash Wood Cottages (approximately 200 m to the south of Area 3).

The borrow pits are located in an area of higher ground, typically at elevations ranging from 13 to 17m AOD. Ground levels fall to north and east towards Minsmere-Walberswick Heaths & Marshes Site of Special Scientific Interest (SSSI) (**Figure 4.1**).

4.2 Hydrology

Figure 1.1 shows the main surface water features surrounding the proposed SZC development site and the potential borrow pit locations. The major surface water feature is the coastal water of the North Sea, to the east. There are also a series of surface freshwater features forming an extensive network of drainage ditches, referred to as the Sizewell Belts. These drainage ditches discharge to an artificial channel (Leiston Drain) which joins the Minsmere Old River, approximately 1.2 km north of the SZC development site footprint.

The Minsmere Old River discharges into the North Sea via a sluice gate (Minsmere Sluice). Operation of the sluice is known to have a significant effect on the water levels and water quality within the marshlands adjacent to the existing Sizewell site (Wood, 2013). In the Water Framework Directive (WFD) 2016 Cycle classification the Minsmere Old River (WFD water body GB105035046270) achieved an ecological status of "Moderate" due to its "Poor" biological quality elements (fish) and "Moderate" supporting elements. Leiston Beck (WFD water body GB105035046271) also achieved an ecological status of "Moderate" due to its "Moderate" supporting elements and "Moderate" physico-chemical quality elements (dissolved oxygen and phosphate)[1] (note that Leiston Beck is upstream of the Leiston Drain).

The Sizewell and Minsmere Marshes to the west and north of the SZC development site are flat and low lying and are characterised by a series of drains, small streams and wetland areas. Drains to the immediate west of the proposed SZC site collect water from Sizewell Marshes and direct it to the north and northeast, into eastern areas of the Minsmere-Walberswick Heaths & Marshes SSSI. Approximately 500 m to the north and east of Area 2 there is a network of drains which feed Minsmere Old River. To the east of Area 3 (approximately 450m), there is a network of drainage ditches which feed Leiston Drain.

There are two designated habitats that are supported by surface water, these are:

- Sizewell Marshes SSSI (Sizewell Marshes); and
- Minsmere-Walberswick Heaths & Marshes SSSI.

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[1] https://environment.data.gov.uk/catchment-planning/WaterBody/GB105035046270 and https://environment.data.gov.uk/catchment-planning/WaterBody/GB105035046271 [accessed 05/08/19]

4.3 Geology

The geological sequence underlying the borrow pits is detailed in **Table 4.1**. This is based on the British Geological Survey (BGS) online geological mapping[2] and a geological review provided in Royal Haskoning (2008) and reproduced by Wood (2012a).

In the area of the borrow pits the superficial deposits comprise the Pleistocene Lowestoft Formation (Diamicton Till (clay) and/or sand and gravels). To the east of the borrow pits and in the vicinity of the proposed SZC development site, superficial deposits comprise an interbedded sequence of peat and clay (referred to as alluvium), Tidal Flat (silty clay) and Beach Deposits (sands and gravels). **Figure 3.1** illustrates the superficial geology of the area. The Norwich Crag Formation (subsequently referred to as the Crag), comprising sands and laminated clays with gravel, underlies the superficial geology in the area around SZC. The Crag is underlain at depth by the London Clay Formation, Harwich Formation (sandy siltstone), Lambeth Group (mudstones, sand and silt), Ormesby Formation (mudstone) and the Chalk Formation.

Table 4.1 Solid geology in the area of the borrow pits

Age	Geological unit	Description	Sizewell specific unit	Description
Pleisto - Pliocene	Crag Group 0-60 m	Mainly fine-grained buff to brown, locally shelly, micaceous sands and laminated clays, with local rounded flint gravels.	Norwich Crag Formation 14-24 m	Medium dense becoming very dense brown slightly silty fine to coarse sand with iron stained and indurated silty clay inclusions and shell fragments.
		Further subdivided into Chillesford Clay (locally present grey silty mudstones), Red Crag (ferruginous shelly sands) and Coralline Crag (hard shelly calcarenite).	27-36 m	Very dense grey green slightly silty fine to coarse sand with occasional grey silty clay inclusions and variable amounts of shell fragments.
Upper London Tertiary	London Clay Formation 0-50 m	Mudstones and Siltstones.	London Clay Formation 12-17 m	Very stiff fissured dark grey micaceous silty clay with occasional mudstone bands.
Lower London Tertiary	Harwich Formation 0-8 m	A layer of sandy siltstone with abundant volcanic ash layers. A layer called "Hales Clay Member" composed of sandy mudstone with rare volcanic ash layers.	Undifferentiated Harwich Formation	Very dense grey green or grey brown silty fine sand with occasional silty clay partings becoming very stiff very silty very sandy clay in parts.
	Lambeth Group (formerly Woolwich & Reading Beds) 0-13 m	Mottled mudstones in upper part and sand and silt in lower part.	Lambeth Group and Ormesby Formation 9-17 m	Very stiff fissured dark grey orange and brown silty occasionally sandy clay with occasional silt and sand partings.
	Ormesby Formation 0-11 m	Mudstone.	-	-
Cretaceous	Chalk Group >310 m	Homogeneous, soft fine-grained white limestone with layers of flint nodules throughout and a thin band of hard nodular well fissured chalk.	Chalk Max 68 m	Slightly weathered to fresh white grey very weak to weak with moderately weak zones chalk with occasional flints.

Notes: Data reproduced from Wood, 2012a. UK EPR Sizewell C. Preliminary Phase 2 contamination assessment. 15930TR00054.

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[2] http://lle.gov.wales/catalogue/item/SourceProtectionZonesSPZMerged/?lang=en [accessed 05/08/19]

An indicative geological section across the area is shown in **Figure 4.2**. This section has been drawn in an east-west direction through Areas 2 and 3. The thickness and extent of each geological layer has been estimated using a sequence of gridded elevation datasets, compiled as part of the Environment Agency's North East Anglian Chalk ("NEAC") regional groundwater model, which encapsulates the study area. This data is gridded at 200 m spatial resolution, each grid uses data from geological logs (where stratigraphic information was available), with interpolation of each layer being constrained by mapped outcrop patterns. Where thicknesses of some units were unknown due to a lack of data, minimum thicknesses have been used. Three more detailed sections are shown on **Figures 4.3 to 4.5** and these incorporate information from the site investigations (Section 3).

The site investigations found that the higher ground at the borrow pits is overlain by Lowestoft Till that is typically 2 to 3 m thick. Lowestoft sand and gravels underlie the area and these deposits are up to 5 m in thickness. In a small number of boreholes (C3, C6, C7, BP7, CBP_C19 and CD_BP12) a stiff laminated clay was encountered at the base of the sand and gravels. This clay was 3 to 8 m thick but was not encountered in the other nearby boreholes and is therefore likely to be of limited lateral extent (**Figures 4.3 to 4.5**). The Crag underlies the sand and gravels and the stiff laminated clay. Borehole SD_BP3 proved the base of the Crag at a depth of 45 m below ground level (-33 m AOD).

4.4 Hydrogeology

The main aquifer units underlying the borrow pits comprise the Crag (Principal Aquifer) which is unconfined below the borrow pits and becomes confined to the east below alluvium deposits in the vicinity of the SZC development site; and the Chalk (Principal Aquifer) which is confined by the London Clay. A granular (sand) layer has also been identified in the upper section of the Harwich Formation below the London Clay, and is also likely to form a Principal Aquifer (Wood, 2012b – Sizewell C Hydrogeological Monitoring – Synthesis Report). The overlying Lowestoft sand and gravel deposits are classified as a Secondary Aquifer A, but in the borrow pits area these deposits are mainly above the water table.

Strata that form part of the Recent Deposits, the London Clay and the lower part of the Lower London Tertiary are likely to have low permeability and so will restrict the vertical movement of groundwater. However, with the exception of the London Clay, these units do not appear to be laterally continuous. Perched groundwater occurs in the Made Ground and permeable layers of superficial deposits.

The regional groundwater flow direction within the Crag is in an easterly direction, although discharge to surface water to the north (Minsmere-Walberswick Heaths & Marshes) and south (Sizewell Marshes) act to control the flow direction locally. Groundwater flow in the Crag aquifer is driven by a hydraulic source area located at least 20 to 22 km to the west. In the borrow pits area the groundwater level varies seasonally between 30 and 40 m AOD and provides the driving head to produce groundwater flow towards the main hydraulic sink which is located in the east along the coastal strand where groundwater levels are around 0.25 to 0.5 m AOD (VLWRC, 2010). Groundwater levels in the marshes just inland from the coast can be lower, where continuous pumping or extensive man-made drainage in the marshy areas may create local groundwater lows.

Modelled groundwater levels (Environment Agency NEAC regional flow model) in the vicinity of the borrow pits for dry (August 1991) and wet (March 2001) conditions are shown on **Figure 4.6**. Modelled groundwater levels below the borrow pits are between 3 and 3.5 m AOD (wet conditions) with an annual seasonal variation of 1 to 2 m. Groundwater flow below Area 2 discharges to springs and seepages which feed surface water in the Minsmere River valley and groundwater flow below Areas 3 and 4 discharges to ditches which feed Leiston Drain.

The results of the groundwater level monitoring programme undertaken by EDF Energy for the period March 2014 to June 2019 at the site investigation boreholes are included in **Appendix A** of this document**.** Examination of the hydrographs for the Crag indicates a downward trend in groundwater levels (except for borehole SD-BP-7) by approximately 0.25 m on average over this period. Groundwater levels were highest in March 2015 and lowest in June 2019. The observed highest groundwater levels (March 2015) around the eastern and southern edge of the potential borrow pit locations were between 2 and 3 m AOD (10 to 12 m below typical ground levels) and were about a metre lower than NEAC modelled groundwater levels for wet conditions (**Figure 4.7**). These observed measurements were taken following a wet winter when groundwater levels would be expected to be high and therefore the NEAC modelled levels may represent an overestimate of actual groundwater levels. Groundwater level contours for March 2015 (high groundwater levels) and June 2019 (low groundwater levels) are shown on **Figures 4.7 and 4.8** respectively. The contours indicate that groundwater flow below the borrow pits is to the northeast and east and this confirms the modelled flow direction. To the south of the borrow pits, groundwater flow is to the southeast and towards the Sizewell Marshes.

Long-term hydrographs (1976 to 2019) have been obtained from the Environment Agency for three boreholes (Corporals Belt, Church Lane and Halfway Cottages) monitoring the Crag aquifer. These are located 2.8 to 4.5 km south of the borrow pits. The hydrographs for these boreholes are consistent with the borrow pit boreholes over the period of overlap and show a similar annual variation and recent downward trend (**Appendix A** of this document). Comparison of the Environment Agency boreholes hydrographs with rainfall data for the Met Office Lowestoft station[3] shows that rainfall is the main factor controlling groundwater levels and that the recent drop in groundwater levels reflects a drier period after 2015 (**Appendix A** of this document). The EA borehole hydrographs indicate that, whilst March 2015 was characterised by high groundwater levels, higher levels were measured in 2001. The EA data indicate that groundwater levels measured in March 2015 were 0.4 m lower than maximum levels measured in 2001 (based on the hydrograph for Halfway Cottages borehole which is the most comparable in water level response to borrow pits borehole hydrographs) (**Table 4.2**).

Table 4.2 Maximum groundwater levels recorded in Environment Agency boreholes

EA monitoring borehole	Peak groundwater level 2001 (m AOD) [a]	Peak groundwater level March 2015 (m AOD) [a]	Difference between peak groundwater levels in 2001 and March 2015 (m)
Corporals Belt	2.17	1.9	0.27
Half Way Cottages	2.76	2.37	0.39
Church Lane	3.24	2.78	0.46

Notes: Hydrographs are provided in Appendix A.

The 2016 Risk Assessment estimated the maximum groundwater level contours across the borrow pits (**Figure 4.9**) as the observed groundwater levels in March 2015 (high groundwater levels), plus an allowance of an additional 0.4 m based on analysis of the hydrograph for the EA Halfway Cottages borehole. This estimate was based on monitoring data available up to 2015 and remains valid as groundwater levels have remained below the 2015 peak in subsequent monitoring (**Appendix A** of this document).

Since the 2016 Risk Assessment Atkins have produced a groundwater model for the SZC area covering the construction period (2020-2032). The modelled maximum groundwater level contours across the borrow pits assuming intermediate climatic conditions range between 2.0 and 3.2 m AOD (**Appendix B** of this document). The maximum groundwater level contours estimated in the 2016 Risk Assessment range between 2 and 3 m AOD and were lower than the Atkins modelled levels in localised areas by up to 0.5 m. This is due to the pessimistic (conservative) model assumption that the infill material at the borrow pits has higher recharge compared to surrounding Lowestoft clays, making groundwater levels in the borrow pit

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[3] https://www.metoffice.gov.uk/pub/data/weather/uk/climate/stationdata/lowestoftdata.txt [accessed 05/08/19]

areas more responsive to rainfall events. As a worst-case scenario, the groundwater level contours from the Atkins model have been used to define the maximum groundwater levels at the borrow pits and the maximum excavation depth to ensure a minimum unsaturated zone thickness of 2 m below the base of the void (**Table 4.3**).

Table 4.3 Definition of maximum groundwater levels at the borrow pits

Borrow Pits Area	Ground level (m AOD) [average]	Max groundwater level from borrow pits boreholes, March 2015 (m AOD) [a]	Max groundwater level corrected using long term data from EA boreholes (m AOD) [b]	Modelled max groundwater level on the basis of Atkins groundwater model [c]	Minimum base of excavation (m AOD) [d]	Unsaturated zone thickness (m)e
Area 2	10.0 to 15.8 [13]	1.8 to 2.5	2.2 to 2.9	2.2 to 3.2	5.2	2.0 to 3.9
Area 3	11.3 to 17.2 [14]	1.5 to 2.4	1.9 to 2.8	2.0 to 3.2	5.2	2.0 to 4.1
Area 4	15.5 to 17.5 [17]	2 to 2.5	2.4 to 2.9	2.2 to 3.0	9.0	>6.0

Notes: a) Hydrographs provided in Appendix A.
b) The 2016 Risk Assessment defined the maximum groundwater levels as the observed groundwater levels in March 2015 (high groundwater levels), plus an allowance of an additional 0.4 m based on analysis of the hydrograph for Environment Agency Halfway Cottages borehole. Maximum groundwater level contours are shown on Figure 4.9.
c) Modelled maximum groundwater level contours from Atkins groundwater model is provided in Appendix B.
d) Defined as 2 m above modelled maximum groundwater level.
e) Calculated using minimum base of excavation and modelled maximum groundwater level range.

No groundwater was encountered in the sand and gravel deposits above the laminated clay encountered in boreholes C3, C6, C7 and CD_BP12. This clay, where present, intersects the upper part of the Crag aquifer (**Figure 4.4**). This suggests that infiltrating water entering the ground above the clay moves vertically downwards to the clay and then laterally across the clay surface to the edge before resuming its vertical downwards movement.

4.5 Hydraulic Conductivity

Testing of monitoring boreholes was carried out as part of the 2014 and 2015 site investigations to determine the hydraulic conductivity of the sand and gravels and Crag. Two types of test were undertaken:

- Falling head tests during drilling. In these tests the length of the test section was typically less than 1 m. Calculated values of hydraulic conductivity derived from these tests ranged from 0.1 to 32.7 m/d;
- Pumping test followed by a recovery test on completed boreholes. These tests comprised pumping out the borehole at a constant rate of 5 to 10 l/min for 10 to 15 minutes and then monitoring the rate of recovery in the borehole (**Appendix C** of this document). The saturated length of the test sections ranged from 4 to 10m. The tests undertaken in 2014 resulted in a small drawdown in water level (typically less than 0.07m) and levels recovered within 1 to 5 minutes indicating a high hydraulic conductivity for the aquifer. Evaluation of the test results indicate a hydraulic conductivity in the range 4 to 21 m/d which is consistent with other data for the Crag (see Section 7 and Table 7.1). Repeat tests were undertaken in some of the boreholes and these provided confirmation of the first test.

The tests undertaken in 2015, resulted in drawdowns of between 5 and 8 m, but once pumping ceased groundwater levels recovered in 0.1 to 0.3 minutes indicating a high hydraulic conductivity. Due to the rapid recovery it was not possible to subject the test data to quantitative analysis, and a hydraulic conductivity of >5 m/d is therefore indicated in **Table 4.3.** Pumping tests undertaken in the Aldhurst Farm area indicate the

Crag can be characterised by high hydraulic conductivity values (>50 m/d). A summary hydraulic conductivity values for the Crag are given in Section 7 (**Table 7.1**) and indicate that they are typically in the range 10 to 20m/d.

Pumping tests were attempted in 2017 but due to the relatively high hydraulic conductivity of the strata and the restricted diameter of the boreholes it was not possible to pump at a high enough rate to achieve drawdown that would be sufficient for quantitative analysis again, confirming the high hydraulic conductivity of the Crag. A soakaway test within trial pit TP_BP_4 (3 m deep in gravelly fine sand), within Area 2 gave an infiltration rate of 1.24 x 10^{-6} m/s.

The results of the tests are summarised in **Table 4.4.**

Table 4.4 Results of hydraulic conductivity tests

Borehole	Test or Screen Section m bgl	Depth to groundwater m bgl	Length of screen section m	Maximum rise in water level m	Hydraulic conductivity m/d
Falling head test during borehole drilling (characterised by short test sections)					
BP6	14.1 to 15.1	15.1	1.0	12.1	0.4
BP7	10.9 to 11.5	8.8	0.6	8.1	33
BP9	12.9 to 13.4	13.21	0.5	7.5	7.3
BP12	14.3 to 14.5	11.22	0.2	3.8	1.6
BP27	9.9 (base of hole)	9.2	Base of hole	9.19	0.1
C7	18.9 to 19.2	13.0	0.3	7.24	0.1
C3	6.7 to 10.2	Dry	3.5	1.05	0.4
Pumping tests on completed boreholes					
Borehole	**Test or screen section m bgl**	**Depth to groundwater m bgl**	**Saturated length of test section m**	**Drawdown in water level m**	**Hydraulic conductivity m/d**
C7	14 to 20	13.46	6	0.44	13
BP6	10 to 20	14.8	5.2	0.05	4
BP7	12 to 20	14.91	5.1	0.06 0.06	3
BP9	8 to 20	12.13	7.9	0.1	8
BP12	12 to 20	10.49	8	0.02 0.02	8
BP27	9 to 20	10.62	9.4	0.07 0.07	21
BP11	8 to 20	15.66	4.3	3.75	>5
BP13	8 to 20	10.95	9	7.3	>5
BP14	8 to 20	12.7	7.3	5.3	>5

Notes: bgl below ground level

4.6 Baseline Groundwater Quality

Borrow Pits Area

Groundwater quality monitoring for the boreholes within and in the vicinity of the borrow pit areas (boreholes BP6, BP7, BP9, BP12, BP27, BP28, C7, CPB11, CPB13, CPB14, SD3, SD6, SD7 and SD8) was undertaken between November 2014 and June 2019. These data have been supplemented by data for boreholes within the wider surrounding area (to the south of the borrow pits) which were monitored as part of a wider groundwater quality monitoring programme undertaken by EDF Energy (Wood, 2012b). The data has been used to define baseline quality conditions in Crag groundwater beneath the borrow pits. The locations of the monitoring boreholes are shown on **Figure 3.1**. A summary of selected groundwater quality data is provided in **Table 4.5**. Groundwater quality plots over time (chloride, sodium, sulphate, iron, nitrate and ammoniacal-nitrogen) are provided in **Appendix D** of this document.

Table 4.5 Groundwater quality summary data in borrow pits area (November 2014 to June 2019)

Substance	Unit	Groundwater Concentration			Comments
		Min	Mean	Max	
pH	-	5.65	6.99	8.08	Data indicates approximately neutral pH conditions.
Alkalinity	mg/l $CaCO_3$	21	177	500	Alkalinity lower than 100 mg/l was measured at boreholes BP28 at the (downgradient edge of Area 2) and BP23 (approximately 520 m downgradient of Area 3). Data indicates fairly high buffering capacity (high alkalinity).
Chloride	mg/l	27	69	180	Data includes two outliers (120 and 180mg/l) at borehole BP27 in April and July 2016 which appear anomalous compared to data across the borrow pits including adjacent borehole BP28 (see water quality plot in Appendix D of this document). Excluding these outliers, min-mean-max concentrations are 27-68-90 mg/l.
Sodium	mg/l	10	25	73	Data includes concentration spike (73mg/l) at borehole SD3 in October 2015 which appears anomalous compared to data across the borrow pits including adjacent borehole BP9 (see water quality plot in Appendix D of this document). Excluding this spike, min-mean-max concentrations are 10-24-50 mg/l.
Sulphate	mg/l	27	70	120	Data includes concentration spike (120 mg/l) at borehole SD3 in October 2015 which appears anomalous compared to data across the borrow pits including adjacent borehole BP9 (see water quality plot in Appendix D of this document). Excluding this spike, min-mean-max concentrations are 27-67-99 mg/l.
Ammoniacal nitrogen	mg/l	0.008	0.43	7.18	Data includes occasional concentration spikes (appear anomalous) between 1.0 and 7.2 mg/l (see water quality plot in Appendix D of this document). Excluding these spikes min-mean-max concentrations are 0.008-0.13-0.72 mg/l.
Nitrate	mg/l	26	121	210	The high nitrate concentrations are likely to reflect inputs to the Crag aquifer from agricultural activities.

Notes: Data for boreholes BP6, BP7, BP9, BP12, BP27, BP28, C7, CPB11, CPB13, CPB14, SD3, SD6, SD7 and SD8.

pH and Alkalinity

pH was recorded in the range of 5.65 to 8.08 (average 6.99). Alkalinity, expressed as mg/l $CaCO_3$, ranged between 110 and 500 mg/l except for borehole BP28. This indicates that groundwater in the Crag has some capacity for buffering pH. Alkalinity lower than 100 mg/l was measured at boreholes BP28 at the downgradient edge of Area 2 and BP23 approximately 520 m downgradient of Area 3.

Chloride and Sodium

Average chloride concentrations across the borrow pits and wider surrounding area is shown in **Figure 4.9**. Chloride concentrations are typically between 27 to 90 mg/l in the area of the borrow pits (chloride concentrations <200 mg/l are considered to be representative of freshwater) and lower than the drinking water standard (DWS) of 250 mg/l. Two elevated concentrations (120 and 180 mg/l) were measured at borehole BP27 in April and July 2016 but data for adjacent borehole BP28 (April 2015 to July 2016) does not show elevated concentrations suggesting that the two elevated concentrations at BP7 are outliers. Average concentrations to the south of the borrow pits range between 45 and 270 mg/l. Concentrations increase towards the coast near the SZC power station with the highest average concentrations measured at boreholes PZ18 (2100 mg/l) and C4D (1932 mg/l) suggesting saline intrusion.

Sodium concentrations range from 10 to 50 mg/l (excluding outlier 73 mg/l) and are typical of freshwater. The higher measurement (73 mg/l) at borehole SD3 in October 2015 appears anomalous compared to data across the borrow pits including adjacent borehole BP9.

Sulphate

Sulphate concentrations range between 26 and 99 mg/l excluding an isolated peak of 120 mg/l at borehole SD3 in October 2015. The measured concentrations are lower than the DWS of 250 mg/l.

Nitrate and Ammonium

Nitrate concentrations are high and typically in the range of 26 to 210 mg/l and exceed the DWS of 50 mg/l as nitrate. The high nitrate concentrations are likely to reflect inputs to the Crag aquifer from agricultural activities. Concentrations of ammoniacal-nitrogen are generally below the DWS of 0.39 mg/l (50 out of 59 samples), though occasional spikes (appear anomalous) are noted between 1.0 and 7.2 mg/l. These concentrations are typically of oxygenated groundwater.

Metals

Concentrations of arsenic, mercury, cadmium, copper, lead and nickel were typically below or only just exceeded laboratory detection limits (<0.01 to <1 µg/l) in most boreholes. Zinc was encountered at concentrations greater than the detection limit in 14 out of 55 samples, with concentrations in the range of <1 to 73 µg/l (maximum at borehole BP28). Nickel (7.8 to 18 µg/l) and cadmium (0.25 to 0.6 ug/l) were consistently detected in samples from borehole BP28 but concentrations were below DWS (20 µg/l and 5 µg/l respectively). Chromium and iron concentrations ranged from <1 to 17 µg/l and <20 to 1100 µg/l although values were more typically less than 5 µg/l and 500 µg/l respectively. Metals concentrations were predominantly below DWS except for iron which exceeded the DWS (200 µg/l) more frequently in 11 out of 55 samples.

Organic Contaminants

The presence of organic contamination (e.g. total petroleum hydrocarbons (TPH), polycyclic aromatic hydrocarbons (PAH), volatile organic compounds (VOC) etc.) was not recorded in groundwater samples above the relevant limit of detection.

Summary

Overall, conditions in the Crag groundwater in the vicinity of the proposed borrow pit locations can be described as approximately neutral pH, with fairly high buffering capacity (high alkalinity) with no evidence of saline or brackish intrusion. Nitrate concentrations are relatively high (above DWS), whilst ammoniacal-nitrogen levels were generally below DWS (excluding occasional spikes). Concentrations of heavy metals were low and close to or below detection limit and there was no evidence of the presence of petroleum hydrocarbons or other organic compounds at concentrations above the laboratory limit of detection.

SZC Power Station Excavation Area

The following provides a brief summary of groundwater quality in the Crag aquifer below the alluvium in the SZC power station footprint excavation area. Chloride concentrations range from <100 to over 6700 mg/l with higher concentrations close to the sea or close to Leiston Drain (at boreholes PZ18 and C4D). Sodium concentrations range from <20 to 13000 mg/l and show a similar pattern to chloride, indicating the saline influence on groundwater quality in this area. Data for the alluvium indicates chloride concentrations range from 80 to 420 mg/l. Sulphate concentrations are low (<70 mg/l except for isolated spike 160 mg/l at borehole C4D), comparable to concentrations recorded in groundwater in the vicinity of the borrow pits. Most nitrate concentrations (20 out of 33 measurements) are less than 1 mg/l suggesting anaerobic conditions. Ammoniacal-nitrogen concentrations are variable ranging from <0.08 mg/l to 7.1 mg/l.

4.7 Baseline Surface Water Quality

Data from the surface water quality monitoring programme undertaken by EDF Energy between January 2010 and June 2019 have been used to update the baseline quality conditions in surface waters near to the proposed borrow pits. The locations of the monitoring sites are shown on **Figure 4.10**. The nearest downgradient monitoring points to the borrow pits are SW13, SW14, SW15 and SW16 (data for May 2010 to January 2013) and G1, G6a, G7a and G8 (data for November 2014 to June 2019) which are located on watercourses at the southern and eastern boundary of the Minsmere-Walberswick Heaths & Marshes SSSI. These points are of particular relevance for determining surface water quality in potential receptors for Crag groundwater originating from below the borrow pits.

Summary surface water quality data for a number of key parameters area presented in **Table 4.6**. Selected surface water quality plots over time are provided in **Appendix E** of this document.

Table 4.6 Surface water quality data summary (January 2010 to June 2019)

Parameter and Units	Mean Concentration (5%ile and 95%ile)*						
	2010	**2011**	**2012**	**2014**	**2015**	**2018**	**2019**
NH_4-N (mg/l)	1.0 (0.06-2.9)	1.23 (0.05-4.5)	1.71 (0.1-7.7)	n.m.	0.32 (0.12 - 0.56)	0.17 (0.09 - 0.26)	0.29 (0.18 - 0.36)
Chloride (mg/l)	224 (65-900)	223 (89-221)	139 (27-355)	75 (56 - 93)	142 (58 - 258)	151 (77 - 281)	149 (78 - 250)
Nitrate (mg/l)	8.7 (2-37)	112 (1.6-49)	13 (5-76)	24 (4.0 - 50)	33.0 (2.7 - 65)	28.2 (8.7 - 50.6)	23.1 (2.3 - 52.7)
pH (-)	7.3 (6.8-7.9)	7.1 (6.1-7.7)	7.5 (6.6-8.0)	n.m.	8.7 (7.1 - 14.2)	n.m.	7.4 (7.3 - 7.4)

Parameter and Units	Mean Concentration (5%ile and 95%ile)*						
	2010	2011	2012	2014	2015	2018	2019
Dissolved oxygen (mg/l)	3.2 (1.4-5.6)	7.1 (2.1-8.4)	4.8 (2.1-7.7)	n.m.	n.m.	n.m.	n.m.
Sodium (mg/l)	173 (30-828)	93 (27-182)	90 (28-141)	35 (29 - 42)	65 (29- 111)	64 (49 - 79)	72 (45 - 115)
Sulphate (mg/l)	64.5 (2.5-221)	54 (5-120)	51 (5-107)	62 (51 - 77)	91 (59- 104)	106 (86 - 116)	91 (79 - 98)

Notes: * 10th percentile and 90th percentile for dissolved oxygen measurements.
Data for locations SW13, SW14, SW15 and SW16 (2010, 2011 and 2012) and G1, G3, G3a, G4, G5, G5a, G6a, G7a, G8 (2014 to 2019).
n.m.- not measured

pH

pH values ranged between 5.90 and 8.60, with the mean value (7.44) approximating to neutral conditions.

Dissolved Oxygen (DO)

DO measurements ranged between 0.6 and 91.7 mg/l with an average of 4.97 mg/l (data available for 2010 to 2012). Measurements were typically higher at SW15 and SW16 to the northeast of the borrow pits and lower at SW14 to the east of the borrow pits. The 10th percentile DO concentrations at locations SW13 to SW16 fail to meet the WFD Environmental Quality Standard (EQS) for "Moderate" quality (54% saturation equivalent to 4.94 mg/l) for a Type 7 river (alkalinity over 200 mg/l as $CaCO_3$).

Chloride and Sodium

Mean sodium and chloride concentrations were 98 mg/l and 177 mg/l respectively. Concentrations were typically higher on Leiston Drain (G1, G8 and SW11), which is periodically inundated with sea water. Peak concentrations at other locations did not exceed 100 mg/l since they are away from areas of sea water incursion.

Nitrate and Ammonium

Nitrate concentrations were variable ranging from less than 0.5 mg/l to greater than the DWS (50 mg/l) with an average concentration of 24 mg/l. Concentrations were higher (maximum of 72 mg/l) at SW15, SW16 and G5 which is likely to reflect the arable land use surrounding these sampling points and the assumed application of fertilisers. Ammoniacal-nitrogen concentrations ranged between 0.08 and 6.4 mg/l. The 90th percentile concentration of ammoniacal-nitrogen was less than the WFD EQS for "Moderate" quality (1.1 mg/l) for a Type 7 river (alkalinity over 200 mg/l as $CaCO_3$) at all sampling points except for SW14 and SW16.

Sulphate

Sulphate concentrations at all sampling locations were typically below 120 mg/l and less than the DWS of 250 mg/l. Peak concentrations have occasionally exceeded this value at SW15 and SW16 and this may relate to occasional sea water incursions.

Priority Substances

The concentrations of Priority Substances (as defined by EU Directive 2008/105/EC) were typically below limits of detections for metals and organics. The exceptions were at SW15 and SW16 where occasional samples have exceeded the dissolved mercury EQS (0.07 µg/l) and numerous exceedences of the EQS for di (2-ethylhexyl) phthalate (DEHP) were recorded during 2012. Mercury concentrations also exceeded EQS at G6a on one occasion. Nickel EQS (4 µg/) was exceeded on one occasion at G6.

Petroleum Hydrocarbons

Sampling locations SW13 to SW16 recorded the presence of total petroleum hydrocarbons (TPH) as C6-C40 (concentrations greater than the detection limit of 10 µg/l) with occasional samples recording concentrations in excess of 50 µg/l. TPH was detected at locations G4, G8, SW4 and SW8 in July 2015 (10-31 µg/l). The source of the hydrocarbons throughout the monitoring network was not determined, however run-off from roads was considered to be a contributory factor (Wood, 2013).

Summary

Monitoring of surface water indicates a predominantly freshwater environment of moderate to poor quality. Water quality was found to be particularly poor in terms of ammoniacal-nitrogen and dissolved oxygen concentrations. Evidence of sea water incursion has been noted at some monitoring locations (e.g. SW11, G8 and G1) along the boundary of Minsmere-Walberswick Heaths & Marshes SSSI.

4.8 Groundwater and Surface Water Abstractions

The locations of licensed and private water abstractions in the vicinity of the borrow pits have been obtained from the Environment Agency on 31 July 2019 and East Suffolk Council on 29 July 2019, respectively. There are eight abstraction locations in the vicinity of the borrow pits and these are listed in **Table 4.7**. The nearest abstractions in the direction of groundwater flow are private potable supply boreholes located at Plantation Cottages (00/00492/PWWELL) and Ash Wood Cottage (00/00494/PWWELL, which are approximately 250 m and 370 m downgradient of the borrow pits. These properties are part of the EDF Energy Nuclear Generation Ltd Sizewell Estate. It is noted that land to the east and northeast of the pits is also part of this estate and, therefore, EDF Energy has control of the nearest downgradient groundwater abstractions.

Table 4.7 Groundwater and surface water abstractions in the vicinity of the borrow pits

Location	Licence Number/Ref	Description	Groundwater or surface water	Distance and direction from borrow pits
Private abstractions				
Round House	01/00047/PWWELL	Domestic but currently inactive	Groundwater	< 50 m south and west of Areas 2 and 3
Plantation Cottages	00/00492/PWWELL	Domestic	Groundwater	220 m northeast of Area 2
Ash Wood Cottage	00/00494/PWWELL	Domestic	Groundwater	220 m south of Area 3
Ebenezer Chapel	01/00015/PWWELL	Domestic but currently inactive	Groundwater	360 m northwest of Area 2
Lower Abbey Farm	00/00046/PWBORE	Irrigation	Groundwater	400 m northeast of Area 2
Licensed Abstractions				

Location	Licence Number/Ref	Description	Groundwater or surface water	Distance and direction from borrow pits
British Energy Generation Ltd	7/35/03/*G/0046	Well - 20 m^3/d, 2500 m^3/yr	Groundwater	330 m northeast of Area 3
E & L Dowley	7/35/03/*G/0064	Well points – 83 m^3/h, 1473 m^3/d, 24900 m^3/yr	Groundwater	590 m north of Area 2
British Energy Generation Ltd	7/35/03/*G/0045	Well – 20 m^3/d, 2500 m^3/yr	Groundwater	640 m south-south-west of Area 3
J R Poll	7/35/03/*G/0051	Borehole - 1 m^3/h, 757 m^3/d, 69200 m^3/yr	Groundwater	720 m to the west of Area 2
A W Mortier (Farms) Ltd	7/35/03/*S/0047	500 m^3/d, 31000 m^3/yr	Surface water	880 m to the northeast of Area 2
J R Poll	7/35/03/*G/0051	Well points – 50 m^3/h, 757 m^3/d, 24900 m^3/yr	Groundwater	1200 m to the southwest of Area 4

Notes: NGRs of abstractions not included at the request of the Environment Agency and East Suffolk Council.

4.9 Geological and Hydrogeological Summary

Details of the geology and hydrogeology for the proposed borrow pits are summarised below.

Area 2. This area is located to the north of Ash Wood and covers an area of 4.53 ha. Ground levels fall from 15.8 m AOD in the southern edge and 14.5 m AOD in the western edge to 10 m AOD in the northeast corner of the area. The average ground level is about 12 m AOD.

The area is underlain by sand and gravels which overly the Norwich Crag. Borehole C7, located on the southern edge of Area 2, identified a clay lens from 7.6 to 16 m depth. This lens is not considered to be laterally continuous over a spatial area of more than 50 to 100m.

Groundwater levels measured in March 2015 (high groundwater levels) in boreholes BP6, BP9, BP28 and C7 ranged from 1.8 m to 2.5 m AOD and indicated groundwater flow is to the northeast towards Minsmere-Walberswick Heaths and Marshes SSSI. The western edge of the Marshes (and nearest watercourse) is approximately 700 m from the north-eastern edge of Area 2. The nearest groundwater abstraction (private unlicensed well) is located at Plantation Cottages (00/00492/PWWELL), approximately 250 m northeast and downgradient of Area 2.

From analysis of long-term hydrographs and modelled maximum groundwater levels, a minimum base level of excavation of approximately 5.2 m AOD (average excavation depth of 7.8 m below existing ground levels) is proposed to give a minimum of 2 m above the high groundwater level (**Table 4.3**).

Area 3. This area is located to the north of Ash Wood and covers an area of 10.77 ha. Ground levels vary from 11.3 m AOD on the northeastern edge and rise to 17.2 m AOD on the southwestern edge of the area. The average ground level is about 14 m AOD.

The area is underlain by sand and gravels which overly the Crag (**Figure 4.6**). The borehole logs for CPB_BP7 and CPB_BP9 confirm that drift deposits are largely absent in this area, except below the higher ground in the south-west corner of this field.

Groundwater levels measured in March 2015 in boreholes BP6, BP7 and BP9 ranged from 1.8 m to 2.1m AOD and indicate that groundwater flow is to the east/east north-east towards Minsmere-Walberswick Heaths and Marshes SSSI. The western edge of the Marshes (and nearest watercourse) is approximately 440 m from the eastern edge of Area 3. The nearest groundwater abstraction (private unlicensed well) is located at Ash Wood

Cottage (00/00494/PWWELL), approximately 220 m south of Area 3. This private well is not downgradient of this area.

From analysis of long-term hydrographs and modelled maximum groundwater levels, a minimum base level of excavation of approximately 5.2 m AOD (average excavation depth of 8.8 m below existing ground levels) is proposed to give a minimum of 2 m above the high groundwater level (Table 4.3).

Area 4. This area is located to the west of Ash Wood and covers an area of 4.60 ha. Ground levels range from 17.5 m AOD on the northern and western edge of this area and fall to between 15.5 m AOD on its southern and eastern edge. The average ground level is about 17 m AOD.

The area is underlain by Diamicton Clays (typically 2 to 3m thick) which overly sand and gravels and the Norwich Crag. Borehole C6 located on the western edge of Area 4, identified a clay lens from 14 to 19 m depth. This lens is not considered to be laterally continuous and was not encountered in borehole CPB_BP11 located in the centre of Area 4.

Groundwater levels measured in March 2015 in boreholes BP6 and BP7 ranged from 1.8 to 2.1m AOD and indicate that groundwater flow is to the east/east northeast towards Minsmere-Walberswick Heaths and Marshes SSSI. The western edge of the Marshes (and nearest watercourse) is approximately 900 m from the eastern edge of Area 4. The nearest groundwater abstraction (private unlicensed well) is located at Ash Wood Cottage (00/00494/PWWELL), approximately 370 m east and downgradient of this area.

The proposed depth of excavation for Area 4 is approximately 8 m, indicating that the base of excavation will be over 6 m above the modelled high groundwater level (**Table 4.3**).

4.10 Land Quality

Introduction

This section provides a description of the land use history at the borrow pit locations and also in the footprint of the proposed SZC cut-off wall, where the backfill materials will be obtained.

Current and Historical Land Use

The broad area identified for the borrow pits is currently occupied by arable farmland with a rural highway running north-south located to the west of Area 2. Historical mapping, presented in the Wood (2010) desk based assessment shows that land use in the footprint of these areas has remained unchanged since 1883.

Between 1884 and 1971, land in the vicinity of the current Sizewell B and proposed SZC development site consisted of low-lying farmland and marshland, traversed by a series of drainage ditches. Land currently occupied by Sizewell B was used for storage of materials and placement of spoil during the construction of Sizewell A in the 1960s. Subsequently, materials excavated during construction of Sizewell B during the 1980s and 1990s were used to infill the area of land identified for SZC power station construction. Hence, ground in the footprint of the proposed SZC cut-off wall contains some potentially contaminated Made Ground, together with re-worked and natural beach deposits, alluvium and Crag.

Future Land Use

When the construction phase has been completed, the borrow pits will be reprofiled to facilitate surface water drainage and the land will return to agricultural use or heathland. On completion of infilling, up to 3 m of granular material will be placed over the pits to allow for settlement and reprofiling.

Land Use in Surrounding Areas

Land use in the vicinity of the borrow pits is predominantly agricultural and has shown little change since 1883 (earliest historical map presented in the Wood desk study report (2010).

Buildings associated with Potters Farm are present at the southern perimeter of Area 2 (The Round House). An area of woodland named Ash Wood is present to the south of Area 3. An area of heathland/rough grazing named Black Walks is located east-northeast of Area 2. The village of Eastbridge, with a mixture of farms and residential properties is located approximately 500 m north of the northern boundary of Area 2. Theberton House and associated farm buildings are located approximately 900 m west-southwest of the boundary of Area 2.

Sensitive Land Uses and Designations

The borrow pits are located within an area designated as a Nitrate Vulnerable Zone (NVZ) that covers a large area of East Suffolk. Areas 2, 3 and 4 are located within the Suffolk Coast Area of Outstanding National Beauty (AONB).

The boundary of the Minsmere-Walberswick Heaths & Marshes SSSI is located approximately 420 m east of the northern boundary of Area 3 at its nearest location. Further to the north, land within Minsmere-Walberswick Heaths & Marshes SSSI is designated as a Ramsar site, a Special Area of Conservation (SAC) and a Special Protection Area (SPA). A further SSSI (Sizewell Marshes) is located 1.1 km east-southeast of Area 3. There are no groundwater Source Protection Zones (SPZs) within 500 m of the borrow pit boundaries.

There are no current or historical landfill sites, licensed waste management/ transfer facilities, trade directory entries, discharge consents or pollution prevention and control sites within 500 m of the borrow pit boundaries.

5. Characterisation of Backfill Materials

This section has not been updated from the 2016 Risk Assessment. It describes the physical and chemical properties of the backfill material for the borrow pits.

5.1 Nature of Deposits

The construction programme for SZC requires excavation of a large volume of material within the area of a hydraulic cut-off wall which will encompass the proposed power station footprint. The nature of the materials within the footprint of the cut-off wall has been subject to several intrusive investigations (Structural Soils, 2009) and is summarised by Jacobs (2010). Further information, particularly relating to chemical quality was obtained during the Phase 2 Land Quality investigation (Wood, 2012a). The properties of the alluvium have also been investigated in relation to potential re-use of these materials for habitat creation (ADAS, 2010).

The ground model prepared by Jacobs summarised the geological sequence within the cut-off wall as Made Ground, Beach Deposits, Alluvium (comprising peat, clays and silts) and Crag. Where possible, materials excavated from within the cut-off wall will be re-used for construction purposes, it is expected that approximately 1.1 Mm^3 of alluvium that could be used to backfill the borrow pits.

Within the cut-off wall, the alluvium is comprised of multiple, interbedded layers of peat and peaty clays and silts ranging from 0.5 to 5.0 m thickness, although in some areas a single layer of peat or organic clay is present. However, excavations for heathland trials (ADAS 2009, 2010) found that the peat typically occurred as discontinuous lenses within the alluvium. The total thickness of the alluvium varies from a maximum of 8.8 m to being absent in areas where Made Ground/Beach Deposits directly overlie the Crag. The peat is described as soft to firm and dark brown and present in both fibrous and amorphous forms. The organic clay is described on borehole logs as very soft to firm, dark brown to black organic clay or silty clay (ADAS 2009, 2010).

Jacobs (2010) provided the following estimate for the composition of the materials within the cut-off wall:

- Peat – 38%;
- Organic clay and peat/clay mix – 31%;
- Clay – 19%; and
- Silt/Sand – 12%.

5.2 Physical and Geotechnical Properties

A summary of the physical and geochemical properties of the alluvium, based on earlier intrusive investigations was presented by Jacobs (2011) and reproduced in this report as **Table 5.1**.

In situ Testing

This section provides a summary of the in-situ geotechnical tests that have been undertaken on the alluvium.

One Standard Penetration test (SPT) was carried out on peat, which gave an N value of 2. According to the correlation postulated by Stroud (1974), this equates to an undrained shear strength of 10 kPa (very soft clay).

Two SPTs on clay gave N values of 2 and 9, equating to undrained shear strengths of 10 kPa (very soft) and 40 kPa (soft/ firm).

A total of 45 hand penetrometer tests were performed on samples of peat recovered from the boreholes, which gave shear strength values of between 25 kPa and 90 kPa (mean 55 kPa), indicating soft to stiff material, with the mean falling within the firm range.

A total of 22 hand penetrometer tests were performed on clay, which gave shear strength values of between 10 kPa and 60 kPa (mean 33 kPa), indicating very soft to firm clay, with the mean falling within the firm range.

Nineteen hand shear vane tests were carried out on peat, giving shear strength values of between 4 kPa and 141 kPa (mean 43 kPa), indicating very soft to stiff material, with the mean falling within the firm range.

Seven hand shear vane tests on clay gave shear strength values of between 15 kPa and 59 kPa (mean 33 kPa), indicating very soft to firm clay, with the mean falling within the soft range.

Laboratory Tests

A total of 96 Moisture Content and Atterberg Limit tests were completed on clay and peat. The results are summarised in **Table 5.1** below:

Table 5.1 Results of Atterberg Limit Tests – Structural Soils, 2009

Material	No. of Tests	Moisture Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
Peat	52	Min 140	Min 146	Min 98	Min 14
		Max 390	Max 653	Max 618	Max 262
		Mean 305	Mean 399	Mean 289	Mean 110
Clay	44	Min 44	Min 47	Min 25	Min 18
		Max 300	Max 487	Max 321	Max 166
		Mean 104	Mean 126	Mean 61	Mean 64

Eighteen samples of peat were subjected to one-dimensional consolidation tests, which gave co-efficient of volume compressibility (m_v) values of between 0.78 m^2/MN and 2.1 m^2/MN (mean 1.53 m^2/MN) for the 100-200 kPa pressure increment. The results indicate material of high to very high compressibility, with the mean falling within the very high compressibility range.

The tests also gave co-efficient of consolidation (c_v) values of between 0.28 m^2/year and 42 m^2/year (mean 6.43 m^2/year).

Seven consolidation tests were carried out on samples of clay, giving m_v values of between 0.56 m^2/MN and 0.97 m^2/MN (mean 0.81 m^2/MN) for the 100-200 kPa pressure increment, indicating clay of high compressibility. The tests gave c_v values of between 0.32 m^2/year and 1.7 m^2/year (mean 0.88 m^2/year).

The undrained shear strength of 15 peat samples was determined by a single-stage undrained triaxial test. The tests gave undrained shear strengths of between 6kPa and 80kPa (mean 37kPa). The results indicate very soft to stiff material, with the mean falling within the soft range.

Five undrained triaxial tests on organic clay gave results of 11kPa and 55kPa (mean 33kPa), indicating very soft to firm clay, with the mean falling within the soft range.

Triaxial testing was only carried out on samples from boreholes located close to the western boundary of the SZC development footprint area, with the higher shear strength values obtained from samples taken from the south-west corner of the site.

A summary of geotechnical design parameters, based on the results of the previous intrusive investigations, was presented by Jacobs (2011) and reproduced in this report as **Table 5.2**.

Table 5.2 Geotechnical design parameters from Jacobs, 2011

Strata	Bulk Unit* Weight kN/m^3	Hydraulic Conductivity (m/s)	Earth Pressure Coefficient Ko	Angle of Shear	Apparent Cohesion kN/m^2	Elastic Modulus MN/m^2
Alluvial Clay	16	1×10^{-9}	0.58	25	0	4.5
Peat	14	1×10^{-7}	0.5	30	0	4

* Bulk unit weight (kN/m^3) is equivalent to bulk density; dividing bulk unit weight by ten gives bulk density in Mg/m^3.

Table 5.2 provides an indication of two parameters of relevance to the assessment of potential risks to Crag groundwater, namely the bulk density and hydraulic conductivity. Both the alluvial clay and peat were considered to be relatively low permeability materials by Jacobs.

An intrusive investigation in 2008 (Structural Soils, 2009) reviewed by Jacobs (2010) contained further detail on the physical and geotechnical properties of the alluvium. This investigation included a total of 23 consolidation tests on samples from the site, results of which are summarised in **Table 5.3**. The soils data in Structural Soils (2009) was used to calculate total porosity, air filled porosity and water filled porosity using the "porosity calculator" function in Environment Agency's Remedial Targets Worksheet (Environment Agency, 2006).

Table 5.3 shows the considerable differences in moisture content between samples of peat and samples of clayey material. In addition, a comparison of the pre-test and post-test data provides a basic indication of the degree of compaction that the material could undergo when placed in the borrow pits; compaction testing and field trials would be required to provide a more robust assessment.

Table 5.3 Summarised Moisture Content, Bulk Density and Porosity Data

	Parameter	Units	Prior to Consolidation Test			After Consolidation Test		
			Min	Mean	Max	Min	Mean	Max
Peat Soils (18 samples)	Moisture content	%	102	309	510	59	144	211
	Bulk density	Mg/m^3	0.96	1.08	1.32	1.17	1.32	1.60
	Dry density	Mg/m^3	0.17	0.30	0.66	0.38	0.57	1.00
	Total porosity	fraction	0.76	0.89	0.94	0.64	0.81	0.96
	Air-filled porosity	fraction	0.04	0.11	0.29	0.000	0.05	0.09
	Water-filled porosity	fraction	0.57	0.79	0.88	0.590	0.75	0.82

	Parameter	Units	Prior to Consolidation Test			After Consolidation Test		
			Min	Mean	Max	Min	Mean	Max
Clay Soils (5 samples)	Moisture content	% wt/wt	52	80	112	33	56	79
	Bulk density	Mg/m^3	1.30	1.49	1.66	1.53	1.70	1.88
	Dry density	Mg/m^3	0.62	0.85	1.10	0.85	1.10	1.41
	Total porosity	fraction	0.60	0.70	0.78	0.49	0.60	0.69
	Air-filled porosity	fraction	0.03	0.05	0.08	0.00	0.01	0.03
	Water-filled porosity	fraction	0.57	0.65	0.69	0.47	0.59	0.67

5.3 Chemical Properties of the Alluvium

An intrusive investigation in 2009 (ADAS 2009, 2010) to characterise the alluvium within the SZC cut-off wall footprint. A total of 51 soil samples from 18 boreholes were subject to laboratory analysis. The location of these boreholes is shown in **Appendix F** of this document and indicates good coverage across the SZC power station development footprint.

The analytical suites focussed on identification of available nutrients (e.g. nitrogen, phosphorous and potassium), indicators of salinity (e.g. sodium, chloride and conductivity), acidity generation potential (e.g. pH, pyritic sulphur and total iron) and metals (e.g. copper, zinc, mercury etc.). The data discussed by ADAS were provided in raw form in Structural Soils (2009) (some transcription errors have been identified in the ADAS reports and these have been corrected in this report). Structural Soils (2009) also included additional results of soil testing (82 samples, including the 51 obtained for ADAS) and leaching tests (27 samples from 8 boreholes).

A subsequent study (ADAS 2010) included a further ten soil samples, five each from peat and organic clay materials. In addition to soil samples, this investigation also reported on leachate quality (parameters relating to salinity and acidity generating potential) from soil plots which had been amended by addition of peat derived from the SZC power station development footprint (within the proposed cut-off wall).

The Wood land quality investigation (Wood, 2012a) included data from a large number of soil samples within the footprint of the SZC cut-off wall, however the vast majority of these samples were taken from Made Ground and materials overlying the alluvium. Seven soil samples from this investigation were available to support the assessment of the chemical properties of the alluvium presented below.

Indicators of Salinity (Chloride, Sodium and Sulphate)

A summary of the soils data obtained by Structural Soils (2009) and reported by ADAS (2009) is presented in **Table 5.4**. This table shows that samples from all three types of soil contained high levels of sodium and chloride. Median concentrations of chloride from all three soil types exceeded the DWS of 250 mg/l, indicating a potential risk to groundwater quality in the Crag. A more detailed review of the chloride data shows that samples obtained from boreholes in the western part of the SZC power station development site were lower (30 to 1 100 mg/l) and samples from the eastern part higher (typically greater than 2 000 mg/l).

Table 5.4 Indicators of Salinity, Reported by ADAS, 2009

Soil Type	**Sodium (mg/kg)**			**Chloride (mg/l)**		
	Min	**Median**	**Max**	**Min**	**Median**	**Max**
Peat (Fibrous)	440	680	3300	91	2750	4100
Peat (Amorphous)	380	1500	18000[a]	30	1400	6800
Peat/Clay mix	300	510	3500	62	1155	2900
Combined dataset	300	730	18000[a]	30	1900	6800

Notes a) Based on distribution of data, result appears to be anomalous.

The data presented in **Table 5.4** should be compared to values for the same parameters obtained during the 2010 investigation (**Table 5.5**). Although taken from a much smaller number of samples, the 2010 data shows comparable concentrations of sodium and chloride to the 2009 data.

Table 5.5 Indicators of Salinity, Reported by ADAS, 2010

Material	**Available Sodium (mg/l)**			**Water Soluble Chloride (mg/kg)**			**Available Sulphate (mg/l)**		
	Median	**Mean**	**Std. Error**	**Median**	**Mean**	**Std. Error**	**Median**	**Mean**	**Std. Error**
Peat only	1950	1934	251	4080	3995	381	1740	2647	762
Peat/clay	4718	4087	420	5700	5688	589	3689	3592	679

In **Appendix G** of this document, distribution plots for the soil analyses for sodium, chloride and sulphate are presented and this information has been used to help define the source term characteristics for the risk assessment (Section 8).

During the heathland creation trials, ADAS also recorded the quality of water leaching from the trial plots, on a monthly basis from September 2009 to March 2010. During this time period, chloride concentrations in drainage from the plot amended by peat soils declined from approximately 2200 mg/l to approximately 1100 mg/l. Chloride concentrations in drainage from the plot amended by peat soils declined from approximately 1500 mg/l to 1400 mg/l during this period. Plots of the variation in leachate quality with time are presented in **Appendix G** of this document. Monitoring over the five-month period, showed that sulphate concentrations in drainage were high (3000 to 4000 mg/l) with no evidence of a decrease in concentration. An earlier study (Davy et al, 1998) undertaken in the 1990s by the University of East Anglia observed similar behaviour for leaching of sulphate from peat. Two experiments were carried out in which leachate quality was monitored over a five year period. In the first experiment, sulphate concentrations in drainage water were high (about 7500 mg/l) during the first 6 to 12 months before declining to less than 500 mg/l over the remainder of the 5-year study period. In the second experiment, sulphate concentrations were again initially high (about 2000 mg/l), but then fell to less than 100 mg/l.

Analysis of the data obtained by ADAS indicated that alluvium in the footprint of the cut-off wall have the potential to generate saline leachate. High concentrations of sodium and chloride appear to be present throughout the volume of potential backfill materials with some indication of higher concentrations in the north and east (i.e. near to the boundaries with Sizewell Drain and the coast). Soils data for sulphate are expressed in different units (%, mg/kg, available as mg/l) in the findings of previous studies and in some cases there is inconsistency in the data and therefore only the data reported at mg/l have been used for this study.

Leachate Tests

Leaching tests in accordance with the NRA protocol (NRA, 1994) were undertaken on 27 samples of alluvium for pH, cyanide, heavy metals, sulphate and organics (volatile organic compounds (VOC), semi-volatile organic compounds (SVOC), polycyclic aromatic hydrocarbons (PAH), total petroleum hydrocarbons (TPH) and phenols). The results for inorganic substances are summarised in **Table 5.6**.

Table 5.6 Summary of Leaching Test Results for Inorganics

Determinand	Number of samples and (Detects)	Concentration		
		Min	Max	Mean
pH	27	6.31	8.69	
Sulphate (mg/l)	19 (18)	<3	180	50
Arsenic (µg/l)	27 (25)	<1	46	11
Boron (µg/l)	27 (25)	<20	1500	340
Cadmium (µg/l)	27 (0)	<0.22	<0.22	<0.22
Copper (µg/l)	27 (22)	<1	11	4
Lead (µg/l)	27 (26)	<0.4	58	4
Nickel (µg/l)	27 (14)	<1.5	120	6
Selenium (µg/l)	27 (17)	<1	5	2
Vanadium (µg/l)	27 (23)	<1	140	36
Zinc (µg/l)	27 (23)	<5	100	26
Mercury (µg/l)	27 (3)	<0.01	0.02	0.01
Cyanide (mg/l)	27 (0)	<0.05	<0.05	<0.05

Leaching test results are also available for shallow peat samples obtained as part of an investigation at Aldhurst Farm (about 2 km to the south). These tests gave very similar results to those provided in **Table 5.6**.

Concentrations of cadmium, cyanide, VOC, SVOC and phenol greater than detection limits were not recorded from leachate analysis. TPH was recorded at concentrations greater than the laboratory detection limit in only one of the leachate samples (total aliphatic TPH 340 µg/l). Three concentrations of mercury marginally greater than the detection limit were reported.

Low levels of PAHs were detected in some samples (**Table 5.7**) although typically concentrations were below detection limits (<22 ng/l). Given the organic nature of the deposit the detection of low levels of PAHs is expected and is attributed to natural rather than anthropogenic origin.

Table 5.7 Summary of Leaching Test Results for PAHs

PAH	Number of Samples and (Detects)	Concentration (ng/l)		
		Min	Max	Mean
Fluoranthene	27 (11)	<17	140	24
Phenanthrene	27 (7)	<22	230	27
Pyrene	27 (12)	<15	170	30
Chrysene	27 (5)	<13	36	14

NB Single detects (exceedance of laboratory limit of detection) also recorded for Acenaphthylene, Anthracene, Benzo(a)anthracene, Benzo(b)fluoranthene, Benzo(a)pyrene, Benzo(ghi)perylene, Indeno(123cd)pyrene and Fluorene.

Leaching of Peat and Acid Generation Potential

Under anaerobic conditions the pH of peat is neutral, but on exposure to the atmosphere, oxidation of pyrite can lead to the release of sulphate, iron and an increase in acidity. The results of the ADAS borehole investigation (ADAS 2009, 2010) concluded that the alluvium has the potential for generating acid leachate, on account of high recorded concentrations of pyritic sulphur.

The ADAS study did not identify any trends in acid generation potential over depth at which the samples were obtained or the pH of the samples. Additionally, pyritic sulphur was recorded in soil samples from both peat types (fibrous and amorphous). ADAS concluded that the acid generation potential of the peat would facilitate its use for creation of heathland habitats; however, the range of pyritic sulphur concentrations across the site resulted in the assumption by ADAS that the rate and extent of acidity generation would also be variable.

In 2010, ADAS undertook a trial in which peat from the site was incorporated into farmland soils in an attempt to create conditions amenable for the creation of heathland habitat. As part of this study, soil samples from the extracted peat and trial plots were taken prior to incorporation. Data for indicators of acid generation potential were consistent with those from the 2009 borehole investigation.

Following incorporation of peat and organic clays, ADAS monitored the pH of topsoil in the trial plots on a monthly basis from September 2009 to March 2010. During this period, the pH in plots where peat was incorporated declined from pH 6.0 to values in the range of pH 3.0-3.3 (**Appendix G** of this document); the data also indicate a delay of several weeks before soil pH changes occurred. The pH of topsoil in plots in which the peat-clay mix was added decreased from pH 6.0-7.0 to pH 5.0-6.0. It was concluded that the mineral fraction of the peat-clay mixture acted to buffer the pH to an extent, however it was unclear whether pH would stabilise in the pH 5.0-6.0 range, or would subsequently decline to levels recorded in the plot in which peat only was incorporated.

During the same monitoring period, the quality of drainage water leaching at a depth of 0.9 m below the trial plots was also recorded. The pH of drainage water from the peat-clay trial plots was found to be relatively stable during the period December 2009 to March 2010, following which an increase to more neutral/alkaline conditions was observed. The pH of drainage water from the peat plot was >5.0, compared to around 3.0 in the overlying soils, suggesting that some attenuation had occurred in the soil pore water. Over time the pH value of the drainage rose to above 5.5.

As part of the Aldhurst Farm habitat creation scheme, peat was excavated and placed on adjoining fields with the objective of creating heathland habitat. Monitoring of the receiving soils also provided evidence that there can be a delay for oxidation of pyrite to occur following material deposition and incorporation.

Evidence for Anthropogenic Contamination

As part of the Phase 2 land contamination assessment, Wood (2012a) undertook an extensive programme of soil sampling in the footprint of the proposed cut-off wall. Seven samples were obtained from materials within the peat or organic clay horizons. These samples were analysed for concentrations of the following substances:

- Metals: arsenic, cadmium, chromium, lead, mercury, nickel, copper, zinc, selenium, hexavalent chromium and water soluble boron;
- pH, sulphate, total cyanide, sulphide and elemental sulphur;
- PAH;
- TPH; and
- Total monohydric phenols;

The main observations from a review of the data are:

- Of the substances listed above, concentrations of cadmium, mercury, hexavalent chromium, total cyanide and total monohydric phenols were not recorded at concentrations greater than detection limit in any samples. PAHs were not recorded at concentrations greater than the laboratory detection limit in three out of the seven samples. Additionally, ten out of the 16 PAH substances tested were below detection limit in all seven samples. In samples where PAHs were present, the margin by which the detection limit was exceeded was minimal (maximum concentration 0.2 mg/kg, compared to detection limit <0.1 mg/kg). TPH concentrations in these seven samples ranged between 0.4 and 6.2 mg/kg. Generally, the heavier (higher molecular weight) TPH fractions (>C12) were present at concentrations greater than detection limit;
- Concentrations of metals recorded during the Phase 2 contaminated land assessment were generally within the ranges of values recorded by the ADAS borehole investigation, which had a much greater number of samples. The exceptions to this were for chromium and lead, where the maximum concentrations recorded during the Wood contaminated land investigation were marginally higher than the equivalent values recorded by ADAS;
- Data obtained during the Wood Phase 2 land contamination investigation do not show that the alluvium in the footprint of the cut-off wall are negatively impacted by potential contaminants. The low concentrations of PAH may represent natural levels in alluvium. The same applies for some substances that fall within TPH fractions, however leaching from Made Ground overlying the alluvium may also be responsible for low levels of TPH in the alluvium. Further assessment of potential risks to human health is presented in Section 8.

Comparisons with Groundwater Quality

Soil testing and the results from heathland creation trials have shown that the concentrations of chloride, sodium, sulphate and iron in drainage from the alluvium can be high with concentrations exceeding DWS or EQS. However, the comparatively low concentrations of these substances in groundwater samples from the vicinity of the proposed SZC power station excavation footprint (where alluvium is currently in-situ) suggest that if the alluvium remains anaerobic then the concentrations of iron and sulphate are likely to be low and below relevant water quality standards.

Concentrations of mercury and cadmium were at or below detection limits in leachate samples, which was consistent with the data from the groundwater monitoring campaigns in the SZC excavation area. Concentrations of organic compounds (e.g. TPH and PAH) in leachate were also consistent with groundwater data, suggesting that the alluvium is not currently having an adverse impact on groundwater quality in the current location of the alluvial deposits.

Summary

Soil and leaching tests of the alluvium has shown that the material is characterised by low concentrations of heavy metals and some organic compounds. PAHs were detected at very low concentrations (<0.25 µg/l, but more typically <0.03 µg/l) in some samples (**Table 5.7**), and these are likely to reflect naturally occurring levels.

The salinity of the alluvium can be high, particularly in the eastern part of the SZC power station footprint excavation area where groundwater is influenced by proximity to the sea and also brackish water in Sizewell Drain. In this area chloride concentrations are typically greater than 2000 mg/l, but in the western area concentrations range from 50 to 1200 mg/l.

Under in-situ anaerobic conditions, the pH of the alluvium is neutral and sulphate concentrations in drainage are low (typically less than 100 mg/l as indicated by leaching tests and groundwater monitoring) but on exposure to the atmosphere, oxidation of pyrite occurs, leading to increased concentrations of iron and a reduced pH in the resulting leachate. Experiments (ADAS 2009, 2010) undertaken to assess the potential to create heathland using excavated peat have shown that drainage is initially characterised by low pH, high sulphate and high chloride concentrations, but with time sulphate and chloride concentrations decrease.

A longer-term trial by University of East Anglia (Davy et al, 1998) showed that over a 5 year period sulphate concentrations can be expected to decline. After placement the concentrations of chloride and sodium in water draining from the peat would be expected to decline as a result of flushing by rainfall (Section 8.4). Concentrations of sulphate may decline more slowly as a result of oxidation of the pyrite (conservative assumption), but in practice this would be countered by a change to anaerobic conditions within the borrow pit backfill that would prevent further oxidation.

5.4 Effects of Excavation and Compaction

This section provides a qualitative overview of the influence of excavation and then placement of the alluvium on its physical and chemical properties. No account is given to the proposed treatment of the backfill with lime which is discussed in Section 6.1.

The alluvium will be excavated over two consecutive summers, with the material transported directly to the borrow pits where it will be placed and compacted. The material will not be stockpiled unless weather conditions prevent working of the material (e.g. waterlogged conditions during heavy and persistent rainfall events). Observations during drilling and excavations for the heathland creation trials indicate that it will not be feasible to separate the peat and clay and the placed material will represent a mixture of the two with the likelihood that the peat will be present as pockets within the placed alluvium.

Testing of the clay has indicated that it is characterised by a low hydraulic conductivity (~10^{-9} m/s) and this is likely to control infiltration and drainage through the mass of placed material (Section 8). The peat is characterised by a high moisture content (**Table 5.3**), however, dewatering prior to excavation will aid drainage of the material, but there is the potential for water to be squeezed out from the peat as the material is placed and then compacted, although drainage pathways are likely to be short and discontinuous. Compaction of the alluvium, together with the break-up of the more permeable zones as a result of excavation is likely to result in a net reduction in hydraulic conductivity of the backfill compared to current in-situ conditions.

On completion of infilling of the borrow pits, EDF Energy also propose to place up to 3 m of granular material to allow for settlement of the alluvium and to facilitate reprofiling, drainage and restoration of the backfilled void. EDF Energy has also considered the potential to use the infilled borrow pits as a temporary stockpile area. Placement of this material will have the potential to induce some compaction and settlement of the area and the squeezing out of pore water. This issue is considered further in Section 8.4.5.

Testing of the alluvium has shown that under anaerobic conditions the pH of the material is neutral and that the sulphate and iron concentrations in drainage would be expected to be low. On exposure to the atmosphere, which could occur during excavation and initial placement of the alluvium, the acidity and concentrations of sulphate and iron in drainage could increase. Data from the heathland trials and from Aldhurst Farm indicate there can be a delay for oxidation of peat to occur which would be of significance to the potential for increase in leachate acidity during the infilling of the borrow pits.

There are some important differences between the heathland creation trials and the proposed backfilling operation which require consideration in the context of the predicted behaviour of the material during bulk excavation and placement in the borrow pits. These are:

- The heathland creation trials involved selection of peat or peat/clay for incorporation into soils within the surface trial plots. This process will have maximised the potential for exposure to atmosphere. For the backfilling operation, the risk of exposure of the deposited materials to the atmosphere will be reduced by minimising handling of the material and by placing the excavated material directly into the pits. The mixed nature of the clay/peat material together with the progressive infilling of the void is also very likely to create an anaerobic rather than aerobic environment;

- It is proposed that the alluvium will be allowed to drain into the underlying Crag within the cut-off wall prior to excavation. This is desirable as it will avoid introducing large volumes of leachate from the alluvium directly into the Crag aquifer and will also reduce the weight of the materials being transferred. However, draining these materials will result in a degree of exposure of the exposed peat to the atmosphere, encouraging oxidation of pyrite and generation of acidity to occur;

- The heathland creation trials involved targeted selection of peat and organic clays which were then blended with existing topsoil under relatively controlled conditions. Given the heterogeneous nature of the alluvium, it is likely that the physical and chemical properties of the backfill materials could vary considerably on a load-by-load basis. Therefore, it will be necessary to backfill the borrow pits in a manner that accounts for these variations in fill properties, in order to avoid creating areas of waterlogged/unstable ground, uneven landforms or preferential pathways to the Crag aquifer. This will be facilitated by excavating the alluvium from multiple working areas to create a mix of materials for backfilling the borrow pits; and

- Compaction of the backfill materials in the borrow pit will result in an initial release of pore water that did not drain prior to excavation. However, in the longer term, compaction will reduce the rate of infiltration, increasing the potential for dilution and buffering to occur within the underlying Crag groundwater.

In summary, it is anticipated that drainage rates from the backfill will largely be controlled by the permeability of the clay as the peat layers will be disrupted by excavation and then placement of the material. Some squeezing out of pore water from the peat might be expected as a result of compaction in the first 1 to 2 years, but this will be limited as drainage pathways will be short and discontinuous.

It is likely that drainage from the backfilled material will initially be characterised by low pH, high sulphate, iron, chloride and sodium but that with time (years) concentrations will decrease as the initial mass of these substances is depleted. In addition, it is reasonable to assume the bulk mass of placed material will become anaerobic, oxidation of pyrite will cease and that the drainage will become neutral in pH and sulphate and iron concentrations decrease.

Treatment of the backfill with lime to improve its handling properties will affect the rate and quality of the drainage and this is considered in Section 6.3.

6. Geotechnical Assessment

This section has been updated from the 2016 Risk Assessment to account for the revised footprint of the borrow pits, and to include a geotechnical risk register. It describes the geotechnical properties of the alluvium and assesses the benefits from lime stabilisation.

6.1 Introduction

This section provides a brief overview of potential geotechnical issues to be considered with respect to the use of the peat and alluvium as backfill for the borrow pits.

The peat and alluvium have contrasting geotechnical properties but ground investigations indicate that the peat exists as non-uniform lenses within the peaty/ organic clay and silt matrix. It would be difficult, costly and time consuming to segregate the material into different fractions during bulk excavations for the purposes of selective backfilling. In any case, an assessment of available laboratory testing carried out on the material indicated the following key characteristics:

- Low Shear Strength;
- High Compressibility; and
- High Liquid and Plastic Limit.

Although no compaction testing has yet been attempted on the material, from the above assessment it could be reasonably surmised that the engineered placement of such material would be problematic, particularly if the material became too wet. It may not be feasible to effectively compact the material, and once placed it may be subject to rutting and/or the bogging down of earthworks plant.

It is understood that prior to the commencement of bulk excavations into the alluvium within the cut-off wall drains will be cut through the alluvium to allow the material to further dewater by draining to the underlying Crag. This will allow improved workability of the material if the moisture content is below the Plastic Limit. However, the workability of the material is dependent upon its Liquid limit and Plasticity Index, rather than its moisture content at any given time. The Liquid Limit of the material is sufficiently high that if the material were to become wet, there would be a large increase in moisture content and the material would become unresponsive to compaction and become increasingly unworkable as the moisture content approached the Plastic Limit.

From the above, it is clear that, without mitigation, the feasibility of using the material as fill would depend greatly on prevailing weather conditions and conditions within the borrow pit. A period of wet weather could result in an increase in moisture content of the material, rendering it unworkable. If this were to occur within the borrow pit, it would be difficult to dry the material and could sterilise an area of filling for a prolonged period. This would have implications on programme, cost and the safety of the works. To mitigate these concerns, it has been decided to utilise lime improvement technologies to increase the workability of the material during placement. Further details are provided in Section 6.2. To date, no further investigation has been undertaken to provide information relating to the amenability of the alluvial materials to lime improvement, and the design of the treatment programme. As such, the advice provided in the 2016 Risk Assessment, with respect to further characterisation of the alluvium and lime improvement trials, remains in effect (Section 9).

It is proposed that following the backfilling of the borrow pits, they will be capped with up to 3 m of overburden to allow for re-profiling, settlement and restoration to agricultural use or heathland creation. This is a non-sensitive use with respect to geotechnical issues and would be an appropriate end-use for the borrow pit footprint. In addition, it is proposed to use the backfilled borrow pits as a site for stockpiling materials, with a maximum stockpile height of 5m, for a period of up to 8 years. An allowance would have to be made for settlement of the material due to self-weight compression and surcharging as a result of the placement of overlying materials following backfilling of the void. However, if the backfill materials are subjected to lime improvement then the degree of compaction that can be imparted to the backfilled material during placement will be greatly increased. It can therefore be reasonably surmised that the subsequent settlement will be much reduced.

6.2 Lime Stabilisation

A feasibility study for backfilling the borrow pits was undertaken by Costain (2015) and concluded that in order to facilitate the backfilling operation and to improve the handling properties of the alluvium, lime should be added and rotavated into the backfill. In summary the backfilling operation will comprise placement of the alluvium in 0.2 to 0.3 m layers, the addition of lime (at a 2 to 4% ratio), rotavation of the lime into the alluvium, and leaving the treated material for a minimum of 24hrs before placement of the next layer. A review of this process is included in **Appendix H** of this document.

The soft compressible nature of the alluvial material indicates that when wet it cannot easily be trafficked by conventional earthworks plant. Whilst Costain has proposed pre-draining the alluvium in the Main Construction Area (MCA), i.e. within the cut-off wall footprint as much as possible, it is still expected that the alluvium will be wet on excavation, as it has poor drainage properties. It will not be practical to dry the material out in the borrow pits given the time frame for infilling.

As a result, Costain has considered that the nature of the material and its inability to support conventional earthworks plant represented a significant constraint and a safety hazard; and therefore, carried out an options appraisal for different methods of placing the material as backfill. The following options were considered:

- Filling with untreated peat – end tip alluvium and push out with long range excavators;
- Causeway method – as above but placement via a network of causeways of material left *in situ;*
- Conveyor system – Placement via a network of conveyors;
- Cell method – place material in discrete bunded and capped cells;
- Lime treatment – *ex situ* treatment of material to improve workability and allow greater degree of compaction.

Overall, Costain concluded that this option would be the most preferable in terms of meeting EDF Energy's requirements. A review of the proposed lime treatment is presented in **Appendix H** of this document.

The chosen methodology to be adopted is lime modification, which works through rapid physico-chemical reactions between the clay and lime minerals, producing immediate changes in soil plasticity. This differs from lime stabilisation, which is a more long term pozzolanic reaction resulting in the formation of cementing agents.

As well as the drying effect caused by the addition of lime (the effect is increased if quicklime is used as the additive), the initial reactions cause significant changes in the engineering properties of the soil. These changes, identified below, usually occur at lime contents of 2% to 4%, although this also depends on the efficiency of mixing:

- Plastic Limit increases, making the soil appear drier. In clay dominant soils the Liquid Limit also reduces; but increases in silt dominant soils. Due to the silt/clay mixtures typical of soils in the UK there is often little net change in the Liquid Limit;
- Clay clods become easier to break down and the soil becomes looser and more friable, improving workability;

- The Optimum Moisture Content (OMC) increases;
- Maximum Dry Density (MDD) is reduced for a given compactive effort;
- Compaction curve becomes flatter, meaning that good densities can be achieved across a wider moisture content range;
- Undrained shear strength and California Bearing Ratio (CBR) increase;
- Soil becomes less susceptible to moisture softening and shrink/swell. and
- Reduction in the amount of leachate produced, as moisture will be absorbed during the hydration process, remaining leachate will also be less acidic in nature.

The above effects all combine to aid bulk earthworks of soft, plastic, cohesive soils. As well as increasing the mobility and safe operations of plant, the stability of the soil will increase and it will be less vulnerable to weather conditions.

Whilst lime improvement is feasible for organic soils (high organic content can hinder lime stabilisation, but does not affect the Lime Improvement process), it will have no effect on peat in isolation. If smaller bodies of peat can be mixed into the soil mass during rotavation, the effect is not likely to be significant. However, careful management may be required on site to ensure that large volumes of peat are not concentrated in one area as otherwise this may result in significant settlement in a particular area, perhaps leading to the formation of depressions and surface water ponding. The degree of settlement observed at the surface will depend on the thickness of peat placed in a particular area, the amount of organic content, and the depth of placement.

In considering the suitability of lime stabilisation of the alluvial soils under the (DoWCoP) (Contaminated Land: Application in Real Environments (CL:AIRE), 2011), the Environment Agency referred to Paragraph 8.1.6 in Appendix 8 which states that construction activities carried out on uncontaminated soils solely for the purpose of improving geotechnical properties are not generally regarded as waste treatment operations and do not require a permit. Lime / cement stabilisation is specifically mentioned as one of these activities and therefore the Environment Agency was content that the proposal fell within CL:AIRE guidelines. If excess bentonite from the construction of the cut-off wall in the excavation area is incorporated into the fill, this will not present a problem under DoWCoP as it is a natural material and is of low permeability. This is acceptable providing there are no hazardous additives contained in the bentonite.

As part of any lime improvement programme it would be recommended to carry out laboratory and field trials in order to assess the efficacy of the process and to define the optimum lime dosing rates. Tests should be carried out on untreated mixtures of the alluvium, and on lime improved material in order to determine the efficacy of the process.

6.3 Influence of Lime Treatment on Drainage Volume and Quality

Lime stabilisation will result in a change in the physical and chemical characteristics of the alluvium and a change in the volume and quality of drainage to groundwater (see also Section 8).

Lime stabilisation has been undertaken as part of the treatment of contaminated soils. The Environment Agency (2004) has published a literature review which is relevant to this study. This report provides a useful summary of the changes to the physical and chemical characteristics of soils arising from the addition of lime. Based on a review of this document it is concluded that overall lime stabilisation will result in a reduced risk to groundwater for the following reasons:

- The hydration process will result in a reduction in the volume of pore water that could be leached. Water is taken up as part of the reaction process and may also be lost as evaporation as the process is exothermic as illustrated by the following reaction;

$$CaO + H_2O \rightarrow Ca(OH)_2 + \text{heat} \uparrow$$

- Whilst the addition of lime may result in a short-term increase (days) in the permeability of alluvium, the precipitation of a cementitious gel (calcium and sulphate hydrates) in pore spaces will result in a decrease in permeability and a decrease in drainage rates in the longer term;
- Rotavation of lime into the alluvium will result in further mixing of this material and a break up of more permeable peat pathways (see Section 6.1);
- The stabilisation process will result in an increase in the mechanical strength of the alluvium and a reduction in the volume of water released by settlement (see Section 6.1);
- The addition of lime will result in an increase in pH to 10 to 11 and a reduction of mobility of contaminants (e.g. metals) (see Section 8).

The addition of lime will result in reaction with pyritic sulpur (FeS) and the generation of sulphate (this would also occur as a result of oxidation of the alluvium as a result of excavation and placement of this material), however sulphate is likely to be precipitated as it hydrates within the alluvium. The addition of calcium oxide may also result in ion exchange of calcium with sodium in the soil matrix and a potential increase in sodium concentrations in drainage, however this will be balanced by a decrease in the permeability of the alluvium and the precipitation of sodium hydrates.

The review has identified the potential for the addition of lime to result in an increase in pH (to between 10 and 11) which can:

- Increase the solubility of amphoteric[4] metals (e.g. zinc, lead, and chromium), albeit these metals would also be mobilised at low pH suggesting no net increase in risk to groundwater (this is discussed further in Section 8.3);
- Lead to the potential solubilisation of humic and fulvic acids and a potential increase in the mobility of PAHs albeit the concentrations of these compounds in previous leaching tests was low. Any change would need to be considered in terms of the likelihood for lower drainage rates.

6.4 Geotechnical Risk Register

The geological and geotechnical information reviewed and summarised in this report has been used to develop a geotechnical risk register (GRR) for the proposals, which is presented in **Appendix I** of this document. The GRR highlights the key geotechnical considerations with regards to the proposed development of the site. The GRR can be updated as a live document at various stages of the project.

6.5 Conclusions

The addition of lime to the alluvium, at optimised dosing rates will improve handling properties and mechanical strength of the material. Geotechnical testing data to date indicates that the material is generally suitable for lime treatment but further testing is required to confirm this, and to aid in the design of the lime treatment.

The geotechnical properties of the material are expected to be suitable for the intended final agricultural or heathland end use.

At this time, it is not fully known how the materials are likely to behave on excavation and placement in the borrow pits, in previous investigations compressibility testing has been carried out on samples described as

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[4] Amphoteric metals form compounds which are soluble in both low pH (acidic) and high pH (basic) conditions

either peat or clay, recovered from boreholes. To date, no samples have been taken of mixtures of the different types of alluvium, which would be more representative of the soil being excavated and brought to the borrow pits *en masse*. Furthermore, we have no knowledge of how much the lime improvement of the material will change (i.e. improve) the soil's behaviour in terms of bearing capacity and settlement under surcharge loading of stockpiles / granular surface cover. Recommendations for further testing are provided in Section 9.2.

7. Characterisation of the Sand and Gravels and Crag

This section has been updated from the 2016 Risk Assessment to include data from the 2017 site investigation. It describes the characteristics of the Crag underlying the proposed locations of the borrow pits.

7.1 Introduction

The site investigations (Section 3) have shown that the borrow pits are underlain by sand and gravel deposits which overly the Crag. The two deposits are similar in character with the exception that the Crag is characterised by a higher calcium carbonate content attributed to the presence of shell fragments. Leachate drainage from the proposed borrow pits will be mainly through the sand and gravels, whereas lateral groundwater flow will be mainly be through the Crag.

The sand and gravels are composed predominantly of fine to coarse grained sands with some flint and quartz gravel.

The Crag deposits are characterised by their highly variable lithology – a mix of gravels, shelly sands, silts and clays. Close to the Sizewell site, the Crag has been mapped at outcrop, overlain in places by the glacial Lowestoft Formation and alluvium (Section 4). The Crag is composed predominantly of interbedded fine to medium-grained sands and clays, with an upwardly decreasing proportion of shelly beds. At its base, the Crag rests unconformably either on Palaeogene deposits (Sizewell) or Cretaceous Chalk (BGS, Minor Aquifer Properties Manual, 2000) to the west.

7.2 Hydrogeological Properties

The aquifer properties of the Crag vary greatly depending upon the grain size of the sediments, the degree of sedimentation and the localised presence of overlying semi-confining glacial sediments. However, the BGS Minor Aquifer Report (2000) notes that the Crag has generally high permeability, although boreholes in close proximity to each other may display different yields dependant on borehole construction. Existing information on the physical properties of the Crag deposits is limited but reported data are presented in **Table 7.1.**

Given the complex distribution of silts and clay lenses within the Crag, vertical permeability is strongly influenced by the lateral continuity of such layers, and the vertical movement of water may be limited in places.

Seasonal water table fluctuations are generally less than 1 m due to the high storage coefficient of the aquifer, and groundwater contours reflect topography where the Crag is underlain by Palaeogene clays. Locally, layered aquifer bodies can occur within the Crag when clay horizons are laterally persistent for some distance. Where such layers occur within the Crag, there is some evidence that they can be sufficiently laterally and vertically continuous to result in a locally stratified aquifer.

A stiff laminated clay lens was identified in four boreholes (C3, C6, C7, BP7, CD_BP12 and CD_BP19, Section 4.3) located to the south of Area 2. This clay lens does not appear to be laterally extensive and perched groundwater was not encountered in the sand and gravels overlying it. The other site investigation boreholes for the borrow pits did not encounter other clay layers within the sand and gravels or Crag.

The sand and gravel deposits are mainly above the groundwater table and are therefore unsaturated.

Table 7.1 Physical and Hydraulic Properties of the Crag

Property	Description
Lithology	Coarse-grained, poorly sorted, cross-bedded, abundantly shelly sands (in East Anglia). Dark green and glauconitic when unoxidised, but typically oxidised to yellow or reddish brown with ferruginous concretions (iron pan). Basal bed of rounded flint pebbles. (BGS).
Mineralogy	The coarser fraction of the Crag is carbonate rich (up to 60% shells). The remaining is dominated by quartz, with trace components of plagioclase, calcite, mica, smectite and kaolin. Smectite is a major component, and the main constituent in the clay fraction, with minor components of illite, illite-smectite and kaolinite.
Local Thickness	Crag: 35 m to 50 m (Jacobs, 2011).
Hydraulic conductivity	1.7 m/d ($2x10^{-5}$ m/s) (Jacobs, 2011). Horizontal - 20 m/d (Jacobs, 2010), 6.0 to 34.6 m/d. (VLWRC, 2010). Vertical - 2 m/d (Jacobs, 2010), 6.0 m/d (VWLRC, 2010). Coralline Crag only: 14.8 m/d (BGS, 2000). Horizontal - 20 m/d (Wood, 2010b) Horizontal – 4 to >21 m/d, mean 10m/d (Section 4.3.1) Horizontal 80 m/d (pumping test of Crag borehole drilled at Aldhurst Farm)
Transmissivity	Median transmissivity is 412 m^2d^{-1}, with an interquartile range of 238-772 m^2 d^{-1} (obtained from 179 records, BGS 2006).
Stativity/Specific Yield	S_s 1.10^{-7} m^{-1} (VWLRC, 2010). Sy 22-30% (VWLRC, 2010).
Porosity	Coralline Crag only: 54% (BGS, 2000). All Crag: 25%-40% (BGS Baseline Report 21, 2006).
Cation Exchange Capacity	3 meq/100 g (recorded for the Chillesford Sand Member at Chillesford Sand Pit, Suffolk) (SEPA Technical Report P2-222/TR, CEC of Selected Lithologies from England, Wales and Scotland). Noted to be a very low value, reflecting the very low proportion of clay minerals in the sample. CEC probably due mainly to smectite.

7.3 Mineralogy

As noted by the BGS (2006), little information exists on the mineralogy of the Crag aquifer and the proportions of clay minerals to sand-size fractions varies considerably both vertically and laterally within the aquifer.

However, the sand (and coarser) fractions are known to be frequently carbonate-rich (up to 60% shells) and micaceous. Although considerable loss of $CaCO_3$ from the upper horizons of the sediments has been observed, it is not clear whether this is due to chemical erosion or is a depositional feature. This decalcification process can result in high concentrations of calcium (Ca) and bicarbonate (HCO_3) in groundwater and involves the dissolution of metastable aragonite and re-precipitation of the $CaCO_3$ as calcite (BGS Baseline Report 21, 2006). Laboratory testing of the Crag samples (**Table 7.2**) shows the calcium carbonate content varies from 1 to 17%. The sand and gravels are characterised by a lower calcium carbonate content (1 to 8%). The fraction of organic carbon content of the Sand and Gravels and the Crag is similar at about 0.06%.

Table 7.2 Summary of Analysis of Soil Samples (2014, 2015 and 2017 site investigations)

Strata	Number of Samples	Calcium Carbonate (%)			Fraction of organic carbon			
		Min	Max	Mean	Number of Samples	Min	Max	Mean
Sand and gravels	19	<0.5	8.4	1.6	14	0.0006	0.0017	0.0006
Crag	11	1	17.1	6.7				

The Crag is always observed to be dark-green at depth, as a result of the high concentrations of glauconite, which contains mixed-valency iron, suggesting precipitation in a moderately reducing environment. Oxidation of glauconite contributes to the reddening of the Crag in surface or coastal exposures.

Cementation of the Crag is known to be variable, with the Crag often observed to be decalcified, which may have altered shelly beds, which become more frequent lower down the sequence (BGS Baseline Report 21, 2006). However, at the near surface, within weathered zones, the Crag displays partial (patchy or lenticular) iron based cementation, as a consequence of the weathering of pyrite (BGS, 2000).

Cation Exchange Capacity

The presence of glauconite results in the Crag generally having a significant ion-exchange capacity, in the order of 5-40 meq/100 g for glauconite (Appelo and Postma, 1994), although this is substantially higher than the value of 3.5 meq/100 g recorded for the clean sands of the Chillesford Sand Member (Norwich Crag) (BGS, 2006).

Leaching tests

Leachate tests were undertaken on samples of sand and gravel and Crag that were obtained as part of the site investigations. The tests indicate that leaching of trace metals would be low with concentrations typically below detection levels. Concentrations of PAHs in leachate were very low and typically below detection limits (<0.02 µg/l). Concentrations of naphthalene (up to 0.18 µg/l)and acenaphthene (up to 0.31 µg/l) in leachate were very slightly elevated but are likely to represent a natural background.

8. Risk Assessment

This section has been updated from the 2016 Risk Assessment as follows: Section 8.2 on human health risk assessment has been updated against current and appropriate human health GAC for commercial and public open space use; Section 8.3 on ground gas risk assessment has been updated to further consider the conceptual model in the context of ground gas; and Section 8.4 on controlled waters risk assessment has been updated to account for the revised footprint of the borrow pits, benefits of lime stabilisation, assessment of increase in groundwater alkalinity due to the addition of lime and assessment of increased drainage due to stockpiling on the borrow pits; and to reflect the revised locations of the borrow pits. This section describes the risk assessment approach and the results of the updated assessment.

8.1 Approach

This section assesses the potential risks to controlled waters (i.e. groundwater, inland surface waters, transitional and coastal waters) and human health, buildings and property that could result from placement of excavated alluvium in the borrow pits. This risk assessment forms a key step in determining the feasibility of the proposed scheme by determining whether the excavated alluvium is 'suitable for use' (under the Development Industry Code of Practice for the Definition of Waste) as backfill materials. Risks to controlled waters, human health, buildings or property may exist where there is an identifiable pathway between a potential source of contamination and a receptor. The presence of a source, pathway and receptor constitutes a potential pollutant linkage (PPL) that requires assessment.

As an initial step, potential sources, receptors and pathways relating to placement of alluvium in the borrow pits have been identified (**Table 8.1**). Subsequently, the risk assessment follows a tiered approach:

Tier 1 - generic, qualitative discussion of potential risks in order to identify more sensitive PPL that require further assessment;

Tier 2 - generic quantitative risk assessment (GQRA), in which concentrations of potential contaminants recorded in source materials are compared directly to relevant screening values, such as soil guideline values (SGV) for protection of human health, or DWS/ EQS criteria for protection of groundwater and surface water resources; and

Tier 3 - detailed quantitative risk assessment (DQRA), in which analytical models or calculations are used to derive site-specific values for determining unacceptable risks to human health or the environment.

Identification of Potential Pollutant Linkages (PPL)

This section discusses the PPL relating to the placement of alluvium as backfill materials in the borrow pits. Geological, hydrological and hydrogeological conditions have been discussed in Sections 4.2-4.4. A detailed description of the nature of the alluvium to be excavated from within the SZC cut-off wall is presented in Section 5.

Sources

Historical information and land use data presented in the desk study report (Wood, 2010a) do not indicate the presence of contaminative land uses at the proposed borrow pit locations. It is possible that entry into groundwater of substances such as nitrate has occurred as a result of the extensive agricultural land in the area, however as this is a diffuse source it will not be possible to distinguish contamination originating at the borrow pit locations from the general background.

Consequently, it is considered that the most relevant potential source of contamination in land identified for borrow pits will be the materials imported from the footprint of the SZC excavation. Details on the nature and properties of this material are provided in Section 5. It is currently intended that materials identified as Made Ground within the cut-off wall footprint will be segregated and not used as backfill for the borrow pits, hence potential risks from contamination in such materials are not considered further in this study.

Receptors and Exposure Pathways

Potential receptors and associated exposure pathways associated with backfilling the borrow pits are summarised in **Table 8.1**.

Table 8.1 Potential Receptors and Exposure Pathways

PPL No.	Receptor	Exposure Pathway
1	Future end users of the site - farmers	Direct contact, ingestion, inhalation (dusts, vapour and gases).
2	Neighbouring site users – farmers and visitors	Direct contact, ingestion, inhalation (dusts, vapour and gases).
3	Buildings and property - limited to isolated farms / farm buildings within close vicinity to the borrow pit options	Migration of ground gases from fill mass and accumulation in confined spaces leading to possible explosive risk and/or inhalation and asphyxiation
4	Crag Aquifer underlying site	Leaching from backfill materials to groundwater underlying the site.
5	Abstractions from groundwater (see Table 4.5)	Leaching from backfill materials to groundwater and migration to the water abstractions.
6	Surface Water in Minsmere-Walberswick Heaths & Marshes SSSI	Leaching from backfill materials to groundwater underlying site, with subsequent lateral migration through the aquifer to surface water.
7	Surface Water in Sizewell Marshes SSSI	Leaching from backfill materials to groundwater underlying the site, with subsequent lateral migration through the aquifer to surface water.

Assessment of risks to human health (PPL 1 and 2, **Table 8.1**) are set out in Section 8.2, the risks to buildings and property in Section 8.3 (PPL 3), whilst risks to controlled waters (PPL 4-6) are discussed in Section 8.4.

8.2 Assessment of Risks to Human Health

Methodology

In order to provide an assessment of risks to humans for the use of alluvium in the borrow pits, a human health GQRA (HH-GQRA) has been undertaken. The HH-GQRA involves comparing contaminant concentrations observed at the site with appropriate generic assessment criteria (GAC). A HH-GQRA forms Tier 2 of the tiered approach to assessing risks from land contamination as set out in the Defra and Environment Agency publication "Model Procedures for the Management of Land Contamination" *(*Defra/Environment Agency, 2004*)* CLR11 (recently replaced by Land contamination: risk management (Environment Agency, 2019).

In the first instance we have used Category 4 Screening Levels (C4SLs) (CL:AIRE, 2013). These are values that have been derived for use in England and Wales to define sites posing low or no risk and adopted by DEFRA and Department for Communities and Local Government (DCLG) for use under UK planning to define suitable-for-use conditions. To date there have only been C4SLs produced for six substances.

In the absence of C4SLs, more conservative Suitable for use levels (S4ULs) (LQM/CIEH, 2015) have been used which are based on minimal risk levels rather than low levels of toxicological concern defined by a detailed toxicological risk assessment. In the absence of C4SLs or S4ULs we have used Wood-derived GAC based on the Environmental Industries Commission/Association of Geotechnical and Geo-environmental Specialists/CL:AIRE (EIC/AGS/CL:AIRE, 2009) GAC for the assessment of risks to human health.

Generic parameters are presently published for the following land uses:

- Residential with consumption of home-grown produce;
- Public Open Spaces – parks and areas near residential housing
- Allotments; and
- Commercial (formerly commercial/industrial).

Criteria used in the current assessment

On completion of the infilling and restoration, the borrow pits will be returned to agriculture or heathland. On this basis, it is envisaged that human receptors at the site will be adults (farm or estate workers), visiting the site infrequently or visitors to the heathland (assumed to be public open space). Therefore, it was considered appropriate to screen available soil quality data against GAC for a generic commercial land use scenario. This is based on more frequent exposure (for adults) than reality, so is conservative.

Screening against GAC for a public open space scenario has also been undertaken. Again this is conservative, implying a greater exposure frequency and more sensitive receptors (children) than is likely to be the case in reality once the borrow pits are returned to agricultural use or heathland.

In the absence of GAC, the laboratory limit of detection has been used for initial screening purposes.

Soil organic matter

GAC based on a 3% soil organic matter (SOM) content have been used in this assessment. Given the nature of the backfill materials and high potential natural organic content this is considered to be health-protective.

Exclusions from the risk assessment

Construction Workers

The risk assessment does not consider risks to construction/ site maintenance workers on the basis that risks to workers will be dealt with under the Health and Safety at Work Act (1974) and regulations made under the Act. Given the nature of the site, risks to below ground / maintenance workers should be managed by undertaking a bespoke risk assessment that is appropriate to the type of work and potential contamination at a location. Where practicable the risks should be designed out and any residual risks are managed by control measures. Use of a generic risk assessment approach where neither the scope of work, nor area of investigation, have been defined can lead to an inappropriate risk classification and should relate to the specific activity proposed.

Site-specific contamination data obtained from all site investigations should be included in the pre-construction information for the proposed works, to enable any contractors to address as necessary in their risk assessments and method statements.

Off-site users

Available soil quality data for the backfill material from the cut-off wall footprint has not identified the presence of measurable concentrations of VOCs, SVOCs or naphthalene. Measurable concentrations of volatile fractions of TPH (>C5-C16) have only been recorded in two of the seven samples, at concentrations marginally above the laboratory limit of detection (aliphatic >C5-C6 - 0.03 mg/kg and aliphatic >C12-C16 – 0.4 mg/kg). As such, risks to off-site users through inhalation of vapours is considered unlikely to be significant and have not been considered further in this assessment. Additionally, no further assessment of risks to off-site users through exposure via wind-blown dust has been undertaken on the basis that:

- The site will be covered during the proposed construction-phase use;
- When the site returns to agricultural use, land will be vegetated for the majority of the year; and
- It is assumed that the farmer responsible for the land will adopt land management practises that seek to minimise erosion of soil.

Potential Contaminants of Concern

Analytical data for seven soil samples obtained from the peat and organic clays within the footprint of the cut-off wall during the Phase 2 land contamination investigation were available to support this assessment (undertaken in 2012). These samples were found to contain:

- Low concentrations of some metals (cadmium, mercury and hexavalent chromium were less than the method detection limit in all samples);
- Low concentrations of PAHs (nine out of 16 targeted PAHs were below detection limit in all samples), with a maximum total PAH concentration of 0.5 mg/kg; and
- Infrequent detects of TPH, primarily heavier (>C12) aliphatics, with a maximum concentration for the sum of all fractions of 6.2 mg/kg.

Laboratory analysis of these samples did not include volatile and semi-volatile organic compounds (VOC and SVOC).

An investigation in 2008 (Structural Soils, 2009) provided the following data on soil quality from within the footprint of the cut-off wall, based on 82 samples from 24 boreholes:

- VOC and SVOC were not present at concentrations greater than method detection limit in any samples;
- Metals and other inorganics were present at low concentrations. A similar range was found in the WoodEC Phase 2 land quality report (Wood, 2012);
- TPH concentrations were below method detection limit in the majority of samples, with infrequent detectable concentrations; and
- Concentrations of PAHs were below detection limits in the majority of samples, with a limited number of relatively low concentrations reported. The maximum recorded soil concentration for Total PAH was 5.9 mg/kg.

No further characterisation of this material is available.

Risk Assessment Results (Human Health)

No new soil chemical data for the alluvium is available since the 2016 Risk Assessment. The data presented in the Phase 2 land contamination investigation (Wood, 2012) were screened directly against current appropriate GAC to provide the primary indication of potential risks to human health. Ranges of potential contaminant concentrations presented in the earlier Structural Soils report were then used to support the findings of the screening exercise.

Screening of Wood (2012) Data

No exceedances of the GAC for metals for commercial or public open space have been identified for the seven samples considered representative of the backfill material.

In the assessment of carcinogenic PAHs we used benzo(a)pyrene as a marker for all carcinogenic PAHs. To ensure this is an appropriate approach, we assessed the mixture present and confirmed it was consistent with that used in the toxicological assessment (in accordance with the approach set out in guidance by the HPA, ,2010). No exceedance of the GAC was identified for benzo(a)pyrene.

Naphthalene was assessed separately as this is volatile and behaves differently to the other PAHs and is not a carcinogenic PAH. No exceedances of the GAC were identified for naphthalene, with all seven sample concentrations below the laboratory limit of detection.

Analysis for total petroleum hydrocarbon was carried out on 7 samples. The data was screened against criteria for individual TPH fractions. In addition, the additive toxicity was assessed by summing the ratios of the concentration and screening criteria for each fraction to give a hazard index. All hazard indices were below 1, indicating that additive concentrations of TPH are below the mixture specific GAC.

Structural Soils (2008) Data

Contaminant concentrations were in the similar range to that identified by the Wood (2012) investigation, for metals, PAHs and TPH.

Soil results were also collected for asbestos, organochlorine and organophsphorus pesticides, BTEX, PCBs, VOCs and SVOCs. The results provided no evidence of gross or significant contamination, with concentrations generally at or below the laboratory limit of detection. Measurable concentrations were below the GAC. No asbestos containing materials were detected.

Conclusions (Human Health Risk Assessment)

Based on the risk assessment presented in this section, it is concluded that there are no unacceptable chronic risks to human health from use of extracted alluvium as backfill materials for the borrow pits. The conclusion applies to both on-site and off-site receptors. The final end-use of the borrow pits for agriculture or heathland is appropriate in this context. This result is consistent with the previous risk assessment findings undertaken in 2016.

8.3 Assessment of Risks from Ground Gas

Introduction

Peat and peaty clay and to a lesser extent other alluvial soils such as silts have the potential to generate ground gases including methane and carbon dioxide. This section of the report presents an assessment of the potential risks from ground gases generated by the borrow pit fill materials to property/buildings and their occupants.

Methodology

The approach that has been adopted in undertaking the ground gas risk assessment (GGRA) is in accordance with the methodology detailed within BS8485:2015 and CIRIA C665 (1995). The GGRA presented below is a Tier 1 semi-quantitative risk assessment for certain ground gases relating to human health and property (i.e. built environment). The gas risk assessment methodology uses the source-pathway-receptor approach and basic risk evaluation taking into account key factors such as surrounding geology, soil types, proximity to built environment and human receptors and current and proposed land.

This has been supported by the calculation of a Gas Screening Value (GSV) for the two key gases of interest (methane and carbon dioxide), using site derived data, which is then compared to the threshold values provided in BS8485 and CIRIA C665. These threshold values determine the gas Characteristic Situation (CS) and the level of risk posed by any exceedence of acceptable ground gas conditions, based on the flow rates and gas concentrations recorded. A gas CS is then described that corresponds to a defined level of protection required to mitigate the risk.

The main sources of information for undertaking the ground gas risk assessment are this report and the following site investigation and monitoring reports:

- Wood (previously Amec Foster Wheeler), 2010a. Desk based assessment for Sizewell EPR site. 15930/TR/00001.
- Wood (previously Amec Foster Wheeler), 2012a. UK EPR Sizewell C. Preliminary Phase 2 contamination assessment. 15930TR00054.
- Wood (previously Amec Foster Wheeler), 2012c, Sizewell EPR – Final Ground Gas Risk Assessment (Campaigns 1 - 7) 15930/TR0007.
- Structural Soils Ltd., 2009. Factual report on supplementary ground investigation at proposed nuclear development at Sizewell 'C'. Report no. 722201.

Other key sources of relevant guidance that have been used include:

- CIRIA 149. 1995. Protecting Development from Methane
- CIRIA. C665. 2007. Assessing Risks Posed by Hazardous Ground Gases to Buildings.
- CIRA 130, 1993. Methane: Its Occurrence and Hazards in Construction
- NHBC/ RSK, 2007. Guidance on the Evaluation of Development Proposals on Sites Where Methane and Carbon Dioxide are Present.
- BS 8485:2015+ A1:2019. Code of Practice for the Characterisation and Remediation from Gas in Affected Developments.
- CL:AIRE, November 2012, Research Bulletin (RB) 17: A Pragmatic Approach to Ground Gas Risk Assessment

Ground Gas (Background)

Ground gas (also sometimes referred to as 'soil gas') principally comprises methane (CH_4) and carbon dioxide (CO_2) as well as other bulk gases i.e. oxygen and nitrogen and trace constituents such as hydrogen sulphide, carbon monoxide, radon and hydrocarbons. In terms of materials re-use and development (i.e. construction activities), it is the risks from methane and carbon dioxide which are the most important to consider because:

- Methane is a flammable and potentially explosive gas and is able to displace oxygen, it can also be asphyxiant in circumstances where it is able to accumulate in confined spaces. Potential risks to human health and property (built environment) are well known and documented. Methane alone, or in combination with, the presence of carbon dioxide and other toxic gases may result in effects on vegetation, by causing oxygen deficiency in soils within the plant root zone due soil gas displacement and/or oxidation of methane to carbon dioxide.

- Carbon dioxide is non-flammable and non-explosive, but it is toxic and asphyxiant at relative low concentrations (3 -22% by volume (v/v)).

Initial conceptual model

Sources of ground gas

The backfill material will comprise excavated alluvial deposits, which are likely to contain a high proportion of peat and organic clay and peat/clay mix (accounting for over 60% of total content of the material). The Structural Soils (2008) investigation (Section 4.3) found that alluvium is comprised of multiple interbedded layers of peat and peaty clays and silts ranging from 0.5 to 5.0 m thickness, although in some areas a single layer of peat or organic clay is present. However, excavations for the ADAS heathland trials found that the peat typically occurred as discontinuous lenses with the alluvium. In practice, alluvium will be excavated simultaneously from multiple working areas which will help ensure mixing and production of a heterogeneous back fill material.

Natural soils, such as alluvium and peat, are often associated with high concentrations of methane and carbon dioxide in monitoring wells. Methane from wetlands (e.g. peat, bogs and marshland) is produced by the microbial decay of organic material under anaerobic conditions. Methane concentrations are typically high, whilst carbon dioxide will also be present (CIRIA, 2007). Peat/ bog areas can typically produce methane and carbon dioxide in the concentration range of 10-90%v/v and 0 -5% v/v, respectively (CIRIA, 1993). Alluvial soils can typically produce methane and carbon dioxide in the concentration range of 0 -5 %v/v and 0 -10% v/v, respectively (CIRIA, 1993).

The gas recorded in these natural soils has been generated historically and has been trapped in the pores due to the limited transport (at low diffusion rates) within the alluvium material. Methane can accumulate at increasing depths in peat columns, but this is not generally associated with high rates of production. RB17 (CL:AIRE 2012) indicates that such material is associated with very little or no current gas generation and that experience from other sites has shown that alluvial or peaty soils do not generate sufficient hazardous gas flows to exceed Characterisation Situation 2 as defined by BS 8485: 2015.

The addition of lime will result in a reduction on moisture content, a decrease in permeability of the infill and an increase in pH. There is limited literature on the influence of lime addition on gas generation, however methanogenesis is optimal under slightly acidic to neutral pH so there is a potential that the addition of lime may reduce or even inhibit methanogenesis.

Receptors

The assessment of risk is required to consider the future end-use of the site as agricultural land. The receptors assumed are future buildings (farm buildings) where gas could potentially accumulate resulting in a risk to human health through inhalation and asphyxiation and presenting an explosive risk.

It is generally assumed for the purpose of ground gas risk assessments that property within 250m of the source site may be at risk from gas migration, however, this depends on factors such as geology, hydrogeology (e.g. groundwater level) and source material characteristics (e.g. gas generation/ flow rates and pressures).

From a review of the Ordnance Survey (OS) map for the borrow pits area the properties listed in **Table 8.2** are within or approximately 250 m from the boundary of borrow pits.

Table 8.2 Summary of ground gas receptors in the vicinity of the borrow pits

Area	Distance (m)	
	The Round House	Ash Wood Cottages
2	25m south	200m south
3 and 4	25m sout	200m south

Gas migration

Potential pathways for ground gas to migrate from the borrow pits are considered to include:

- Vertically upwards through the fill materials, escaping as diffuse surface emissions from the surface of the site;
- Lateral migration through the permeable sands and gravels of the Lowestoft Sand and Gravels and Crag strata; and
- Migration via man made conduits e.g. land drainage pipes.

The extent to which gases that are produced by the backfill materials will migrate vertically upwards through the fill depends on the nature of the fill placed above and their degree of compaction and permeability.

The method of backfilling the excavated alluvium will be by controlled engineered filling i.e. in a series of thin lifts (200-300 mm) with associated compaction. Compaction of the alluvium, together with the break-up of the more permeable zones as a result of excavation, is likely to result in a net overall reduction in hydraulic conductivity of the backfill compared to current in-situ conditions. This is likely to produce a series of low permeability layers (possible hydraulic conductivity in the range 10^{-9} to 10^{-11} m/s or $8.7x10^{-7}$ to $8.7x10^{-5}$ m/d), minimising the potential for vertical upward migration.

The geology in the vicinity of the borrow pits comprise up to 3m of Lowestoft Diamiction (Glacial Till) underlain by about 10 m of Lowestoft Sand and Gravels and then Norwich Crag. This would mean that the peat and alluvial fills will be placed into surrounding Lowestoft Sand and Gravels and Glacial Till (where present) close to the surface. Groundwater is present at 10 to 12 m below ground level, meaning that the fill would be placed within the unsaturated zone. The surrounding sands and gravels are likely to be fairly permeable, facilitating the potential for lateral gas migration.

Migration via man made conduits is also possible. Given the site context and land use, land/field drains would seem to be the most likely type of conduit. Such drainage (if present) is likely to be within the upper 1 - 2m of the ground, however, is unlikely to be contiguous with nearby properties and buildings.

Summary of Existing Gas Monitoring Data

In order to support the assessment of the potential gas risk from the alluvium that will be placed in the borrow pit(s), a review of relevant gas monitoring data from the source site (i.e. Proposed SZC development footprint) has been undertaken.

The key sources of relevant information are the Phase 2 Contamination Assessment (Wood, 2012a), Final Ground Gas Risk Assessment (Wood, 2012c) and Structural Soils (2009). No new ground gas monitoring data is available since the risk assessment undertaken in 2016.

Results from boreholes screened within the alluvial deposits or made ground directly above the alluvial deposits have been considered in the assessment. This approach is consistent with that undertaken in the 2016 risk assessment.

Ground gas monitoring for the Wood boreholes (G2, G3, G4, GW11S and GW15) was conducted between March 2011 and September 2011. The Wood monitoring was undertaken during periods of low (<1000 mb) or falling pressure and during various tidal stages (i.e. falling or rising) to determine the possible impact of air pressure and tidal effects on the gas regime.

Structural Soils monitored four boreholes screened within the alluvial deposits (BH5, BH7, BH19A, and BH21). This monitoring was conducted daily over a period of 1 to 2 weeks during the site investigations carried out in October 2008. The data set is therefore limited and extends over a much shorter period than the Wood monitoring data. Also, the boreholes were not allowed to stabilize following installation and prior to the commencement of gas monitoring, with the ground subject to disturbance during the site investigation works. As such limited reliance can be placed on these monitoring results.

A summary of the monitoring data from these 9 boreholes is presented in **Table 8.3**.

Table 8.3 Summary of ground gas monitoring data for alluvial deposits (Wood and Structural Soils Data)

Borehole No.	Response Zone (m bgl) and Geological Strata	Atmospheric Pressure (mb)	CH_4 (% vol.)	CO_2 (% vol.)	O_2 (% vol.)	Flow Min – Max (l hr-1)	Static Water Level (m bgl)	Measured Total Depth (m bgl)
GW11S	6.0 - 8.7 Alluvium/peat	1004-1035	0.5-18.6	0.1-4.3	15.0-20.2	-0.3-0.1	0.55-0.918	8.648-8.73
GW15	0.6 - 4.78 Made Ground (above Alluvium)	1003-1035	0-83.8	12.1-13.6	0.5-7.6	-1.8-0.3	0.06-0.790	4.702-4.79
G2	4.4 - 7.8 Alluvium	1003-1034	0-0.4	0	19.9-20.9	-0.1-0.1	0.63-0.957	7.702-7.73
G3	4.1 - 7.0 Alluvium	1004-1035	0-20.3	2.4-5.9	11.4-19.8	-0.1-0.1	0.22-0.889	6.68-6.704
G4	5.7 - 9.0 Alluvium	1003-1035	3.3-35.3	0.2-3.5	14.2-20.2	0.0-0.2	1.237-1.342	8.93-8.98
BH5*	1.00 – 9.00 Made Ground / Alluvium	1006 -1021	14 -77	0.3- 2.0	0.3 -18.5	0.1 (Max peak flow >30)	0.71 -0.78	-
BH7*	9.50 -12.50 Crag Sand (below Alluvium)	1008-1021	0.1	0.1	20.8 -21.3	0.1 (Max peak flow 1.3)	0.8 – 0.93	12.11 -12.12
BH19A*	1.00 – 9.00 Made Ground / Alluvium	1006 -1021	6.7 - 56.0	0.4 -4.6	7.3 -20.8	0.1 (Max peak flow 0.7)	0.78 -0.84	8.31 -8.38
BH21*	1.20 -9.00 Made Ground / Alluvium	1010-1021	0.1- 80.0	0.1 -6.1	2.9- 21.3	0.1 (Max peak flow 0.1)	0.34	8.92 -8.94

Notes: All boreholes located in Zone Central

>1% Significant concentrations of methane are identified as those concentrations greater than the 1% v/v using the widely accepted threshold detailed in Table 8.5 of CIRIA C665

>5% Significant concentrations of carbon dioxide are identified as those concentrations greater than the 5% v/v using the widely accepted threshold detailed in Table 8.5 of CIRIA C665

* Structural Soils Boreholes / Data

** Groundwater levels were recorded at shallower depths than the monitoring standpipe response zone. As a result, the gas data obtained reflect saturated soil conditions.

The results show high concentrations of methane and to a lesser degree carbon dioxide, in several boreholes. A higher percentage of methane than carbon dioxide is typical for alluvium soils, as the carbon dioxide dissolves out of the gas trapped in the soil pores and is not replenished by new gas generation. The steady state flow rates typically encountered were also very low (typically <0.1 -0.3 litres/ hour) which is consistent with the type of material under consideration and guidance in RB17. At BH5 a peak flow of >28 and >30 litres per hour (i.e. greater than the instrument could record) was obtained at the start of each monitoring exercise on five occasions. The high peak flow rates were transient lasting typically for only 10 to 20 seconds.

Some of the highest methane and carbon dioxide concentrations in the Wood boreholes were in GW15 which is screened in the Made Ground overlying peat and alluvial soils. This indicates that upward migration of ground gas and surface emission of migrating gas occurs in-situ. Conversely, and also of interest, is that ground gas concentrations in Structural Soils BH7 (slotted in the Crag Sand underlying the Alluvial deposits) were all <0.1 (v/v) suggesting that gas generated from the in-situ soils does not migrate vertically downwards into the underlying sands.

The results of the Wood and Structural Soils monitoring have been used to generate Gas Screening Values (GSVs) in accordance with the methodology given in BS8485 and CIRIA 665.

Table 8.4 Maximum gas screening value calculations

Borehole	Steady flow Rate (l/hr)	CO_2 (% v/v)	CO_2 GSV	CO_2 CS level	CH_4 (% v/v)	CH_4 GSV	CH4 CS level
GW11S	0.1	4.3	0.0043	CS1	18.6	0.0186	CS1
GW15	0.3	13.6	0.0408	CS1	83.8	0.2514	CS2
G2	0.1	0	0	CS1	0.4	0.0004	CS1
G3	0.1	5.9	0.0059	CS1	20.3	0.0203	CS1
G4	0.2	3.5	0.007	CS1	35.3	0.0706	CS2
B5	0.1	2.0	0.002	CS1	77.0	0.077	CS2*
BH7	0.1	0.1	0.0001	CS1	0.1	0.0001	CS1
BH19A	0.1	4.6	0.0046	CS1	56.0	0.056	CS2
BH21	0.1	6.1	0.0061	CS1	80.0	0.080	CS2

Notes: *BS8485 indicates that for CS2 typical flow rates are <70l/h (otherwise consider an increase to CS3). CS2 is therefore considered to be appropriate given steady state and peak flow rates recorded at this location.

The results confirm that, on the basis of the steady state borehole concentration and flow rates, the GSV for the peat and alluvial materials range between CS1 and CS2 (i.e. very low to low risk).

Conclusions (Ground Gas Risk Assessment)

The ground gas risk assessment has concluded that the risk from the peat and alluvium proposed to be used as backfill for borrow pits is very low to low. Available gas monitoring data also supports this conclusion with the gas screening values corresponding to characteristic situation 1 to 2 (very low to low risk sources). This result is consistent with the previous risk assessment findings undertaken in 2016.

Prior to and during infilling, it is proposed that gas monitoring is undertaken in the groundwater monitoring boreholes (**Appendix J** of this document). These boreholes are screened above the water table and suitable for gas monitoring. In addition, dedicated gas monitoring boreholes will be constructed around the boundary of the borrow pits nearest to The Round House to provide assurance that gas generation rates are low and do not pose a risk to the property. Boreholes (approximately 10) will be located every 20 m of borrow pit perimeter on the edges of Areas 2 and 3 in the vicinity of The Round House property and monitoring will be undertaken monthly during infilling. The gas monitoring results would be reviewed routinely to determine if any further actions are necessary or if monitoring needs to be undertaken in the longer term (including the need for monitoring boreholes within the borrow pits). During infilling, gas measurements will also be routinely undertaken (monthly) in probes driven 1 to 2 m into the fill to confirm that rates of gas generation are low.

8.4 Assessment of Risks to Controlled Waters

Introduction

The borrow pits will be excavated to an average depth of 8 m to provide 973,500 m^3 of suitable engineering material. They will then be backfilled with soils from the SZC excavation footprint. For the purpose of the controlled waters risk assessment it is assumed that the base and sides of the excavation will be unlined. Once filling and settlement has finished, reprofiling of the final landform will facilitate surface water drainage and replacement of topsoil will allow the land to be returned to agricultural use or heathland. Excavation of the sand and gravels to an average of 8 m bgl will leave a minimum unsaturated zone thickness of 2 m (above maximum groundwater levels, **Table 2.1**).

This section assesses the potential risks to controlled waters that could result from the placement of excavated alluvium in the borrow pits and represents an update of previous assessments (Wood, 2014c, 2015a and 2016). The assessment has also taken account of proposals to: treat the alluvium with lime; to place up to 3 m of granular material over the backfilled alluvium to allow for settlement and to facilitate reprofiling the site; and to use the infilled borrow pits as a temporary stockpiling area.

Source Pathway Receptors

The assessment has considered a source-pathway-receptor approach. The source-pathway-receptor linkages for controlled groundwaters are summarised in **Table 8.1** and illustrated in **Figure 8.1**.

Source

The source material is defined as the alluvium infill to the borrow pits. The characteristics of the infill are described in Section 5. In summary, the alluvium is anticipated to comprise approximately 38% peat, 19% clay, 31% clay/peat mix and 12% silt/sand. Testing of the material has shown that it is characterised by:

- High chloride (typically 1 000 to 3 000 mg/l) and sodium concentrations (typically 500 to 2000 mg/l);
- High pyrite concentrations (about 1%). Previous heathland creation trials have shown that on exposure to the atmosphere oxidation of pyrite results in an acidic drainage characterised by high sulphate concentrations (about 3 000 mg/l). However, under anaerobic conditions oxidation of pyrite does not occur and pH is neutral and sulphate concentrations are low (<100 mg/l);
- Low heavy metal concentrations (leaching tests show the concentrations are either below detection levels or are within the baseline range for groundwater); and
- Non-detectable concentrations of organic compounds (VOCs, SVOCs) with the exception of some PAHs (e.g. phenanthrene) which was identified in some leaching tests at low concentrations (<0.1 µg/l).

The addition of lime will change the rate and quality of drainage (Sections 6.3 and 8.4.10), with the most likely effect being a reduction in the source term (drainage and concentrations). The use of the infilled borrow pits as a temporary area for stockpiling will result in increased settlement of the infill and short-term increase in drainage rates.

Pathways

Infiltration of rainfall into the borrow pits is likely to leach contaminants from the infill to create leachate. Leachate will drain from the sides and base of the borrow pits into the underlying sand and gravels and Crag. However, the relatively low hydraulic conductivity of the infill is likely to restrict infiltration and limit leaching.

Receptors

The main controlled water receptors are summarised in **Table 8.1** and include:

- The Crag Aquifer. For hazardous substances the compliance point has been taken as the water table. For non-hazardous substances a compliance point 50 m downgradient of the borrow pits has been used as the aquifer is designated at Principal status;
- Potable abstractions. The nearest (approximately 250 m) downgradient active abstraction is a private potable supply borehole located at Plantation Cottages (00/00492/PWWELL). These properties are part of the EDF Energy Nuclear Generation Ltd Sizewell Estate. It is noted that land to the east and northeast of the pits is also part of this estate and, therefore, EDF Energy has control on the nearest downgradient groundwater abstractions; and
- Surface water fed by groundwater. The nearest watercourses (drains) are located about 450 m downgradient of the borrow pits and these drain into the Minsmere-Walberswick Heaths & Marshes SSSI. For the risk assessment a compliance point of 450 m has been used. This is considered to be conservative as any groundwater discharge to surface water will be diffuse over the area of the SSSI.

Surface Water Management

During infilling and under most conditions, rainfall falling over the borrow pit area would be expected to be absorbed by the peat, given the rapid infill rates. However, for some rainfall conditions surface water may collect within the borrow pits. This surface water would be routed, where practical, to temporary sumps from where it would be pumped to the wider SZC construction site water management scheme. This surface water is likely to be of relatively low salinity, but would be characterised by elevated suspended soils (including organic matter). Treatment with lime will allow engineered compaction, which is likely to reduce the permeability of the infill material which will increase the potential for run-off. The surface water management scheme will be developed to ensure appropriate management of clean and contaminated surface water. Contaminated water would not be discharged to ground, unless appropriate treatment has been undertaken and the discharge agreed with the Environment Agency.

Once the backfilling works are completed (including reprofiling to facilitate surface water drainage), topsoil and subsoil will be placed over the borrow pits and the land returned to agriculture or heathland. The restoration will also involve placing land drains in the subsoil and above the low permeability backfill material. There are no surface watercourses in the vicinity of the borrow pits and therefore surface water run-off from the restored borrow pits will readily drain into the surrounding permeable sand and gravel deposits. The surface water drainage will need to be designed to ensure groundwater levels will not mound below the base of the borrow pits.

Contaminants of Potential Concern

A qualitative assessment has been undertaken to identify contaminants of potential concern through comparison of the likely quality of water draining from the infill with EQSs for non-hazardous contaminants and minimum reporting values (MRVs) for hazardous substances.

Information on the backfill source term has been based on:

- Soil and leachate testing (Section 5.3) of the proposed infill material;
- Soil testing for the heathland creation trials (Section 5.3);
- Monitoring of soil drainage for the heathland creation trials (Section 5.3).

A review of this information shows that the main contaminants of concern are:

- Sulphate, chloride, sodium, iron and pH (non-hazardous contaminants) as these are likely to exceed water quality standards; and
- PAHs (phenanthrene) (hazardous substances) as leaching tests indicate these may be present in drainage albeit at very low concentrations. These substances are likely to be naturally occurring.

Heavy metals and organics (with the exception of some PAHs) are not considered to be a risk as concentrations are low and either below detection limits or below EQSs. Whilst oxidation of the fill (no lime treatment) could result in acidic drainage and mobilisation of some metals, pH buffering calculations (Section 8.4.8) have confirmed that that reaction with calcium carbonate in the unsaturated zone would neutralise this acidity and prevent migration of metals to the water table. The risk from PAHs has been investigated using the LandSim model (Section 8.4.10).

Methodology

LandSim Model

A quantitative assessment of the potential impacts on groundwater has been undertaken using the Environment Agency's LandSim model v2.5.17 (Section 8.4.7). This assessment has considered contaminant concentrations and travel times to the following compliance points:

- at the base of the unsaturated zone directly beneath the borrow pits (for hazardous substances);
- at compliance points in groundwater at 50 m and 250 m downgradient of the borrow pits (for non-hazardous pollutants); and
- at 450 m downgradient of the borrow pits to assess the potential impacts on groundwater feeding Minsmere-Walberswick Heaths & Marshes SSSI (for non-hazardous pollutants).

The LandSim model has been used for this assessment as it:

- has been developed for the Environment Agency to represent the impacts of landfills and can be readily modified to represent the use of alluvium as a backfill material within the borrow pits;
- can be set up to represent a variable source term;
- can represent contaminant movement through the unsaturated and saturated zones;
- results can be interrogated to determine drainage rates from the backfill, changes in source term over time, groundwater flow rates, contaminant travel times, and contaminant concentrations at different points along the flow path including the likely quality of groundwater feeding surface water; and

- is probabilistic allowing ranges in parameter values to be taken into account.

For the proposed backfilling scheme, the model has been set up as follows:

- Backfilling (operation) phase of 2 years, to represent the period of backfilling the pits;
- Restoration phase (the model has been run conservatively for a period of 10 000 years which is significantly greater than estimated travel times to receptors);
- No engineering control measures such as an engineered cap or impermeable liner at the base or sides of the infilled void; and
- Declining source term using LandSim default decay values.

A conservative approach has been adopted in undertaking the assessment through:

- The use of a probabilistic model such that variation in parameter values have been taken into account;
- Presentation of predicted concentrations as 95%ile as well as 50%iles. A 95%ile result indicates that there is a 1 in 20 chance of the predicted concentration being exceeded, a 50%ile represents the most likely case;
- Review of the data to define a plausible range of parameter values, but also taking into account maximum values in defining input parameter ranges (provided in **Appendix N** of this document), except where data indicate these are anomalous (outliers) or the data are not consistent with the conceptual understanding (for instance a low or very value of hydraulic conductivity is not consistent with the groundwater modelling and observed hydraulic gradients); and
- Definition of the source term as this is considered to present the key variable for the risk assessment. A conservative source term has been defined based on a reasonable 'worst' case taken from the heathland creation trials. These represent a worst case in terms of generating poor quality water draining from the infill because they represent water quality resulting from extensive exposure to the atmosphere of a material that was either 100% peat or 50% peat and 50% clay). In practice, peat represents about 38% of the infill material.

Assessment of pH Buffering Capacity of Unsaturated Zone

The heathland creation trials showed that where the peat and clay deposits are exposed to the atmosphere, oxidation of pyrite can result in acidic drainage characterised. For the peat/clay trials, the pH in drainage ranged from 6 to 7 and for the peat trial the pH ranged from 4.7 to 6 (**Appendix G** of this document). Of the two, the peat/clay trial is more likely to be representative for the material to be backfilled in the borrow pits and therefore the drainage from the base of the infill is more likely to be characterised by a pH above 5.

This acidic drainage (assuming no lime treatment) could also increase the mobility of metals including cadmium and mercury (hazardous substances). Leaching tests (Section 5.2) have shown that under neutral pH conditions (pH of about 7), the concentrations of mercury and cadmium are below detection limits and therefore do not pose a risk.

This potential lowering of pH can be buffered by reaction with calcium carbonate. Drainage from the borrow pits will move vertically down through the sand and gravel (unsaturated zone) and then migrate laterally through the Crag saturated zone. The Crag is characterised by a high calcium carbonate content (1 to 17%) (Section 7.3). The sand and gravels have a lower calcium carbonate content (1 to 8%) (Section 7.3). Groundwater in the Crag is also characterised by high alkalinity (200 to 400 mg/l as $CaCO_3$). The buffering capacity of the system is therefore high with the consequence that any acidic drainage will be neutralised through contact with sand and gravel.

Calculations have been undertaken (**Appendix K** of this document) to assess the pH buffering capacity through reaction with calcium carbonate of the sand and gravel in the unsaturated zone below the borrow pits. These calculations consider whether there is sufficient calcium carbonate to react with the drainage water and to raise the pH of the drainage water from 5 to 7. Calculations have also been made for a pH value of 4 to provide a conservative assessment.

Assessment of Increase in Alkalinity due to Lime Stabilisation

Lime stabilisation will result in a change in the physical and chemical characteristics of the alluvium, that will permit engineering compaction and a change in the volume and quality of drainage to groundwater (Section 6.3). In summary the main effects will be:

- Decrease in the hydraulic conductivity of the infill and a decrease in drainage rates;
- The stabilisation process will result in an increase in the mechanical strength of the alluvium and a reduction in the volume of water released by settlement (the addition of lime is unlikely to affect the properties of the peat but the process of rotavation to incorporate lime will result in further mixing of this material and a breakup of potentially more permeable peat lumps);
- Reduce the volume of pore water that could drain from the deposit due to hydration of the lime;
- Increase the pH of the drainage (e.g. acidic drainage is unlikely) which will decrease the mobility of most metals. Amphoteric metals such as zinc, lead and chromium can be soluble at higher pH, however the risk to groundwater is likely to be lower compared to acidic drainage;
- The increase in pH may increase the potential for solubilisation of humic and fulvic acids and a potential for an increase in the mobility of PAHs albeit the concentrations of these compounds in previous leaching tests was low;
- The addition of lime can also result in the oxidation in pyrite and release of sulphate; however, sulphate is likely to precipitated as hydrates within the fill material and therefore concentrations of sulphate in drainage are likely to less as a result of the addition of lime;
- Ion exchange of calcium (lime) with sodium within the soil matrix may result in an increase in sodium concentrations in drainage, however precipitation of sodium as hydrates would also be expected to occur.

The addition of lime will result in increased pH and alkalinity within porewater and leachate within the borrow pits. Some of this may move vertically downwards to contribute to an increase in alkalinity in groundwater beneath the pits that may flow towards, and discharge into the marshes. An assessment has been undertaken (**Appendix L** of this document) to determine whether lime stabilisation poses a risk to downgradient surface water receptors, specifically from a potential increase in alkalinity.

Assessment of Impacts due to Stockpiling

On completion of infilling, EDF Energy propose to use the borrow pits as a temporary stockpiling area. The maximum height of the stockpile would be 5 m and it would be in place for up to 8 years.

The placement of a stockpile over the infilled borrow pits will result in increased settlement of the infill. Peat (~38% of excavated material) is characterised by a high water filled porosity (57 to 88%, from testing of peat material by Structural Soils, 2009). Loading of peat creates the potential that poor quality pore water will be squeezed out from the mass of the infill and impact on groundwater. Similarly, the air-filled porosity (4 to 29%) is also likely to reduce as a result of settlement.

The amount and rate of settlement will depend on the loading from the stockpiles (stockpile height), the rate of loading (how quickly the stockpiles are placed), the duration of loading, the consolidation properties of the alluvium and the pathway(s) (e.g. permeability of fill and distance to the edge of the pit) for water within the peat to migrate through to the edge of the pit. The process of excavation and placement of the infill is likely to ensure that the peat is distributed through the infill and to disrupt the development of more permeable pathways. Prior to excavation of the alluvium from within the SZC footprint, the underlying Crag will be dewatered which may result in some drainage of the alluvium and a reduction in moisture content.

The methodology for calculating the likely settlement of the backfill material caused by the stockpiling of materials is described in **Appendix M** of this document, together with the input parameters and the assumptions made in calculating the amount of settlement. These calculations were based on the results of consolidation tests which were undertaken as part of the 2009 site investigation (Structural Soils, 2009). There is uncertainty regarding the estimate of settlement as calculations were based on results from testing of in-situ material rather than testing of excavated material. The calculated settlement is likely to represent an overestimate as the stockpile will be progressively removed with time.

The calculations are sensitive to the stockpile height and to the geotechnical properties of the peat and clay. Geotechnical property values are based on laboratory testing of undisturbed materials and do not take account of changes in properties as a result of excavation, handling and placement of the material which will also result in a mixed material. Furthermore, the settlement calculations are based on the placement of untreated, rather than lime treated, backfill material. It can be reasonably assumed that the settlement of lime improved soils would be less than untreated soils, given their improved workability and suitability for compaction. It is recognised that peat does not undergo any appreciable improvement under lime treatment. However, large bodies / loads of unmixed peat are unlikely to be placed in the borrow pits as a result of:

- Peat will be mixed and broken up amongst the rest of the soil mass during rotovation;
- Observation and monitoring of the materials as they are excavated in order to ensure that large bodies of peat are not placed in one area; and
- The lime spreader and mixers will travel over the placed alluvium to ensure that the mixing process helps to incorporate any peat pockets within the rest of the material.

Using best and average geotechnical property values of the peat and clay (worst-case values are considered too pessimistic given that lime treatment limits settlement of the backfill material) the total amount of settlement for a 5 m stockpile is estimated at between 0.5 to 0.6 m and 1.5 to 2 m respectively. The calculations also show that most of the settlement (80 to 98%) will occur over a 5-year storage period assuming no removal of the material during this period (**Table 8.5**).

Table 8.5 Estimated backfill settlement due to stockpiling (stockpile height 5 m)

Case parameters estimate [a]	**Total backfill settlement (m) (assuming stockpile in place indefinitely)**	**Backfill settlement after placement (m)**					**Equivalent drainage rate in LandSim in first 5 years reducing to 30 mm/yr after 5 years (mm/yr)[b]**
		1 Year	**2 years**	**3 years**	**4 years**	**5 years**	
Best	0.50-0.60	0.35-0.40	0.45-0.50	0.50-0.55	0.55-0.60	0.55-0.60	90-120
Average	1.50-2.00	1.0-1.3	1.2-1.5	1.4-1.7	1.5-1.8	1.6-1.9	290-360

Notes: Full calculations provided in Appendix M.
a) Best and average case estimates of settlement use a combination of best and average case estimates for the geotechnical parameters of the backfill material (coefficient of volume compressibility, coefficient of consolidation and geological correction factor).
b) From Table 8.6.

An estimate of the equivalent drainage rates from the base of the pits to groundwater (as mm/year) has been made in the 2014 Risk Assessment (Wood, 2014) based on an initial thickness of infill (8 m) settling by between 4% (~0.3m settlement) and 25% (~2 m settlement) over a period of 5 years and assuming that 90% (average water filled saturation of peat) of this settlement can be attributed to squeezing out of the water filled porosity and 10% due a reduction in air filled porosity. The calculations indicate that settlement of the backfill material by 0.5 to 0.6 m (best estimate) and 1.5 to 2 m (average estimate) results in equivalent drainage rates modelled in LandSim of between 90 and 360 mm/yr (**Table 8.6**).

Table 8.6 Estimate of drainage rates as a function of settlement

Total amount of settlement (%)	**Time over which drainage due to settlement occurs (years)**	**Equivalent rate of drainage mm/year (approximate)[a]**
4 (0.3m)	5	60, reducing to 30 after 5 years
5 (0.4m)	5	75, reducing to 30 after 5 years
6 (0.5m)	5	90, reducing to 30 after 5 years
8 (0.65m)	5	120, reducing to 30 after 5 years
16 (1.3m)	5	240, reducing to 30 after 5 years
20 (1.6m)	5	290, reducing to 30 after 5 years
25 (2 m)	5	360 reducing to 30 after 5 years
Base scenario (no stockpile)	2	90, reducing to 30 after 2 years

Notes: a) Figures rounded to nearest 5 mm/year.

LandSim Model Input Parameters

The input parameters for the LandSim model are provided in **Appendix N** of this document and have been derived from site specific data and/or literature values.

Key Assumptions/ Limitations and Sensitivity Analysis

The main uncertainties for this assessment are considered to be:

- The degree of oxidation of pyrite as a result of excavation and placement of the alluvium and whether the results from the heath land trials are representative. Whilst some oxidation would be expected during excavation and placement of the alluvium, the rapid placement of the backfill and compaction would limit exposure. In addition, any ground gas generated by the alluvium will reduce oxygen availability. These effects would be expected to result in an oxygen poor environment;
- The effects of lime treatment. This will result in oxidation of pyrite, but the sulphate created will be incorporated within calcium, aluminium and sulphate hydrates and therefore this process is unlikely to increase sulphate concentrations in drainage to groundwater;
- Initial sulphate concentrations. A conservative assumption has been used for the risk assessment whereby initial sulphate concentrations were based on the results from the heathland trials where exposure to atmosphere and subsequent oxidation of pyrite would have been maximised;
- The rate of decline of the sulphate source term. Excavation and exposure of alluvium will permit oxidation and the generation of sulphate. However, given the rapid rate of infilling of the borrow pits over two consecutive summers anaerobic conditions are anticipated to be quickly

re-established leading to low sulphate conditions. Any sulphate generated will be subect to incorporation into hydrates. However, for risk assessment purposes the time for sulphate concentrations in the fill to decrease by 50% has conservatively been assumed to be 10 years;

- The rate of drainage from the backfill during the infilling phase and the rate of release of pore water from the peat due to settlement given:
  - The amount of settlement that may occur. The addition of lime will increase the mechanical strength of the clays and silts in the alluvium which may limit settlement, but some compaction of the peat will occur, albeit excavation, placement and rotavation of the alluvium is likely to result in a more mixed and stronger material;
  - The likelihood of short discontinuous flow paths due to mixing of clay and peat during excavation, placement and addition of lime (rotavation);
  - The change in hydraulic conductivity of the fill resulting from the addition of lime (precipitation of hydrates within the infill);
  - The uptake of water (pore water and rainwater) due to hydration of lime.

Uncertainty in the input parameters has already been taken into account through defining ranges of input values (see **Appendix N** of this document), but this also been explored through sensitivity analysis. The sensitivity runs were undertaken for sulphate (non-hazardous pollutant) and phenanthrene (hazardous substance) and the following scenarios:

- Decrease in the source term by 50%. From the discussion above the source term used is likely to represent an overestimate of actual concentrations;
- Increase and decrease in the rate of decline of the sulphate source term by ±50% to investigate the influence of uncertainty on how this term is used to represent the change from high to low sulphate concentrations as a result of a change to anaerobic conditions;
- Increase and decrease in the infiltration rate during the backfilling phase by ±50% to investigate further potential uncertainty on drainage rates from the fill during backfilling;
- Increase in the period of higher infiltration from 2 to 5 years;
- Decrease in unsaturated zone thickness by 50% to investigate the sensitivity of the results to this parameter; and
- Increase and decrease in the hydraulic conductivity of the saturated zone by ±25% to investigate the potential influence of uncertainties in this value. The values determined from the site investigation may represent an underestimate due to the small drawdown observed during permeability testing.

Risk Assessment Results: pH Buffering Capacity of Unsaturated Zone

The assessment of the pH buffering capacity of the sand and gravels assuming no lime treatment is provided in **Appendix K** of this document. This assessment confirms that only a small percentage (<1%) of the available calcium carbonate content present within a 2m thickness of sand and gravels would be consumed (even for highly conservative assumptions regarding drainage rate, initial pH and calcium carbonate content). Therefore, it is concluded that the pH of drainage water from the infill would be neutralised within the unsaturated zone and there would be no risk of transport of trace metals to the water table. Equally a rise in pH through the addition of lime is not considered to affect the risk of transport of trace metals. To ensure sufficient neutralisation a minimum 2m thick unsaturated zone below the borrow pits is proposed.

Risk Assessment Results: Increase in Alkalinity due to Lime Stabilisation

The assessment of whether lime stabilisation will pose a risk to downgradient surface water receptors, specifically from a potential increase in alkalinity is provided in **Appendix L** of this document. This assessment found that there is likely to be an increase in groundwater alkalinity beneath and downgradient of the borrow pits. However, concentrations in groundwater are unlikely to rise significantly above the baseline. It is therefore concluded that lime modification will not adversely affect surface water quality in the Minsmere & Walberswick Heath Marshes SSSI.

Risk Assessment Results: LandSim

LandSim results reported as the 50 percentile (most likely) and 95 percentile (pessimistic) predictions are presented in **Table 8.7** for the base scenario (no lime treatment and no stockpiling), **Table 8.8** for the lime treatment scenario and **Tables 8.5** and **8.6** for the stockpiling scenario. Selected results as predicted concentrations over time are also presented in **Appendix O** of this document. The results are discussed below.

Base Scenario

The results for the Base Scenario show that:

- The predicted maximum concentrations of sulphate, chloride and sodium in groundwater 50 to 450 m downgradient of the borrow pits are above background groundwater quality, but there are no exceedences of DWS at the 50%ile and even at the 95%ile prediction levels;
- The predicted maximum concentrations of ammoniacal-nitrogen (50%ile predictions) in groundwater 50 m downgradient of the borrow pits are marginally above background groundwater quality, but these decrease to within background and below EQS at distances over 450 m (discharge point to surface water) and are not considered to be significant. The 95%ile predicted concentrations are within background groundwater and surface water quality (see plot in **Appendix F** of this document);
- There is either no predicted (50%ile and 95%ile) breakthrough of iron or breakthrough at very low concentrations below WQS;
- There is no predicted breakthrough of phenanthrene (50%ile and 95%ile) at the base of the unsaturated zone;
- The predicted concentrations of all substances (50%ile and 95%ile) at distances over 450 m (groundwater discharge point to surface water) are within background surface water quality;
- The predicted concentrations of chloride, sodium and sulphate increase rapidly after 30 to 40 years, then reducing by 35% after a further 60 years (see plots in **Appendix O** of this document);
- Travel times for the maximum concentrations to reach the 50 m compliance point are 22 to 32 years (95%ile). For the nearest receptor (private well) located 250 m downgradient of the borrow pits, travel times are predicted to be about 30 to 40 years (95%ile). Travel times to the nearest surface watercourse (450 m downgradient) are predicted to be about 35-52 years (95%ile) (see plots in **Appendix O** of this document).

Due to conservative assumptions regarding the source term concentrations and rates of infiltration, these results are considered to represent a conservative (worst case) assessment. These calculated values take no account of the benefit from the addition of lime.

Table 8.7 LandSim predicted maximum concentrations and travel times (base scenario)

Compliance point	**Substance**	**Maximum concentration at compliance point in mg/l [Travel time to maximum concentration in yrs]**		**Background quality (mg/l) as min-mean-max**	**WQS (mg/l)**
		50%ile	**95%ile**		
50m	Chloride	100 [18]	149 [25]	GW: 27-68-90 SW: 55-108-330	250 (DWS)
250m		95 [28]	132 [32]		
450m		91 [35]	124 [35]		
50m	Sodium	64 [19]	129 [23]	GW: 10-24-50 SW: 20-56-152	200 (DWS)
250m		57 [28]	111 [30]		
450m		53 [37]	100 [37]		
50m	Sulphate	113 [30]	169 [32]	GW: 27-67-99 SW: 2-57-379	250 (DWS)
250m		99 [39]	142 [40]		
450m		92 [53]	128 [52]		
50m	Ammoniacal-N	0.28 [34]	0.60 [22]	GW: 0.008-0.13-0.72 SW: 0.007-0.62-5.46	0.39 (DWS) 1.1 (EQS)
250m		0.27 [30]	0.57 [40]		
450m		NB	NB		
50m	Iron	NB	NB	GW: 0.02-0.12-0.409 SW: 0.007-0.87-4.86	0.2 (DWS) 1 (EQS)
250m		NB	NB		
450m		NB	NB		
Base of UZ	Phenanthrene	<1x10^{-5}	<1x10^{-5}	GW: <1x10^{-5}	1x10^{-4}

Notes: a) GW- Groundwater. SW – Surface water. UZ- unsaturated zone.
WQS- water quality standard. DWS- Drinking Water Standard. EQS- Environmental Quality Standard. NB- no breakthrough above background groundwater quality.
EQS for ammoniacal-nitrogen is WFD EQS for "Moderate" quality and Type 7 river (alkalinity over 200 mg/l as $CaCO_3$)
In the absence of EQS, MRV or DWS for phenanthrene, the WQS used is the DWS for the sum of four PAHs (benzo(b)fluoranthene, benzo(ghi)perylene, benzo(k)fluoranthene and indeno(1,2,3-c,d)pyrene).

Lime Treatment Scenario

The results for the lime treatment scenario show that:

- The predicted maximum concentrations of sulphate, chloride and sodium in groundwater 50 to 450 m downgradient of the borrow pits are lower than without lime treatment (base scenario). Maximum concentrations continue to be above background groundwater quality, but below DWS for the both 50%ile and 95%ile predictions;
- Lime treatment of the infill has limited effect on the predicted maximum concentrations of ammoniacal-nitrogen in groundwater. The maximum concentrations (50%ile) at 50 m downgradient of the pits are marginally above groundwater background, but these decrease to

within background concentrations at distances over 250 m and are not considered to be significant;

- There is no predicted (50%ile and 95%ile) breakthrough or breakthrough at very low concentrations of iron below WQS and within background groundwater and surface water quality;
- There is no predicted breakthrough of phenanthrene (50%ile and 95%ile) at the base of the unsaturated zone;
- The predicted concentrations of all substances at distances over 450 m (discharge to surface water at Minsmere-Walberswick Heaths & Marshes SSSI) are within background surface water quality;
- Concentrations of chloride, sodium and sulphate are predicted to increase rapidly after 30 to 40 years to maximum concentrations below the base scenario (no lime treatment), and then after 50 to 80 years concentrations reduce to similar levels to the base scenario;
- Travel times are slightly longer than the base scenario (no lime treatment). Travel times for maximum concentrations to reach the 50 m compliance point are 20 to 55 years (95%ile). For the nearest receptor (private well) located 250 m downgradient of the borrow pits, travel times are predicted to be about 35 to 50 years (95%ile). Travel times to the nearest surface watercourse (at about 450 m distance downgradient) are predicted to be about 40-60 years (95%ile).

The results indicate that lime treatment of the infill is likely to reduce the risks to groundwater and surface water due to : the rate of drainage through the infill decreases (permeability of the infill is reduced and pore water is used in hydration reactions); the mobility of most substances is lower under higher pH conditions, and precipitation of sodium and sulphate hydrates is likely to reduce the source term concentrations.

Table 8.8 LandSim predicted maximum concentrations and travel times (lime treatment scenario)

Compliance point	**Maximum concentration at compliance point in mg/l [Travel time to maximum concentration in yrs]**			**Background quality (mg/l) as min-mean-max [a]**	**WQS (mg/l)**
	Substance	**50%ile**	**95%ile**		
50m	Chloride	89 [17]	122 [18]	GW: 27-68-90 SW: 55-108-330	250 (DWS)
250m		85 [30]	115 [32]		
450m		82 [40]	110 [40]		
50m	Sodium	46 [19]	78 [20]	GW: 10-24-50 SW: 20-56-152	200 (DWS)
250m		43 [30]	72 [35]		
450m		42 [39]	69 [39]		
50m	Sulphate	96 [36]	134 [35]	GW: 27-67-99 SW: 2-57-379	250 (DWS)
250m		89 [51]	121 [47]		
450m		84 [58]	114 [62]		
50m	Ammoniacal-N	0.28 [40]	0.59 [56]	GW: 0.008-0.13-0.72 SW: 0.007-0.62-5.46	0.39 (DWS) 1.1 (EQS)
250m		NB	NB		

Compliance point	Maximum concentration at compliance point in mg/l [Travel time to maximum concentration in yrs]			Background quality (mg/l) as min-mean-max [a]	WQS (mg/l)
	Substance	**50%ile**	**95%ile**		
450m		NB	NB		
50m	Iron	0.171 [430]	NB	GW: 0.02-0.12-0.409 SW: 0.007-0.87-4.86	0.2 (DWS) 1 (EQS)
250m		NB	NB		
450m		NB	NB		
Base of UZ	Phenanthrene	$<1x10^{-5}$	$<1x10^{-5}$	GW: $<1x10^{-5}$	$1x10^{-4}$

Notes: a) GW- Groundwater. SW – Surface water. UZ- unsaturated zone.
WQS- water quality standard. NB- no breakthrough above background groundwater quality.
EQS for ammoniacal-nitrogen is WFD EQS for "Moderate" quality and Type 7 river (alkalinity over 200 mg/l as $CaCO_3$)
In the absence of EQS, MRV or DWS for phenanthrene, the WQS used is the DWS for the sum of four PAHs (benzo(b)fluoranthene, benzo(ghi)perylene, benzo(k)fluoranthene and indeno(1,2,3-c,d)pyrene).

Stockpiling Scenario

The results for the stockpiling scenario show that:

- The predicted maximum concentrations of chloride, sodium, sulphate and ammoniacal-N at the 50%ile are above background groundwater quality but are below the DWS at all compliance points (50 m, 250 m and 450 m) except for the highest settlement/drainage rate (360 mm/yr) where concentrations are slightly above DWS at 50 m, but these decrease to below WQS at distances over 250 m;
- The predicted 95%ile maximum concentrations of chloride, sodium and sulphate could exceed DWS for settlement/drainage rates above 90 mm/yr at 50 m and 120 mm/yr at 250 m. At the discharge point to surface water (450 m), there is only a small exceedance of DWS for sodium and sulphate;
- The predicted 95%ile maximum concentrations of ammoniacal-nitrogen in groundwater at 50 m are within baseline groundwater quality except for the higher settlement/drainage rates (>360 mm/yr), but these decrease to within background at distances over 250 m and are not considered to be significant; and
- There is no predicted (50%ile and 95%ile) breakthrough of iron for all settlement/drainage rates; and
- There is no predicted breakthrough of phenanthrene (50%ile and 95%ile) at the base of the unsaturated zone.

The impact on water quality from stockpiling over the borrow pits is mainly associated with the initial squeezing out of pore water over a relatively short time scale (~5 years). For best case assumptions for settlement, the LandSim calculations indicate that the impact on water quality would not exceed WQS at the 50%ile or 95%ile predictions at distances over 250 m with only marginal exceedances at 50 m for sulphate and sodium.

For average case assumptions for settlement and 50%ile predictions, concentrations would only marginally exceed WQS at a distance of 50 m whilst for 95%ile predictions, the impact on water quality would not exceed or marginally exceed WQS (for sulphate and sodium) at distances over 450 m. However, the calculations overestimate settlement (and also water impact) because they take no account of the reduced settlement behavior of the infill following lime treatment.

Table 8.9 LandSim predicted maximum concentrations and travel times at 50%ile (stockpiling scenario)

Compliance point	Substance	Maximum concentration at compliance point in mg/l 50%ile [Travel time to maximum concentration in yrs]					Background quality(mg/l) a	WQS (mg/l)
		No stockpiling	5m stockpile (best estimate)		5m stockpile (average estimate)			
		90mm/yr over 2 years (Base Run)[b]	90mm/yr over 5 years[b]	120mm/yr over 5 years[b]	290mm/yr over 5 years[b]	360mm/yr over 5 years[b]		
50m	Chloride	101 [19]	131 [15]	148 [14]	241 [13]	277 [14]	GW: 27-68-90 SW: 55-108-330	250 (DWS)
250m		95 [28]	110 [21]	118 [18]	170 [18]	189 [17]		
450m		92 [35]	103 [30]	108 [31]	141 [22]	156 [23]		
50m	Sodium	62 [20]	90 [14]	105 [14]	189 [13]	220 [13]	GW: 10-24-50 SW: 20-56-152	200 (DWS)
250m		57 [28]	72 [21]	79 [19]	125 [19]	143 [17]		
450m		55 [37]	65 [28]	69 [27]	99 [23]	110 [23]		
50m	Sulphate	115 [30]	158 [28]	171 [27]	247 [24]	272 [23]	GW: 27-67-99 SW: 2-57-379	250 (DWS)
250m		100 [39]	126 [38]	135 [39]	178 [34]	193 [35]		
450m		91 [52]	111 [53]	117 [52]	146 [45]	157 [45]		
50m	Ammoniacal-N	0.30 [27]	0.31 [25]	0.32 [26]	0.35 [27]	0.35 [26]	GW: 0.008-0.13-0.72 SW: 0.007-0.62-5.46	0.39 (DWS) 1.1 (EQS)
250m		0.29 [35]	0.286 [35]	0.290 [23]	0.290 [31]	0.290 [23]		
450m		0.27 [37]	0.282 [39]	0.282 [40]	0.285 [32]	0.285 [28]		
Base of UZ	Phenanthrene	<1x10^{-5}	<1x10^{-5}	<1x10^{-5}	<1x10^{-5}	<1x10^{-5}	GW: <1x10^{-5}	1x10^{-4}

Notes: a) GW – Groundwater. SW – Surface water. UZ- unsaturated zone.
b) Drainage rates equivalent to predicted settlement (Table 8.5).
Predicted maximum iron concentrations are below background water quality. NB- no breakthrough above background
EQS for ammoniacal-nitrogen is WFD EQS for "Moderate" quality and Type 7 river (alkalinity over 200 mg/l as $CaCO_3$)
WQS- water quality standard. In the absence of EQS, MRV or DWS for phenanthrene, the WQS used is the DWS for the sum of four PAHs (benzo(b)fluoranthene, benzo(ghi)perylene, benzo(k)fluoranthene and indeno(1,2,3-c,d)pyrene).

Table 8.10 LandSim predicted maximum concentrations and travel times at 95%ile (stockpiling scenario)

Compliance point	Substance	Maximum concentration at compliance point in mg/l 95%ile [Travel time to maximum concentration in yrs]					Background quality(mg/l) a	WQS (mg/l)
		No stockpiling	5m stockpile (best estimate)		5m stockpile (average estimate)			
		90mm/yr over 2 years (Base Run)^b	90mm/yr over 5 years^b	120mm/yr over 5 years^b	290mm/yr over 5 years^b	360mm/yr over 5 years^b		
50m	Chloride	148 [21]	203 [15]	233 [16]	416 [17]	487 [17]	GW: 27-68-90 SW: 55-108-330	250 (DWS)
250m		138 [32]	160 [26]	174 [19]	264 [21]	300 [21]		
450m		124 [44]	143 [32]	152 [32]	209 [28]	232 [26]		
50m	Sodium	134 [20]	203 [16]	243 [16]	470 [15]	560 [16]	GW: 10-24-50 SW: 20-56-152	200 (DWS)
250m		112 [30]	153 [23]	174 [23]	292 [19]	338 [19]		
450m		105 [33]	131 [30]	145 [31]	226 [26]	258 [26]		
50m	Sulphate	176 [30]	260 [21]	295 [21]	488 [18]	553 [19]	GW: 27-67-99 SW: 2-57-379	250 (DWS)
250m		150 [42]	203 [28]	226 [28]	335 [26]	371 [26]		
450m		131 [42]	174 [35]	188 [35]	263 [32]	292 [35]		
50m	Ammoniacal-N	0.59 [35]	0.630 [20]	0.64 [22]	0.76 [19]	0.83 [19]	GW: 0.008-0.13-0.72 SW: 0.007-0.62-5.46	0.39 (DWS) 1.1 (EQS)
250m		0.57 [45]	0.591 [21]	0.59 [28]	0.61 [26]	0.61 [25]		
450m		NB	0.580 [30]	0.580 [31]	0.590 [25]	0.590 [29]		
Base of UZ	Phenanthrene	$<1x10^{-5}$	$<1x10^{-5}$	$<1x10^{-5}$	$<1x10^{-5}$	$<1x10^{-5}$	GW: $<1x10^{-5}$	$1x10^{-4}$

Notes: a) GW – Groundwater. SW – Surface water. UZ- unsaturated zone
b) Drainage rates equivalent to predicted settlement (Table 8.5).
Predicted maximum iron concentrations are below background water quality. NB- no breakthrough above background
EQS for ammoniacal-nitrogen is WFD EQS for “Moderate” quality and Type 7 river (alkalinity over 200 mg/l as $CaCO_3$)
WQS- water quality standard. In the absence of EQS, MRV or DWS for phenanthrene, the WQS used is the DWS for the sum of four PAHs (benzo(b)fluoranthene, benzo(ghi)perylene, benzo(k)fluoranthene and indeno(1,2,3-c,d)pyrene).

Impact on Surface Water

The LandSim model results indicate that for all scenarios the predicted concentrations of ammonium, chloride and iron in groundwater 450 m downgradient of the borrow pits (discharge point to surface water) are within the baseline range for surface water and therefore there is no risk of derogation of surface water quality from these contaminants.

The predicted concentrations of sulphate and sodium in groundwater discharge to surface water are above the average baseline surface water quality for the stockpiling scenario only. However, the calculations overestimate settlement (and also water impact) because they take no account of the reduced settlement behavior of the infill following lime treatment.

In practice, groundwater discharge to the Minsmere-Walberswick Heaths & Marshes SSSI will be diffuse rather than a point discharge. The groundwater discharge rate to surface water is relatively low and in the range 100 to 200 m^3/d or about 0.25 m^3/d/m (width of aquifer). Given the area over which groundwater discharge is likely to occur (hundreds of m^2), it is highly unlikely that any change in the concentrations of sulphate or sodium in surface water would be measurable in relation to the observed variation in surface water quality.

Water Framework Directive (WFD)

The results of the risk assessment have shown the potential for concentrations of chloride, sulphate and sodium to be above the groundwater baseline but that there are no exceedences of EQSs for these parameters at compliance points. For surface water, the only parameter in modelled groundwater discharge which is predicted to be above the typical baseline (as average concentrations) is sulphate. Concentrations in the groundwater discharge to surface water are below the EQSs and as the discharge will be over a wide area it is considered to be very unlikely that there will be any discernible change in surface water quality. It is therefore predicted that there will be no risk of the proposed backfill affecting the status of the groundwater body and the associated surface water receptors including the Minsmere-Walberswick Heaths & Marshes SSSI.

Hazardous Substances (Phenanthrene) (Groundwater)

Leachate tests (Section 8.4.3) have indicated the potential for some PAHs (hazardous substances) to be leached at low concentrations (mean concentration <0.03 µg/l). Phenanthrene was included in the assessment as this substance recorded the highest PAH concentration (**Table 5.7**) and is one of the more mobile PAHs. The results of the LandSim run summarised in **Tables 8.7 to 8.10** show no breakthrough of phenanthrene at the water table and therefore this substance is not of concern.

The pH buffering calculations have also concluded that the pH of acidic drainage would be neutralised within the unsaturated zone and therefore the migration of hazardous metals (e.g. mercury) does not represent a risk. The addition of lime and an increase in pH will further reduce the risk of migration of hazardous metals.

Sensitivity Analyses

The results of the sensitivity analysis are shown in **Table 8.11** for sulphate (non-hazardous pollutant) and phenanthrene (hazardous substance) as an example.

Table 8.11 LandSim predicted maximum concentrations and travel times Sensitivity Scenarios

Scenario	Determinand	Compliance Point	Maximum concentration in the Crag in mg/l [Travel time to maximum concentration]		Background quality (mg/l)	Water Quality Standard (mg/l)
			50%ile	95%ile		
Base Scenario	Sulphate	50m	96 [36]	134 [35]	GW: 27-67-99 SW: 2-57-379	250 (DWS)
		250m	89 [51]	121 [47]		
		450m	84 [58]	114 [62]		
	Phenanthrene	Base UZ	<1x10^{-5}	<1x10^{-5}	GW: <1x10^{-5}	1x10^{-4}
Source term						
Decrease in the rate of decline of sulphate source term by 50%	Sulphate	50m	140 [32]	214 [28]	GW: 27-67-99 SW: 2-57-379	250 (DWS)
		250m	121 [52]	177 [47]		
		450m	111 [66]	159 [57]		
Decrease in source concentrations by 50%	Sulphate	50m	91 [31]	127 [28]	GW: 27-67-99 SW: 2-57-379	250 (DWS)
	Phenanthrene	Base UZ	<1x10^{-5}	<1x10^{-5}	GW: <1x10^{-5}	1x10^{-4}
Increase in the rate of decline of the sulphate source term by 50%	Sulphate	50m	103 [30]	148 [26]	GW: 27-67-99 SW: 2-57-379	250 (DWS)
Infiltration rate and backfilling period						
Increase in infiltration rate during backfilling phase by 50%	Sulphate	50m	115 [32]	169 [26]	GW: 27-67-99 SW: 2-57-379	250 (DWS)
	Phenanthrene	Base UZ	<1x10^{-5}	<1x10^{-5}	GW: <1x10^{-5}	1x10^{-4}
Decrease in infiltration rate during backfilling phase by 50%	Sulphate	50m	116 [27]	173 [26]	GW: 27-67-99 SW: 2-57-379	250 (DWS)
	Phenanthrene	Base UZ	<1x10^{-5}	<1x10^{-5}	GW: <1x10^{-5}	1x10^{-4}
Increase in backfilling period from 2 to 5 years	Sulphate	50m	158 [29]	276 [19]	GW: 27-67-99 SW: 2-57-379	250 (DWS)
	Phenanthrene	Base UZ	<1x10^{-5}	<1x10^{-5}	GW: <1x10^{-5}	1x10^{-4}
Decrease in Infiltration rate during backfilling phase (10-30-50 mm/yr) and restored phase (5-15-25mm/yr)	Sulphate	50m	98 [40]	139 [35]	GW: 27-67-99 SW: 2-57-379	250 (DWS)
	Phenanthrene	Base UZ	<1x10^{-5}	<1x10^{-5}	GW: <1x10^{-5}	1x10^{-4}
Decrease in Infiltration rate during backfilling phase (20-60-100 m) and increase in backfilling period (5years)	Sulphate	50m	145 [28]	231 [28]	GW: 27-67-99 SW: 2-57-379	250 (DWS)
	Phenanthrene	Base UZ	<1x10^{-5}	<1x10^{-5}	GW: <1x10^{-5}	1x10^{-4}
Unsaturated Zone Thickness						
	Sulphate	50m	117 [29]	175 [20]		

Scenario	Determinand	Compliance Point	Maximum concentration in the Crag in mg/l [Travel time to maximum concentration]		Background quality (mg/l)	Water Quality Standard (mg/l)
			50%ile	95%ile		
Decrease in unsaturated zone thickness by 50% (minimum 2 m)	Phenanthrene	Base UZ	<1x10^{-5}	<1x10^{-5}	GW: <1x10^{-5}	1x10^{-4}
Hydraulic conductivity of saturated zone						
Increase in hydraulic conductivity of saturated zone by 50%	Sulphate	50m	106 [27]	149 [21]	GW: 27-67-99 SW: 2-57-379	250 (DWS)
		250m	95 [32]	131 [30]		
		450m	89 [44]	120 [35]		
Decrease in hydraulic conductivity of saturated zone by 50%	Sulphate	50m	137 [38]	220 [35]	GW: 27-67-99 SW: 2-57-379	250 (DWS)
		250m	110 [63]	168 [39]		
		450m	98 [80]	144 [57]		

Notes: a) GW – Groundwater. SW – Surface water. UZ- unsaturated zone. DWS- Drinking Water Standard

The analysis has shown that the model is sensitive to source the term (concentration and rate of decline), length of the backfilling phase, drainage rates and hydraulic conductivity but even using a variation of ± 50% the results are still consistent with the findings in the Base Scenario. The results are less sensitive with respect to changing the thickness of the unsaturated zone.

Changes in the thickness of the unsaturated zone do not alter the findings of the assessment for hazardous and non-hazardous substances. However, given the lower calcium carbonate and organic content of the sand and gravels compared with the Crag, the final design will need to ensure an appropriate thickness of unsaturated zone is retained below the excavation.

The model results are sensitive to the hydraulic conductivity of the saturated zone (e.g. dilution of groundwater flow), however the choice of parameter values is considered to be conservative given the analysis of the site investigation permeability tests which are likely to have underestimated the hydraulic conductivity of the Crag due to the small drawdown measured.

Discussion of Results

The results indicate that:

- The sand and gravels which underlie the borrow pits are characterised by a moderate calcium carbonate content and pH buffering calculations have shown that solution of this mineral would buffer any acidic drainage from the backfill and therefore the migration of hazardous metals (e.g. cadmium and mercury) does not represent a risk. The addition of lime and resulting increase in pH would reduce the risk of migration of these metals;
- Phenanthrene, and by implication, or other organics, are not predicted to breakthrough at the water table below the borrow pit locations;

- Chloride, sulphate, sodium and iron are not predicted to exceed water quality standards (DWS or EQS) in groundwater or in surface water receptors from the 50% and 95%ile LandSim model runs;
- Chloride, sodium and sulphate concentrations are likely to increase above baseline in groundwater 50-450 m down gradient of the borrow pits;
- Concentrations of ammoniacal-nitrogen, chloride and sodium in groundwater discharge to surface water are within the baseline range and therefore are not predicted to impact on surface water quality;
- Sulphate concentrations in groundwater discharge to surface water are predicted to be above the typical surface water baseline range, (as average concentrations) but are significantly below the EQS of 400 mg/l and below peak concentrations in surface water. Based on the conceptual model, the discharge of groundwater to surface water will be diffuse (over an extensive area) and given the nature of the surface water system no discernible change in surface water quality is predicted;
- The addition of lime is likely to reduce the risk to groundwater as: permeability of the infill is reduced; pore water is used in hydration reactions; the mobility of most substances is lower under higher pH conditions, and precipitation of sodium and sulphate hydrates is likely to reduce the source term; and
- The impact on water quality from stockpiling over the borrow pits is mainly associated with the initial squeezing out of pore water over a relatively short time scale (~5 years). For best case assumptions for settlement, the LandSim calculations indicate that the impact on water quality would not exceed WQS at the 50%ile or 95%ile predictions at distances over 250 m with only marginal exceedances at 50 m for sulphate and sodium. For average case assumptions for settlement and 50%ile predictions, concentrations would only marginally exceed WQS at a distance of 50 m whilst for 95%ile predictions, the impact on water quality would not exceed or marginally exceed WQS (for sulphate and sodium) at distances over 450 m. However, the calculations overestimate settlement (and also water impact) because they take no account of the reduced settlement behavior of the infill following lime treatment.

Monitoring and Action Plan

Infilling the borrow pits would be supported by a groundwater monitoring programme. Action levels at these monitoring points would be agreed with the Environment Agency. A remediation plan would be developed which would be implemented if trigger levels were exceeded. The general principles for a monitoring and action plan for the borrow pits is set out in **Appendix J** of this document.

9. Conclusions and Recommendations

9.1 Conclusions

The excavation of the area within the cut-off wall of the SZC power station development site may generate approximately 1.1 Mm^3 of alluvium. This material is not suitable as engineering fill around power station structures. This report has assessed the suitability of the material to provide backfill to a borrow pit(s) which may be excavated to win Crag Sand as engineering fill and for landscaping purposes. EDF Energy identified potential locations (Areas 2, 3 and 4) for the borrow pits (**Figure 1.1**), which would provide 973,500 m^3 of suitable engineering material, extending over a pit footprint area of 20 ha and an average excavation depth of 8 m. The risk assessment assumes a worst-case scenario in which all three borrow pits (Area 2, 3 and 4) would be used for backfilling of alluvium. Previous assessments also considered Area 1 which has not been taken forward as a potential borrow pit location. This depth would give a base of excavation at least 2 m above the maximum recorded and predicted groundwater levels.

The borrow pits are underlain by sand and gravels which overly the Crag Principal Aquifer. Groundwater flow below the borrow pits is towards the Minsmere-Walberswick Heaths & Marshes SSSI with discharge to ditches and streams which feed the marshes. A review of updated licensed and private water supply sources has identified two private sources down gradient of the borrow pits (at distances of 250 m and 370 m from the potential pit locations), but these properties are part of the EDF Energy Nuclear Generation Ltd Sizewell Estate and are therefore subject to management control by EDF Energy.

No new chemical testing data is available for the alluvium since the 2016 Risk Assessment. The human health risk assessment concluded that there are no unacceptable chronic risks to human health from use of extracted alluvium as backfill materials for the borrow pits. The conclusion applies to both on-site and off-site receptors. The final end-use of the borrow pits for agriculture is appropriate in this context. This result is consistent with the previous risk assessment findings from work undertaken in 2016.

No new ground gas monitoring data is available since the 2016 Risk Assessment. The ground gas risk assessment has concluded that the risk from the peat and alluvial soils proposed to be used as backfill for Areas 2, 3 and 4 is very low to low. Available gas monitoring data indicates the proposed backfill materials correspond to Characteristic Situation 1 to 2 (very low to low risk sources).

The geotechnical characteristics of the alluvium and peat have been reviewed and the results are consistent with the 2016 Risk Assessment findings. The material is characterised by high liquid and plastic limits which indicates that handling and management control will be required during excavation, placement and compaction of the material. The addition of lime will improve handling properties and mechanical strength of the material. The geotechnical properties of the material are suitable for the intended final agricultural or heathland end use.

Testing of the alluvium material has shown that it is characterised by high chloride and sodium concentrations, high pyrite concentrations, low heavy metal concentrations and non-detectable concentrations of organic compounds (VOCs, SVOCs) with the exception of some PAHs (e.g. phenanthrene) which was identified in some leaching tests at low concentrations (<0.1 ug/l).

The alluvium material is likely to be characterised by low permeability which will restrict drainage of the material. Excavation and placement of the material is likely to result in temporary exposure to the atmosphere and therefore as a worst case the initial drainage is assumed to be characterised by a high sulphate concentrations, but in the longer term conditions in the backfill would be expected to become anaerobic preventing further oxidation of pyrite and a decrease in sulphate concentrations in drainage.

The addition of lime will affect the rate and quality of the drainage. The main effects will be: a reduction in permeability of the fill; a reduction in pore water due to hydration of the lime; a rise in pH (e.g. no acidic drainage) and alkalinity, a reduction in the mobility of most metals; and the precipitation of sodium and sulphate hydrates within the alluvium.

The 2016 Risk Assessment for controlled waters has been updated to take account of; the revised borrow pit footprint, a site investigation undertaken in 2017 and the benefit of the addition of lime and temporary stockpiling over the infilled borrow pits. The findings from this updated assessment are:

- Base scenario (no lime treatment and no stockpiling on the borrow pits)
    - No breakthrough of phenanthrene at the base of the unsaturated zone;
    - No breakthrough above or breakthrough marginally above measured background concentrations for ammoniacal-nitrogen and iron in groundwater;
    - Small increase in concentrations of chloride, sodium and sulphate in groundwater downgradient of the borrow pits but no exceedances of WQS;
    - No impact on surface water (and therefore on the dependent habitats) from sodium and chloride as concentrations in groundwater discharge are within the measured baseline range for surface water; sulphate concentrations in groundwater (92 -128 mg/l) discharging to surface water are likely to be above the baseline, but are below 400 mg/l (EQS) and below peak concentrations in surface water. The groundwater discharge will also be diffuse (over an area) and therefore any change in surface water quality is unlikely to be measureable;
- Lime treatment scenario
    - The addition of lime reduced predicted maximum concentrations of sulphate, chloride and sodium with no significant changes in ammoniacal-N and iron. No breakthrough of phenanthrene at the water table is predicted;
    - There is likely to be a short-term increase in groundwater alkalinity beneath and downgradient of the borrow pits due to the addition of lime. However, a qualitative assessment indicates that concentrations in groundwater are unlikely to rise significantly above the measured baseline. It is therefore concluded that lime modification will not adversely affect surface water quality in the Minsmere & Walberswick Heath Marshes;
    - The sand and gravels which underly the borrow pits are characterised by a moderate calcium carbonate content and pH buffering calculations have shown that solution of this mineral would buffer any acidic drainage from the backfill and therefore no risk of a breakthrough of hazardous metals at the water table is predicted.
- Stockpiling scenario (5 m stockpile)
    - The impact on water quality from stockpiling over the borrow pits is mainly associated with the initial squeezing out of pore water over a relatively short time scale (about 5 years); and
    - Assuming best and average case properties of the alluvium it is concluded that a stockpile of less than 5 m is unlikely to adversely affect water quality. Although sulphate and sodium concentrations are predicted to exceed marginally the relevant WQSs at the discharge point to surface water, the predictions overestimate settlement (and therefore impact on water quality) because they take no account of the reduced settlement behavior of the infill following lime treatment.

9.2 Recommendations

As part of any lime improvement programme it is recommended that laboratory scale and field trials are carried out in order to assess the efficacy of the process and to define the optimum lime dosing rates. This can be done either in the laboratory on recovered samples of material (with the addition of lime being carried out in the laboratory), or in a demonstration area on site, prior to the bulk earthworks operations.

Tests should be carried out on untreated mixtures of the alluvium, and on lime-improved material in order to determine the efficacy of the process, and to assess the settlement characteristics likely to be exhibited by the treated material due to stockpiling. The testing should include, but not necessarily be limited to the tests listed in **Table 10.1**.

Table 10.1 Recommended laboratory testing

Test Description	**BS1377 Reference**	**Clause No**
Natural Moisture Content	Part 2	Clause 3
Atterberg Limits	Part 2	Clauses 4 & 5
Dry Density / Moisture Content Relationship	Part 4	Clause 3.3
Moisture Condition Value (MC Calibration)	Part 4	Clause 5
One Dimensional Consolidation	Part 5	Clause 3
Unconsolidated Undrained Triaxial Compression	Part 7	Clause 8

As peat materials will not undergo any appreciable improvement under lime treatment, careful management will be required to ensure that large bodies of peat are not deposited in the borrow pits. A large body of peat will be susceptible to large settlements, especially if placed close to the surface, and therefore large amounts of peat should not be deposited together (i.e. a lorry load of peat with no clay or silt) and consideration should therefore be given to reserving a segregation area for peat (either at the excavation site or at the borrow pits, where large bodies of peat can be stored and then mixed gradually into the material as backfilling progresses). Smaller clods of peat will be broken up and disseminated within the rest of the material by rotovation during lime addition and mixing.

The infilling operation will need to be supported by a materials management strategy to ensure that peat is distributed through the mass of fill.

Compliance monitoring and testing forms an integral part of lime improvement / stabilisation projects. A specification / CQA plan will be required to define the types and frequencies of acceptability and validation testing to be undertaken during the backfilling operation.

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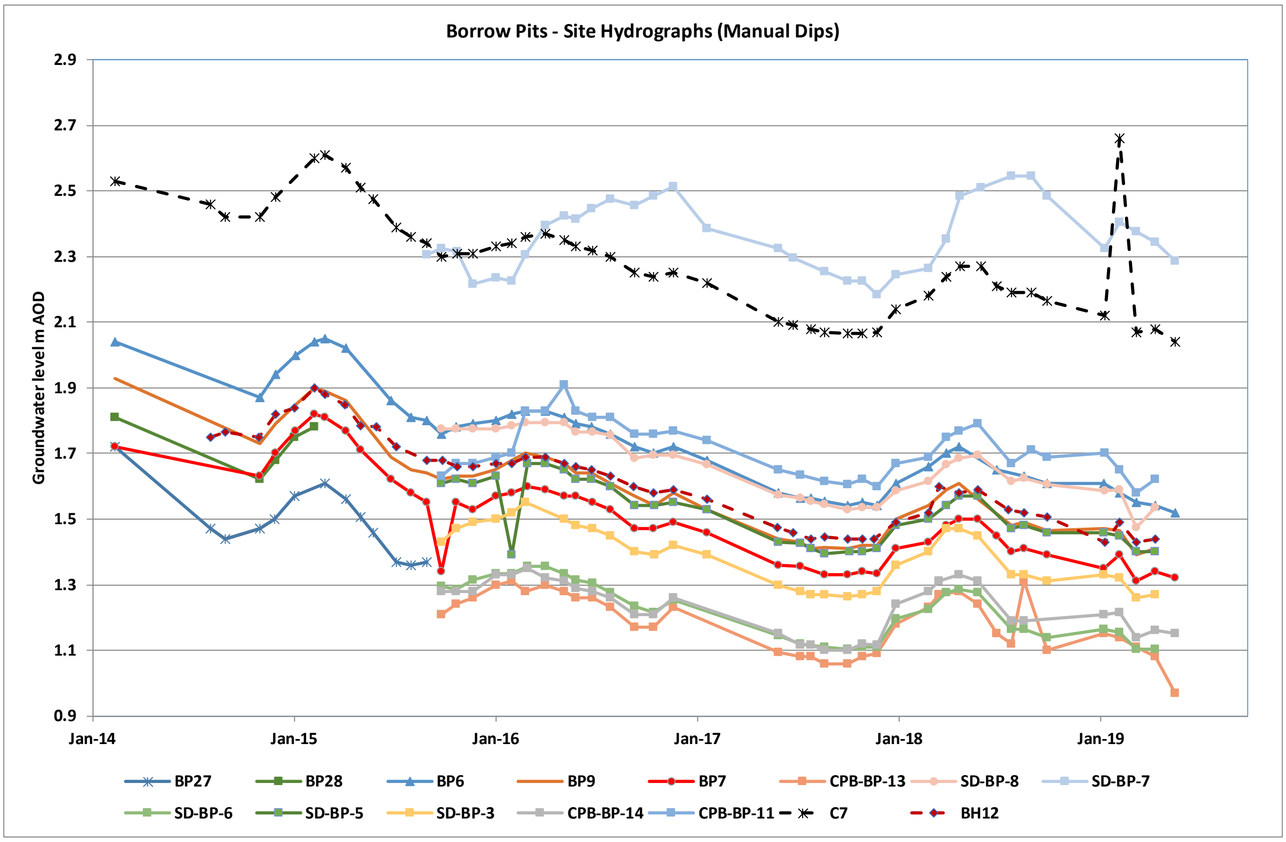
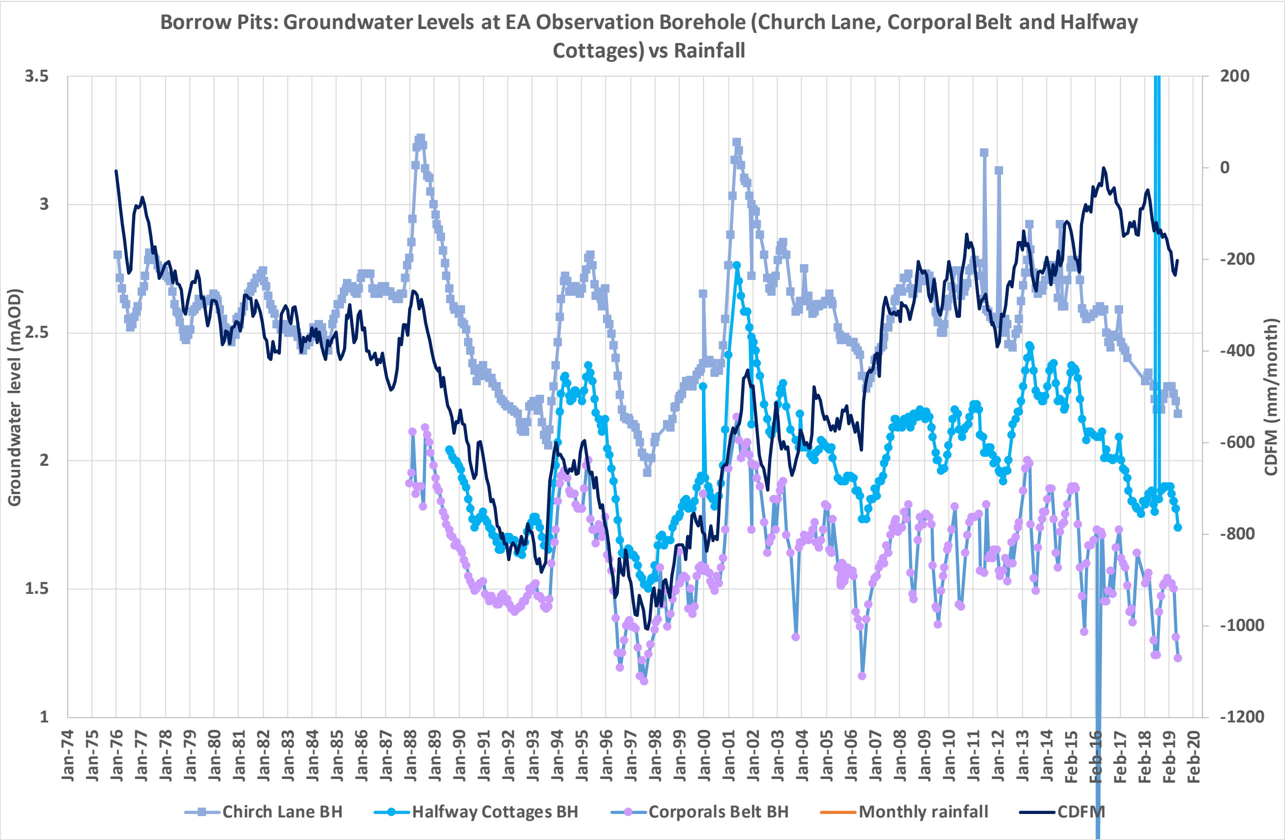
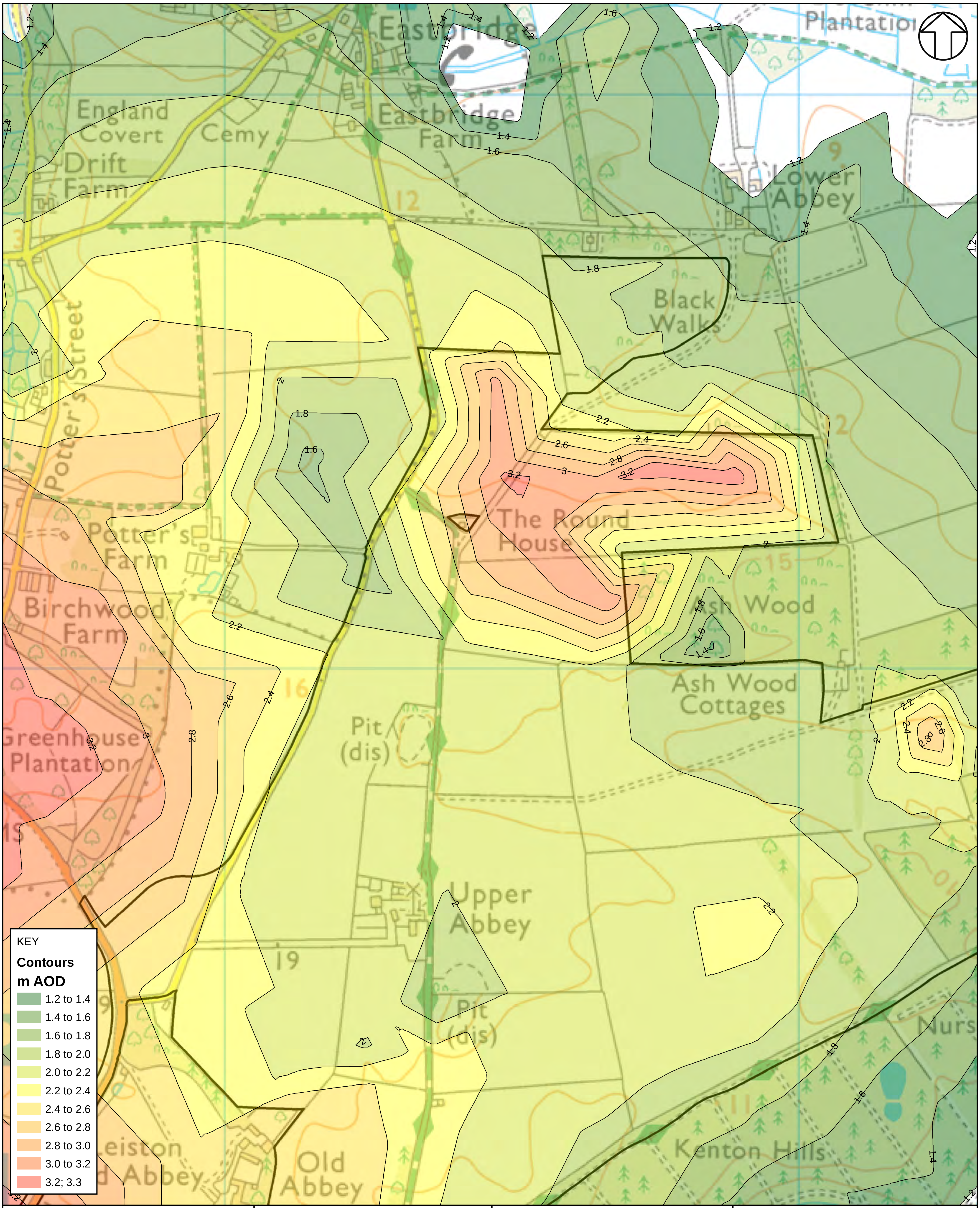
Appendix A
Groundwater Level Monitoring Data





CDFM- cumulative deviation from mean rainfall

Appendix B
Atkins Modelled Maximum Groundwater Levels



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MAXIMUM CONTOURS IN THE WATER TABLE AQUIFER - INTERMEDIATE SCENARIO (19 JANUARY 2023) DRAFT

DOCUMENT:
DRAFT

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DRAWING NO:

DATE:	DRAWN:	SCALE :
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0 60 120 180 240 300
M

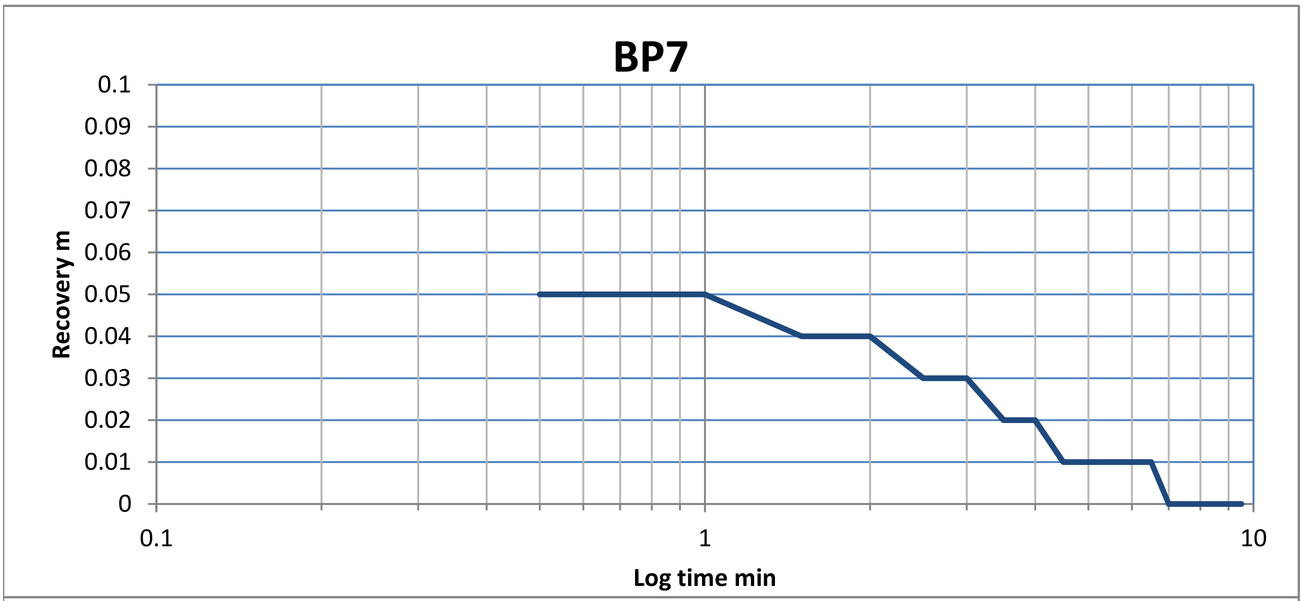
Appendix C
Pumping Out Permeability Tests

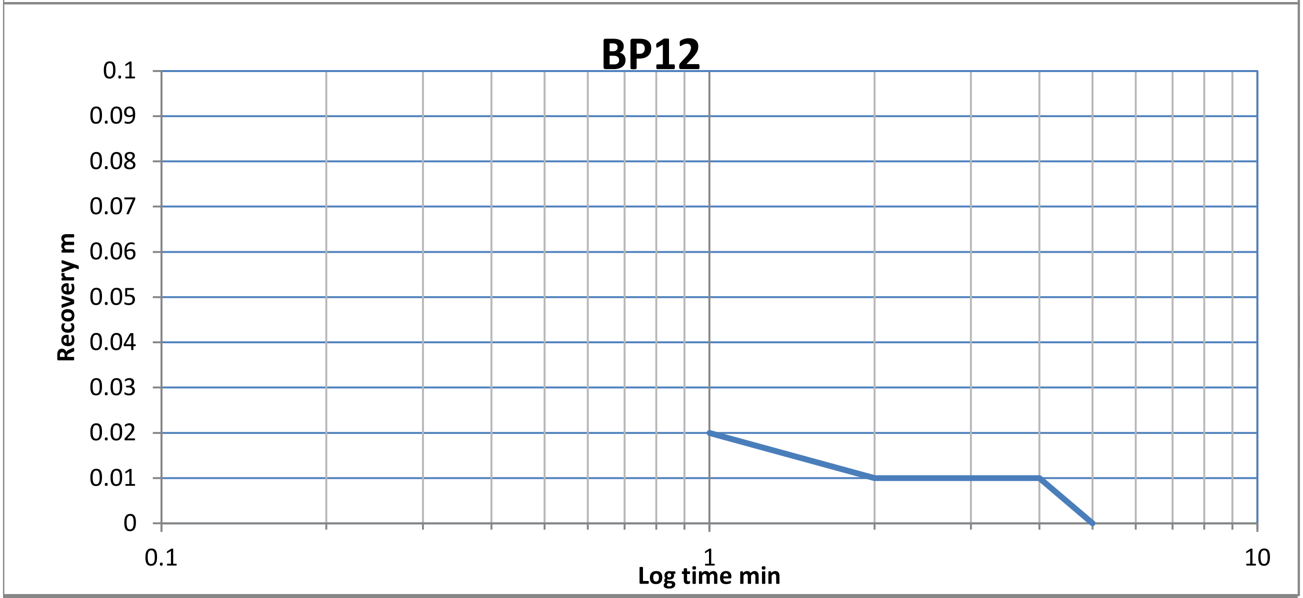
Appendix C Summary of Pumping Tests

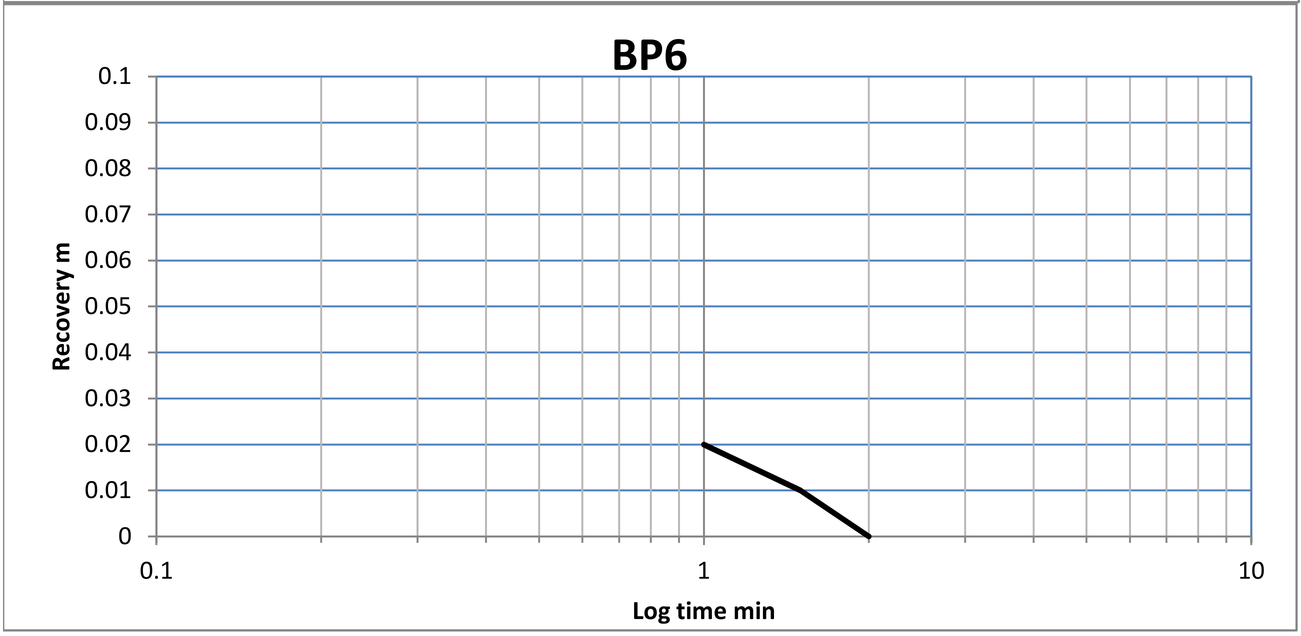
Borehole	Test or Screen Section m bgl	Depth to groundwater m bgl	Saturated length of test section m	Pumping rate m3/d	Duration of pumping mins	Drawdown in water level m	Time for recovery in water level min	Hydraulic conductivity m/d
C7	14 to 20	13.46	6	10	10	0.44	1.5	13
BP6	10 to 20	14.8	5.2	6	15	0.05	2	4
BP7	12 to 20			5	15	0.06	7	3
		14.91	5.1	5	15	0.06	4.5	
BP9	8 to 20	12.13	7.9	10	10	0.1	0.25	8
BP12	12 to 20			11	10	0.02	5	8
		10.49	8	11	10	0.02	5	
BP27	9 to 20			10	10	0.07	0.75	21
		10.62	9.4	10	60	0.07	0.75	
BP11	8 to 20	15.66	4.3	39	45	3.75	0.25	>5
BP13	8 to 20	10.95	9	39	50	7.3	0.2	>5
BP14	8 to 20	12.7	7.3	39	50	5.3	0.25	>5
SDP3	35 to 45m							>5

bgl below ground level

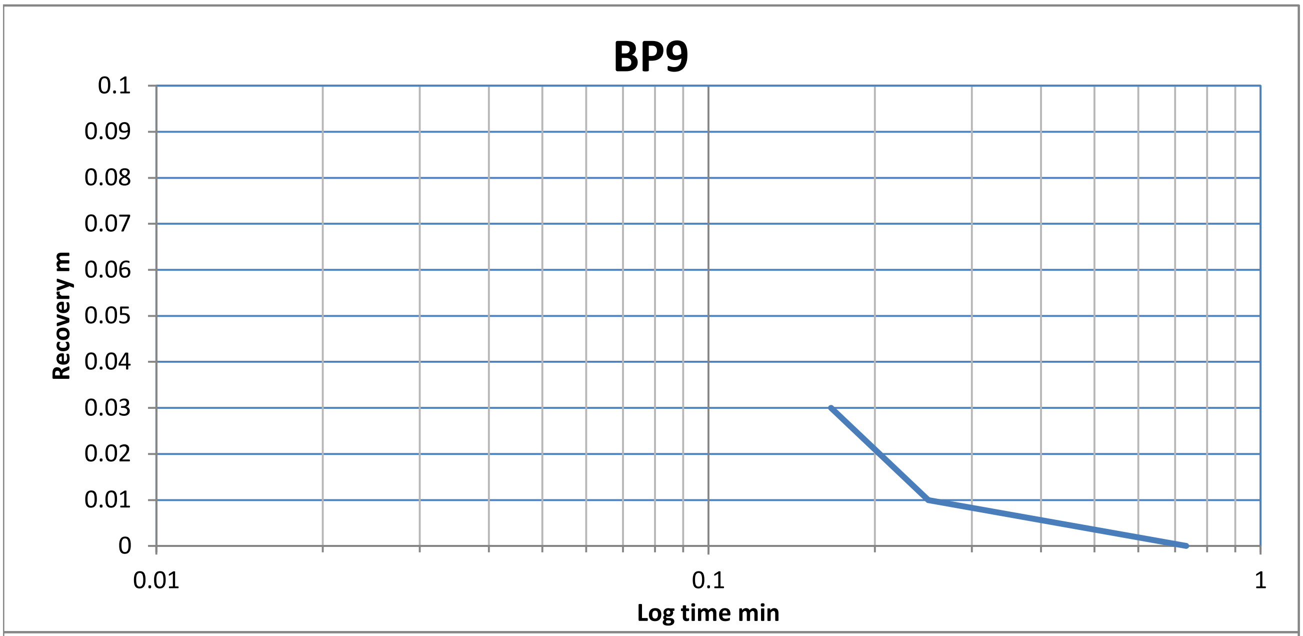
Recovery Plots

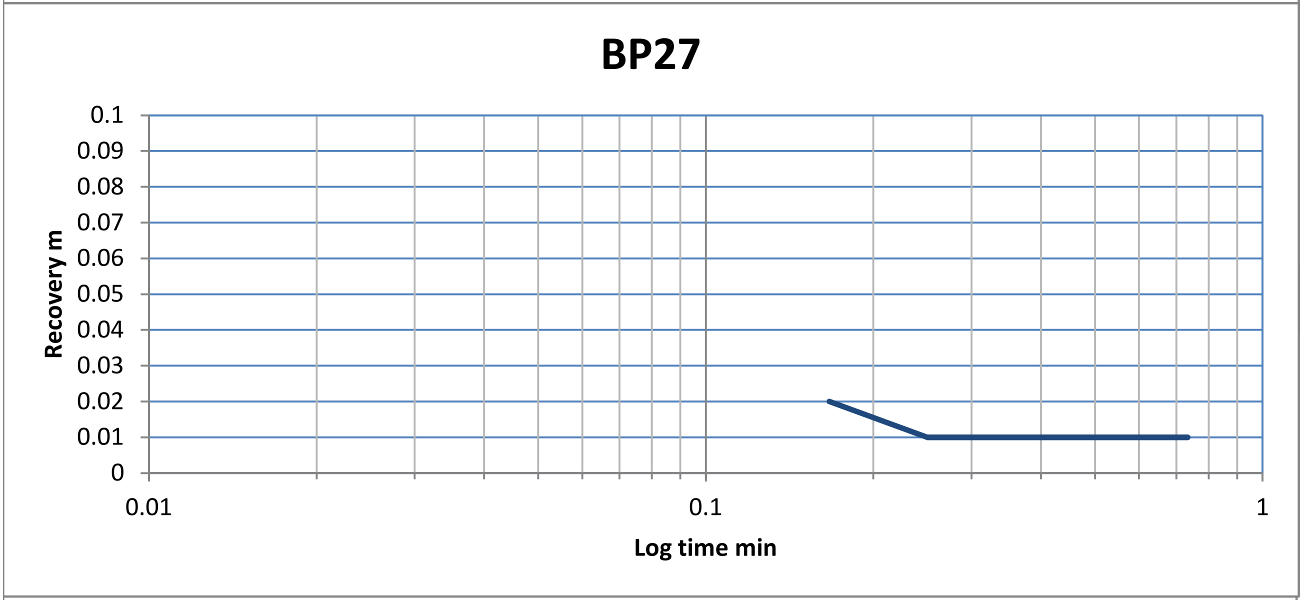


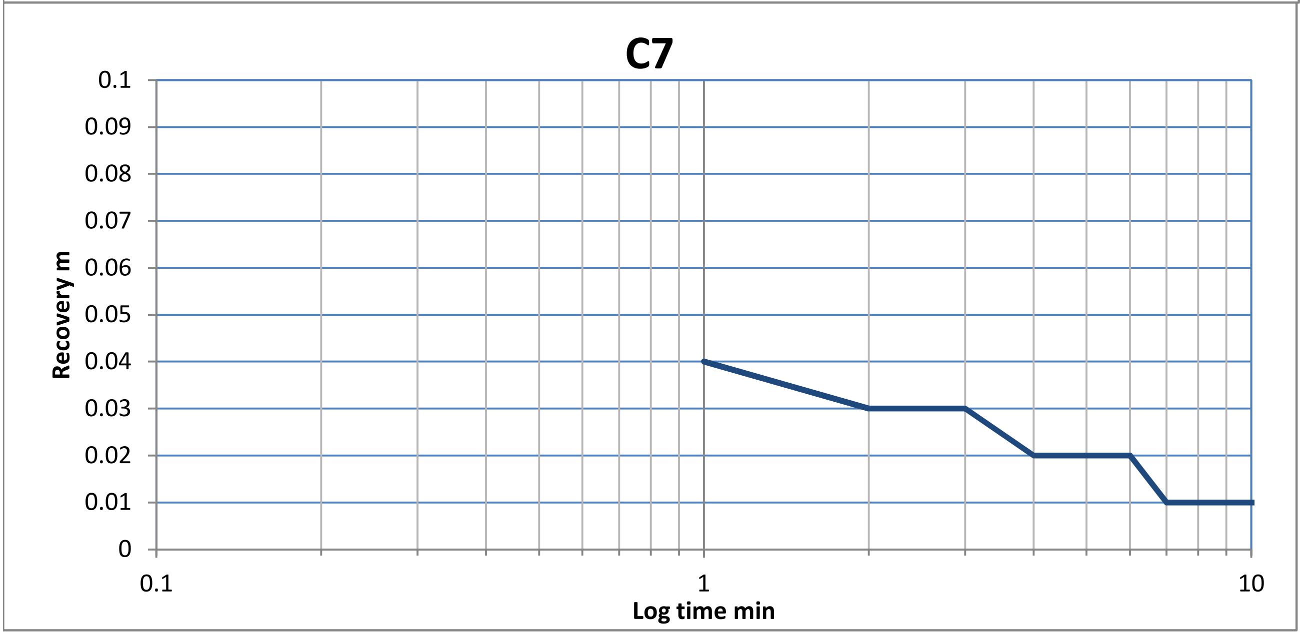




Recovery Plots







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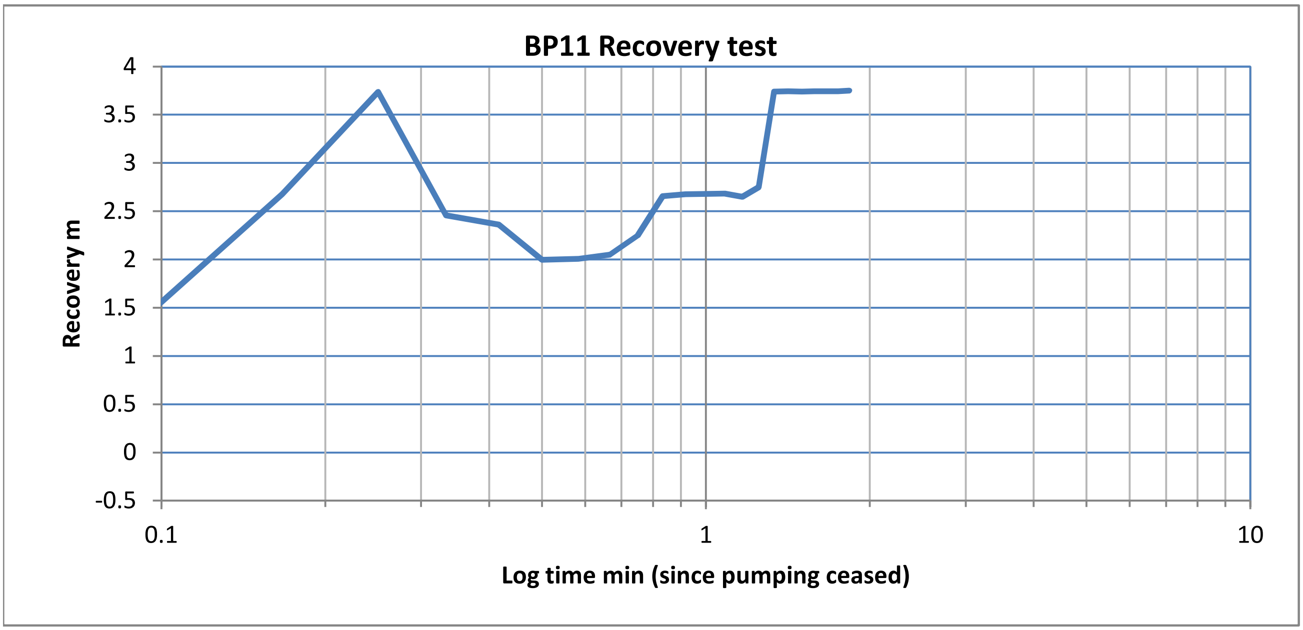
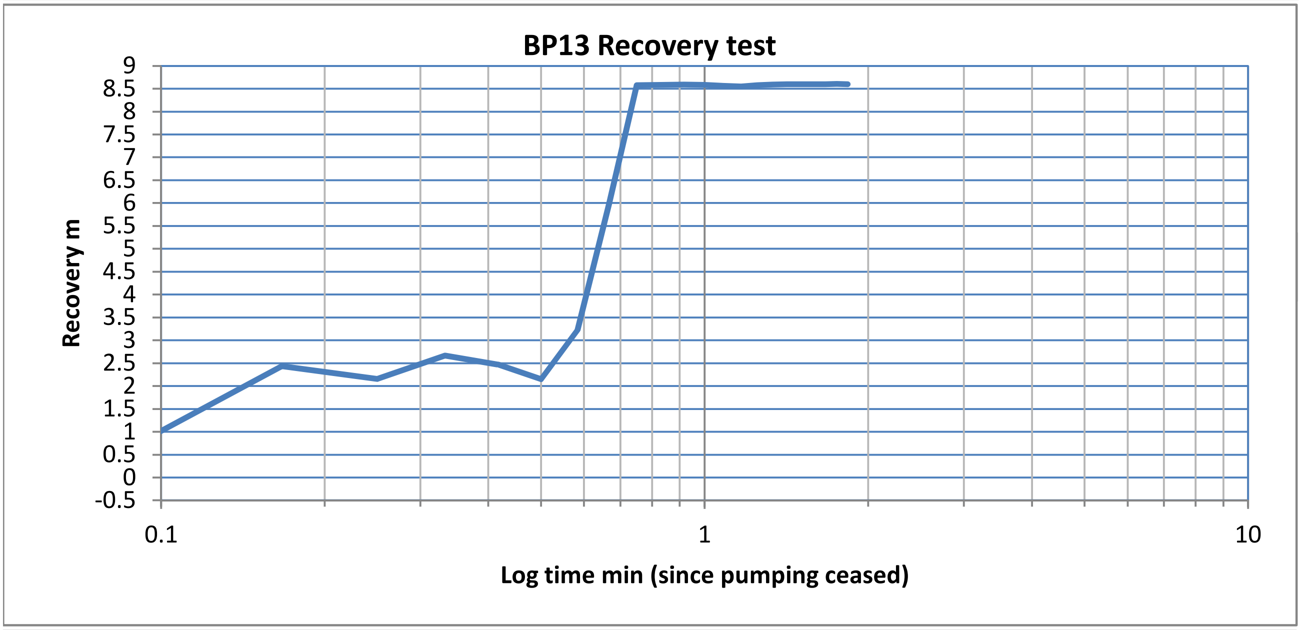
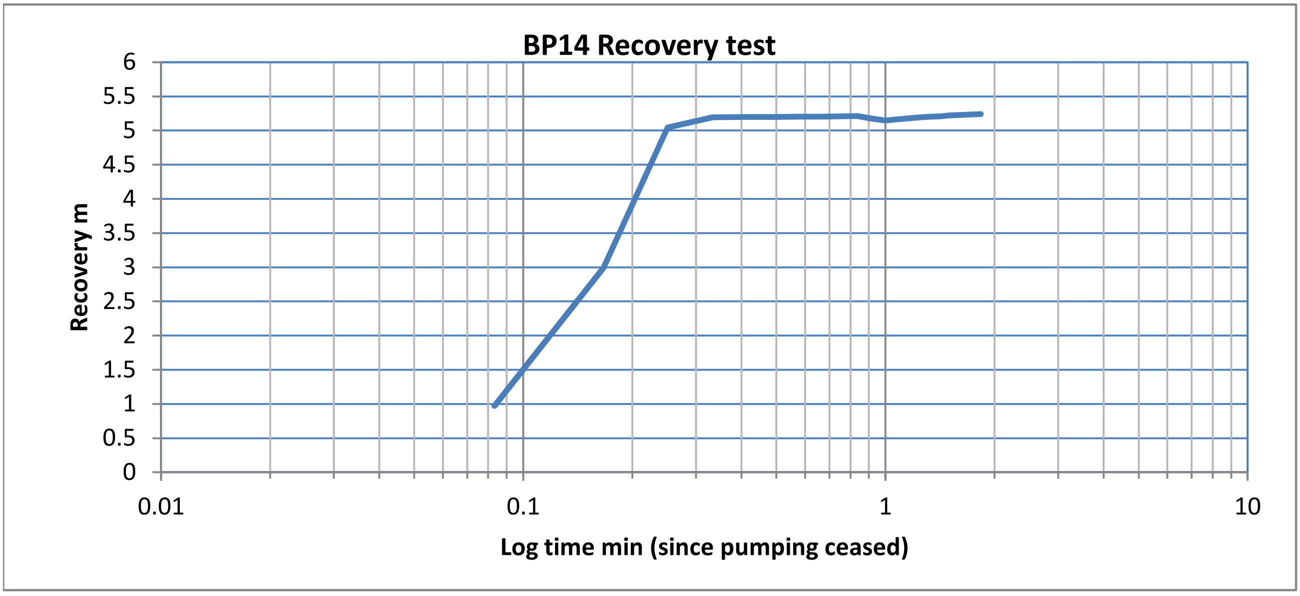
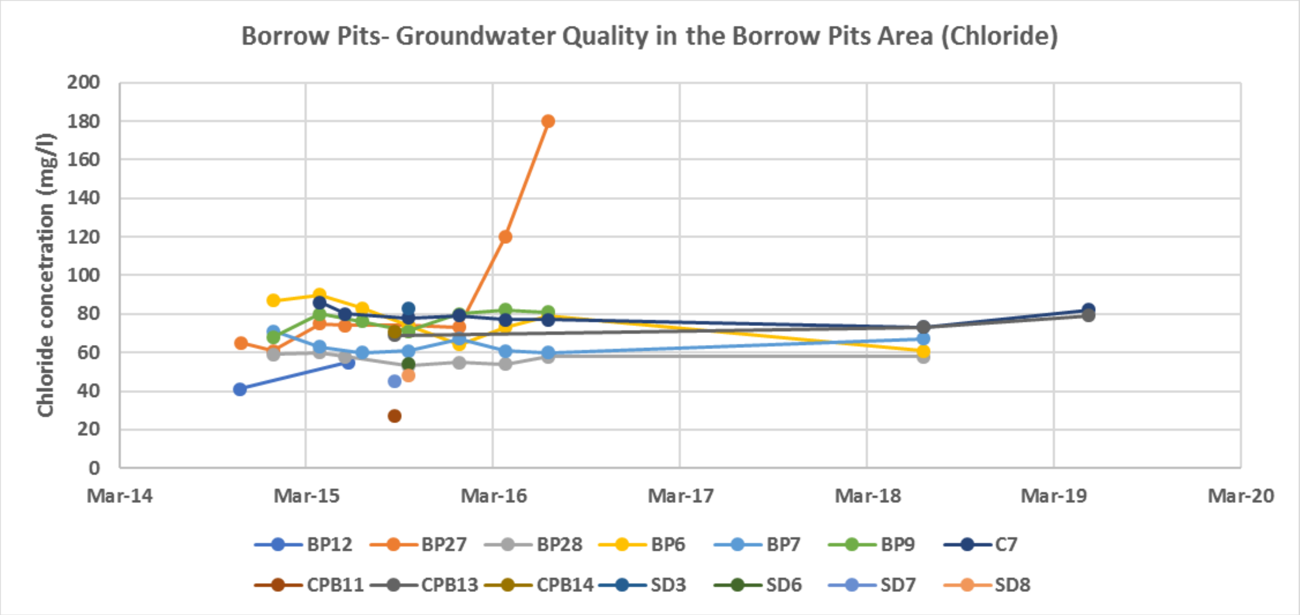
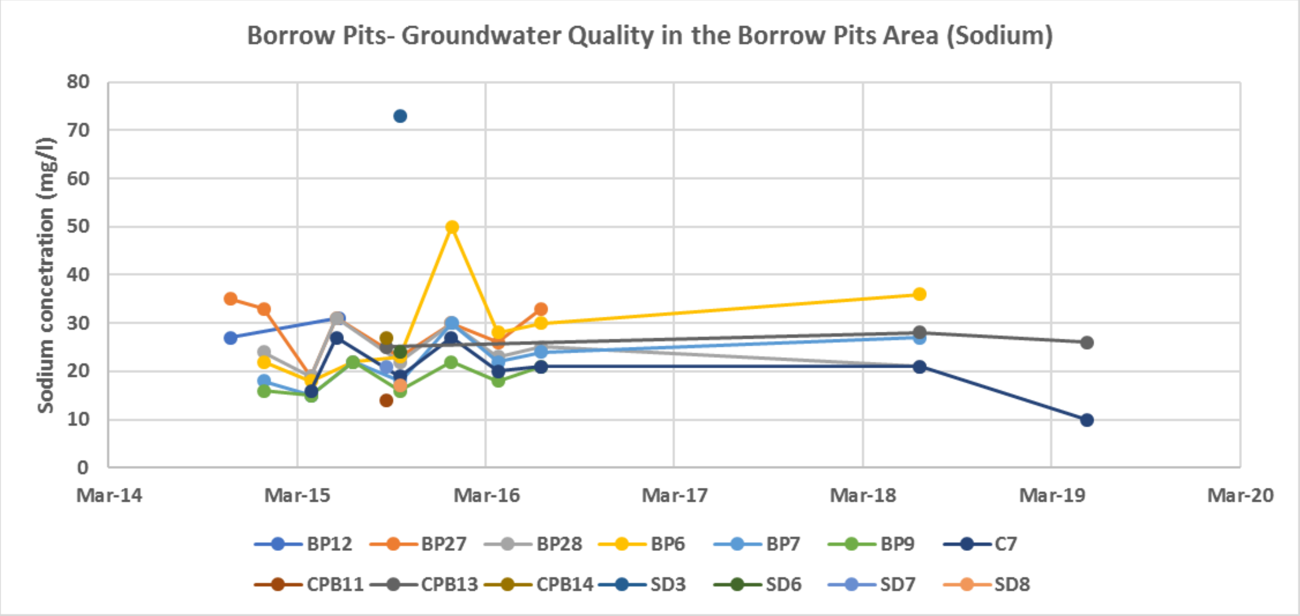


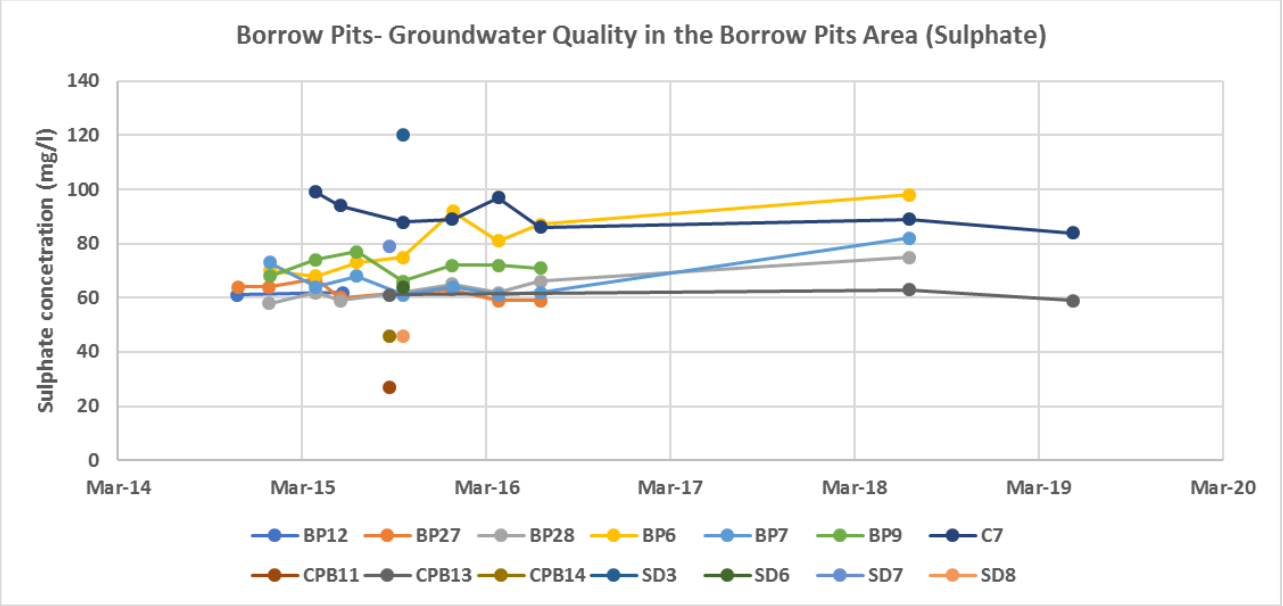


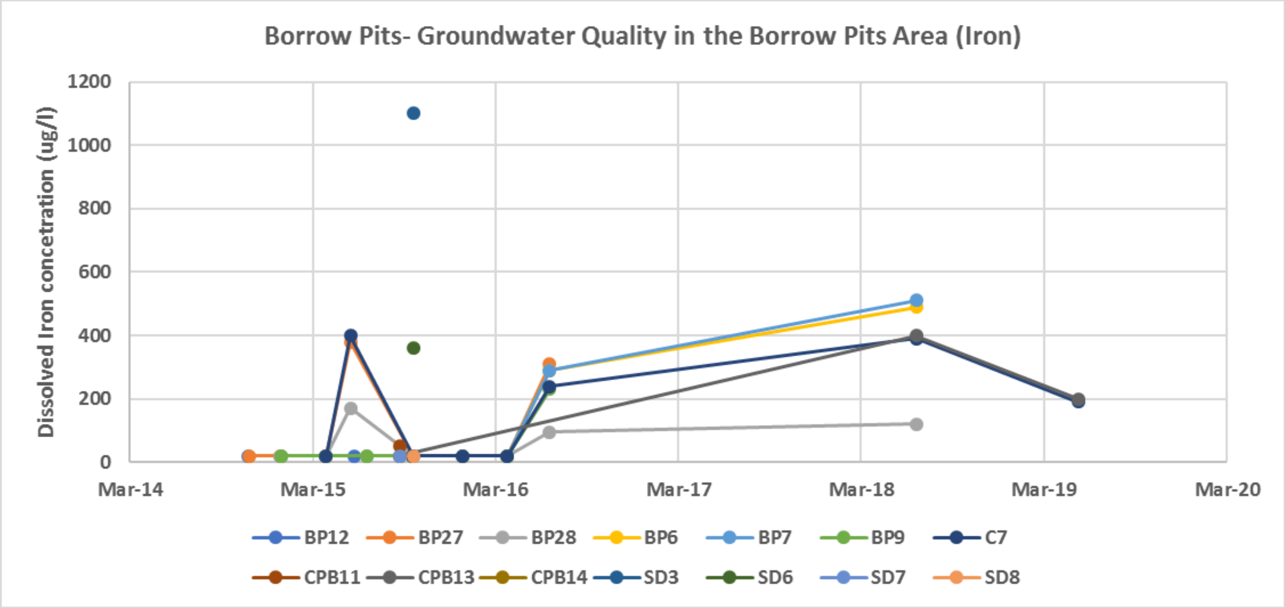


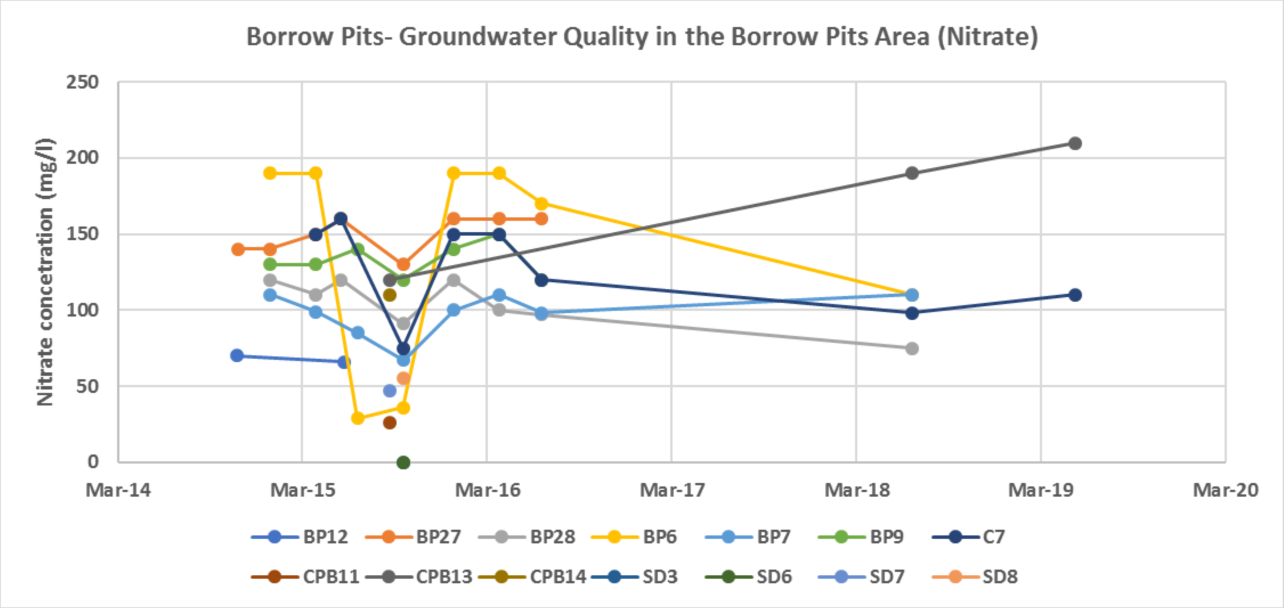
Appendix D
Groundwater Quality Monitoring Plots

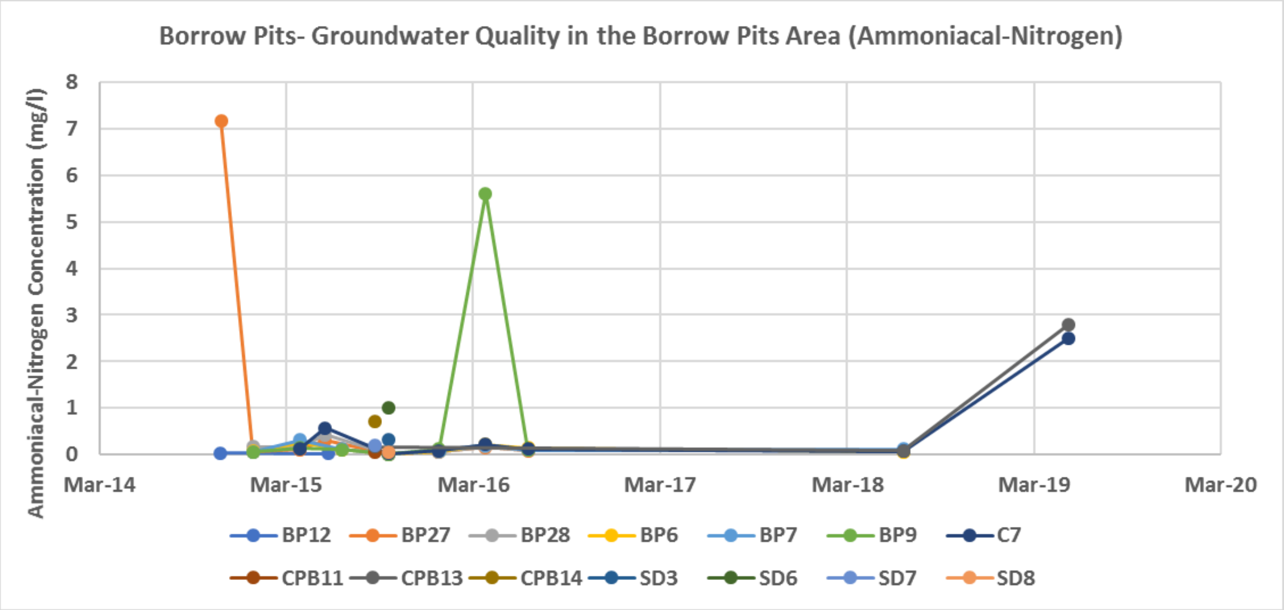

Borrow Pits- Groundwater Quality in the Borrow Pits Area (Chloride)
Chloride concetration (mg/l)
200
180
160
140
120
100
80
60
40
20
0
Mar-14
Mar-15
Mar-16
Mar-17
Mar-18
Mar-19
Mar-20
BP12
BP27
BP28
BP6
BP7
BP9
C7
CPB11
CPB13
CPB14
SD3
SD6
SD7
SD8


Borrow Pits- Groundwater Quality in the Borrow Pits Area (Sodium)
Sodium concetration (mg/l)
80
70
60
50
40
30
20
10
0
Mar-14
Mar-15
Mar-16
Mar-17
Mar-18
Mar-19
Mar-20
BP12
BP27
BP28
BP6
BP7
BP9
C7
CPB11
CPB13
CPB14
SD3
SD6
SD7
SD8

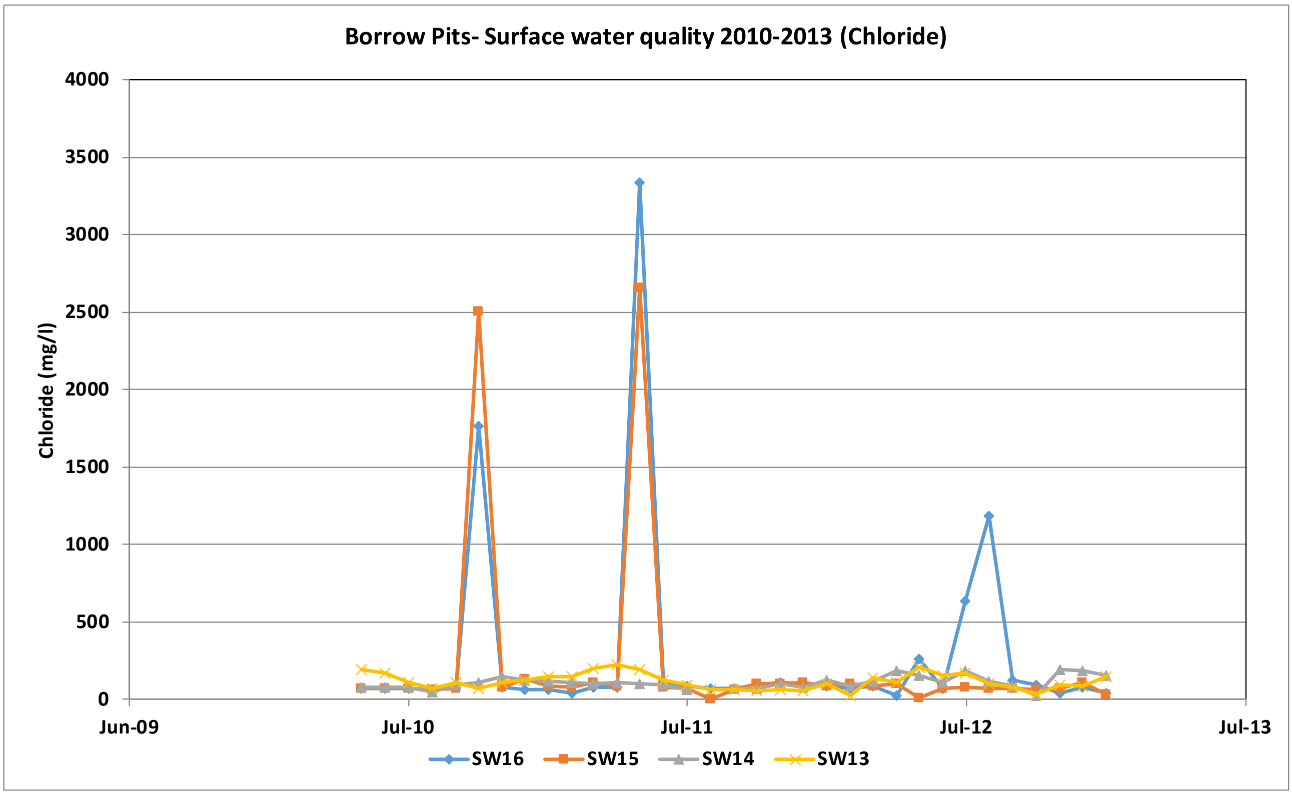

Borrow Pits- Groundwater Quality in the Borrow Pits Area (Sulphate)
Sulphate concetration (mg/l)
140
120
100
80
60
40
20
0
Mar-14
Mar-15
Mar-16
Mar-17
Mar-18
Mar-19
Mar-20
BP12
BP27
BP28
BP6
BP7
BP9
C7
CPB11
CPB13
CPB14
SD3
SD6
SD7
SD8

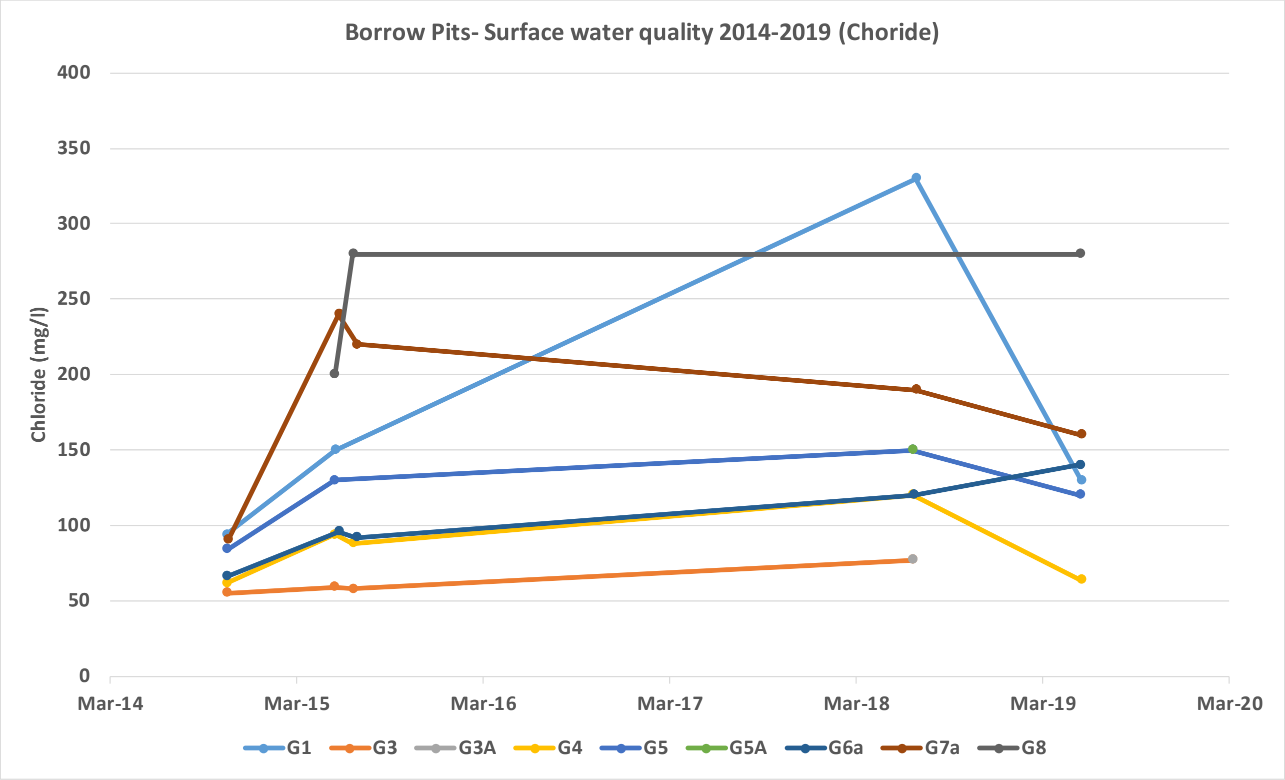

Borrow Pits- Groundwater Quality in the Borrow Pits Area (Iron)
Dissolved Iron concetration (ug/l)
1200
1000
800
600
400
200
0
Mar-14
Mar-15
Mar-16
Mar-17
Mar-18
Mar-19
Mar-20
BP12
BP27
BP28
BP6
BP7
BP9
C7
CPB11
CPB13
CPB14
SD3
SD6
SD7
SD8

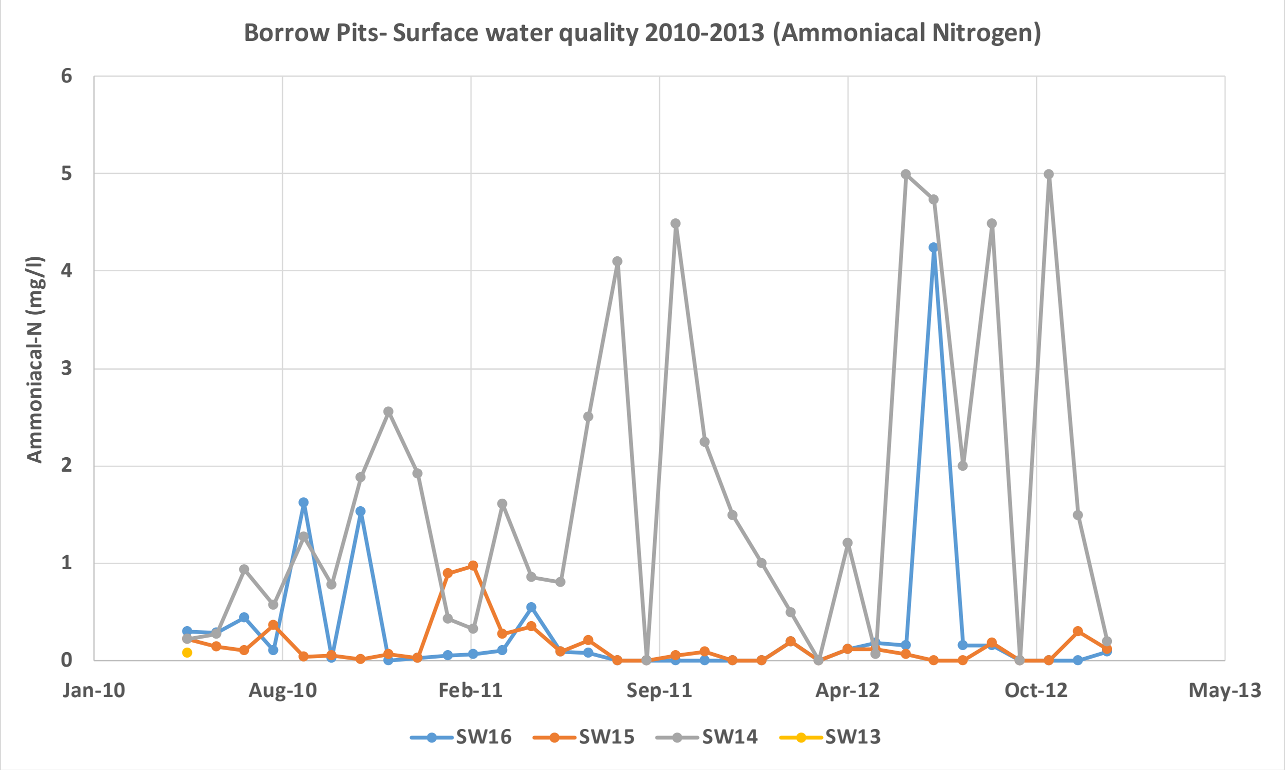

Borrow Pits- Groundwater Quality in the Borrow Pits Area (Nitrate)
Nitrate concetration (mg/l)
250
200
150
100
50
0
Mar-14
Mar-15
Mar-16
Mar-17
Mar-18
Mar-19
Mar-20
BP12
BP27
BP28
BP6
BP7
BP9
C7
CPB11
CPB13
CPB14
SD3
SD6
SD7
SD8

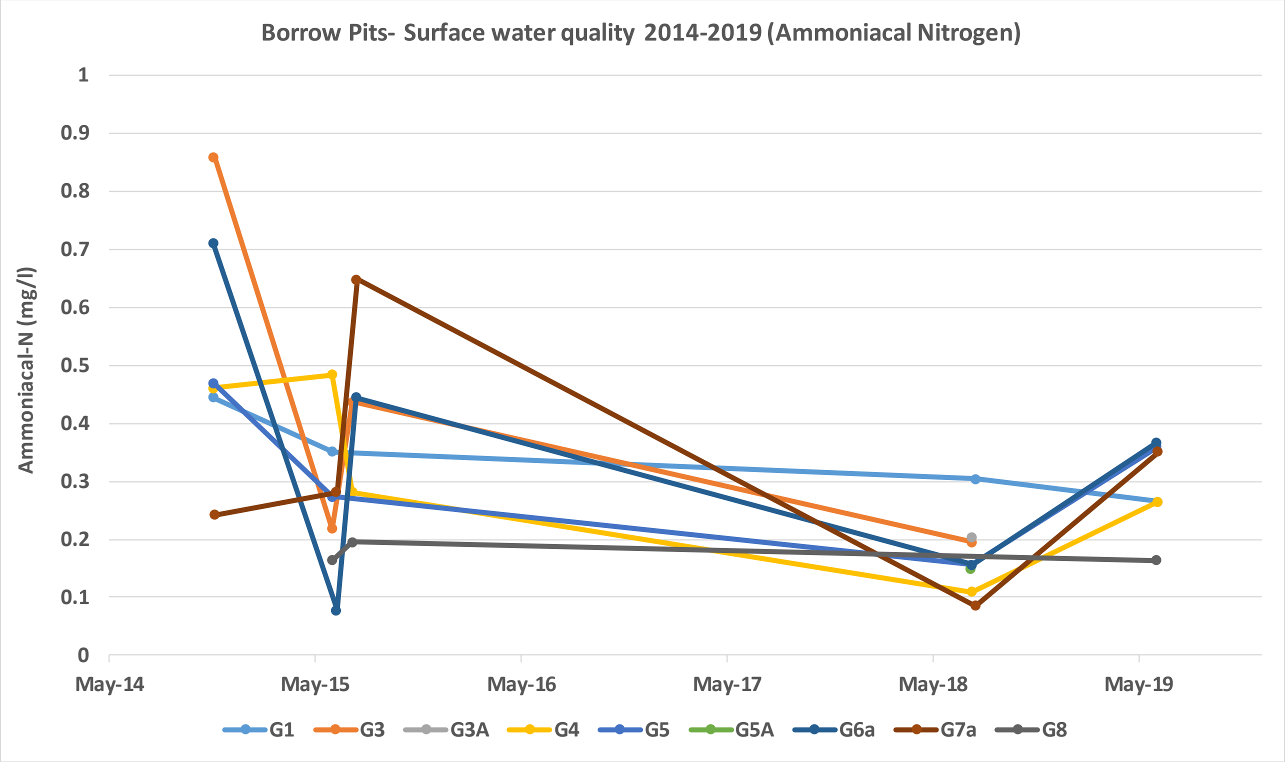

Borrow Pits- Groundwater Quality in the Borrow Pits Area (Ammoniacal-Nitrogen)
Ammoniacal-Nitrogen Concentration (mg/l)
8
7
6
5
4
3
2
1
0
Mar-14
Mar-15
Mar-16
Mar-17
Mar-18
Mar-19
Mar-20
BP12
BP27
BP28
BP6
BP7
BP9
C7
CPB11
CPB13
CPB14
SD3
SD6
SD7
SD8

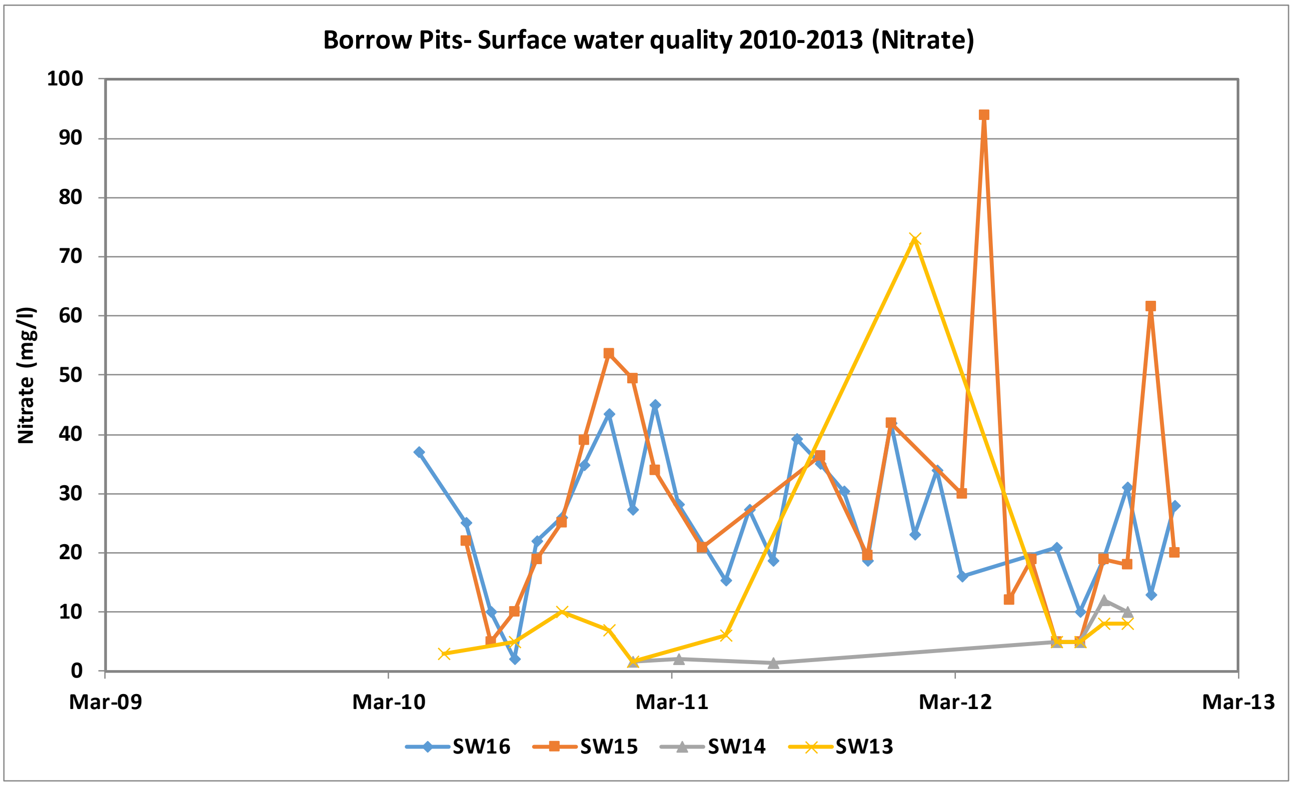
Appendix E
Surface Water Quality Monitoring Plots

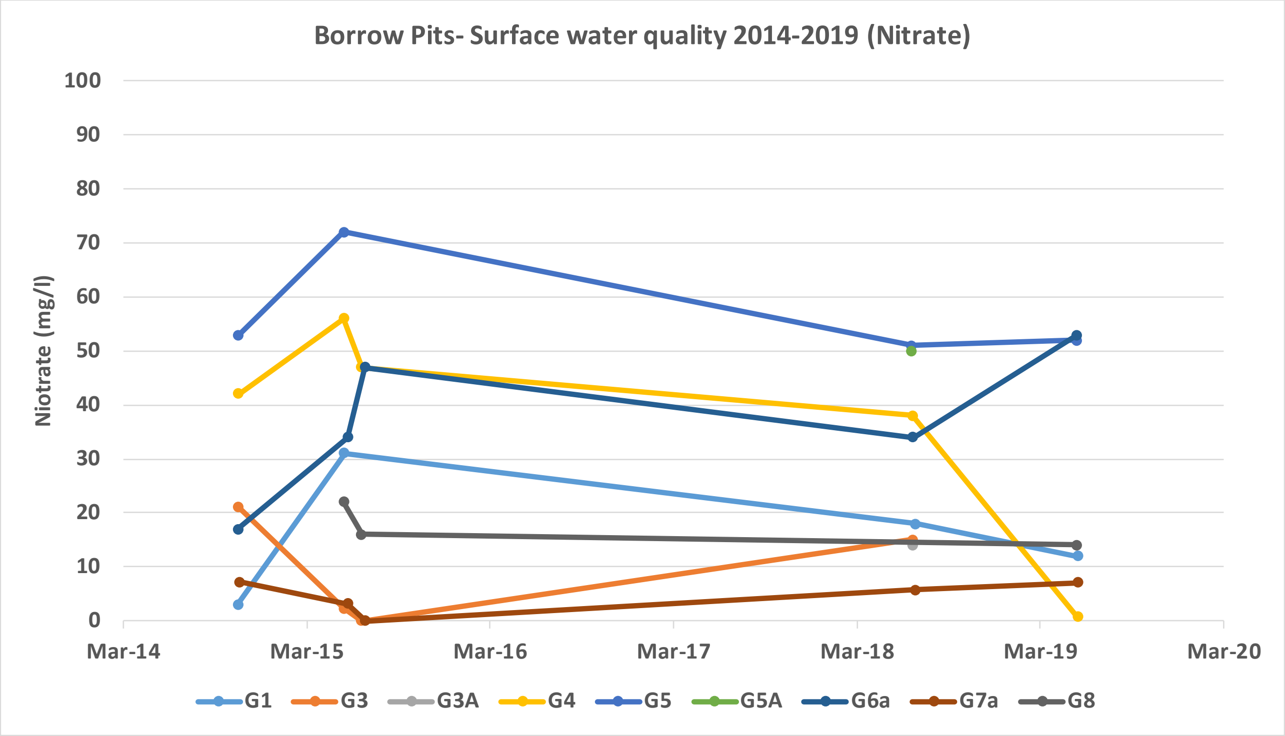

Borrow Pits- Surface water quality 2010-2013 (Chloride)
Chloride (mg/l)
4000
3500
3000
2500
2000
1500
1000
500
0
Jun-09
Jul-10
Jul-11
Jul-12
Jul-13
SW16
SW15
SW14
SW13


Borrow Pits- Surface water quality 2014-2019 (Choride)
Chloride (mg/l)
400
350
300
250
200
150
100
50
0
Mar-14
Mar-15
Mar-16
Mar-17
Mar-18
Mar-19
Mar-20
G1
G3
G3A
G4
G5
G5A
G6a
G7a
G8

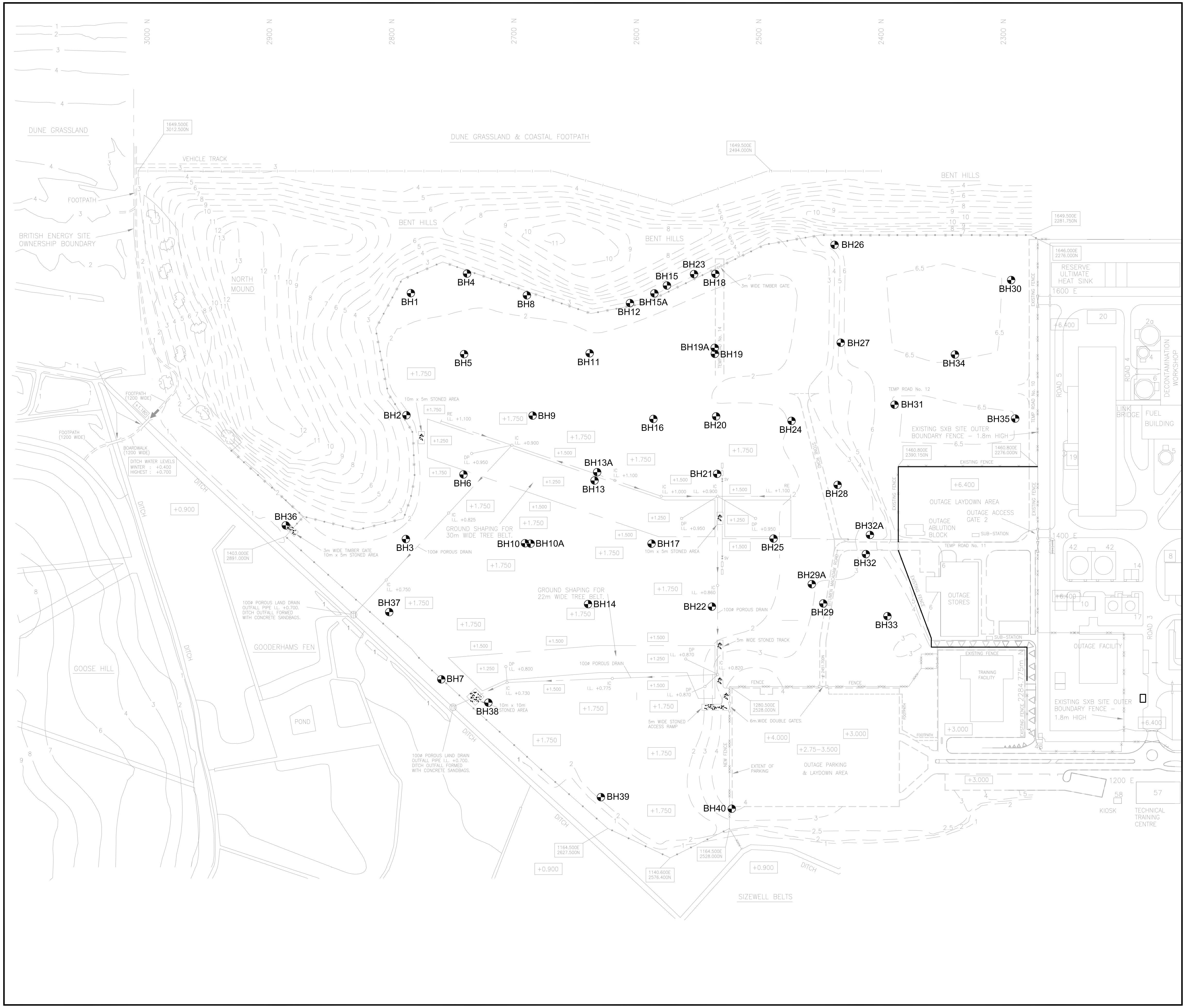

Borrow Pits- Surface water quality 2010-2013 (Ammoniacal Nitrogen)
Ammoniacal-N (mg/l)
6
5
4
3
2
1
0
Jan-10
Aug-10
Feb-11
Sep-11
Apr-12
Oct-12
May-13
SW16
SW15
SW14
SW13


Borrow Pits- Surface water quality 2014-2019 (Ammoniacal Nitrogen)
Ammoniacal-N (mg/l)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
May-14
May-15
May-16
May-17
May-18
May-19
G1
G3
G3A
G4
G5
G5A
G6a
G7a
G8


Borrow Pits- Surface water quality 2010-2013 (Nitrate)
Nitrate (mg/l)
100
90
80
70
60
50
40
30
20
10
0
Mar-09
Mar-10
Mar-11
Mar-12
Mar-13
SW16
SW15
SW14
SW13


Borrow Pits- Surface water quality 2014-2019 (Nitrate)
Niotrate (mg/l)
100
90
80
70
60
50
40
30
20
10
0
Mar-14
Mar-15
Mar-16
Mar-17
Mar-18
Mar-19
Mar-20
G1
G3
G3A
G4
G5
G5A
G6a
G7a
G8

Appendix F
Borehole Location Plan for 2009 Investigation



LEGEND

BH ● Borehole Location

REV.	DATE	DESCRIPTION	BY	CHD.	APR.
00	17.02.2009	-	CPM	JW	-

DIMENSION	SCALE	ORIGIN SIZE
m	1:300	A3

STRUCTURAL SOILS LIMITED

The Old School
Still House Lane
Bedminster
Bristol BS3 4EB

Tel: 0117 947 1000
Fax: 0117 947 1004
admin@soils.co.uk
www.soils.co.uk

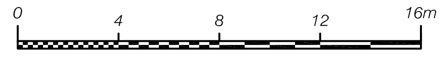
CLIENT
British Energy Ltd.

PROJECT
Sizewell 'C' - Supplementary Ground Investigation

TITLE
EXPLORATORY HOLE LOCATION PLAN

JOB NO.	FIGURE
722201	Figure 2

DRAWING STATUS	REV.
-	00



Appendix G
Alluvium analysis and ADAS Trial Monitoring Results

Appendix G Results from ADAS Heathland Trials (ADAS, 2010)[10] (water quality of soil drainage)

pH

Figure 2. Change in topsoil pH following incorporation of peat materials at Sizewell

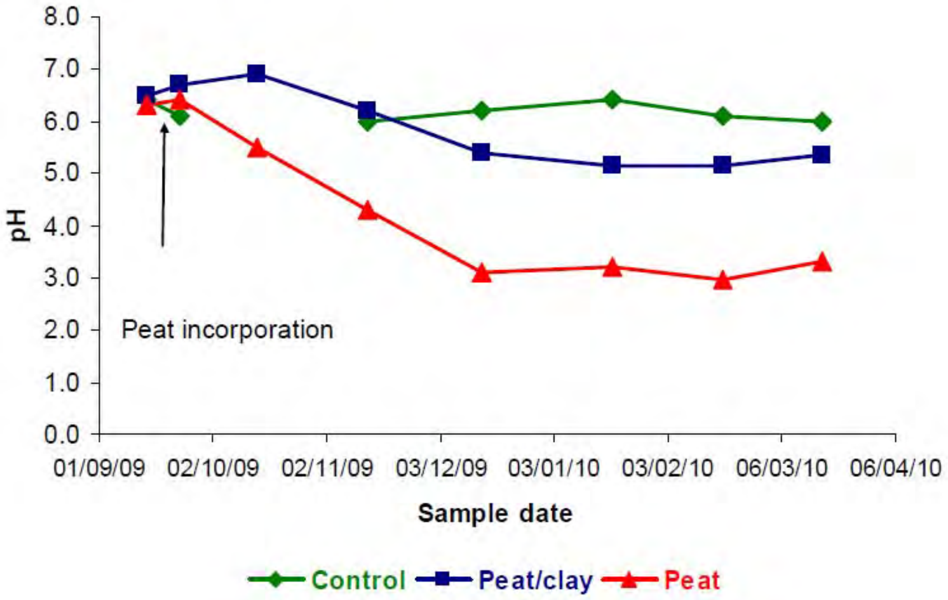
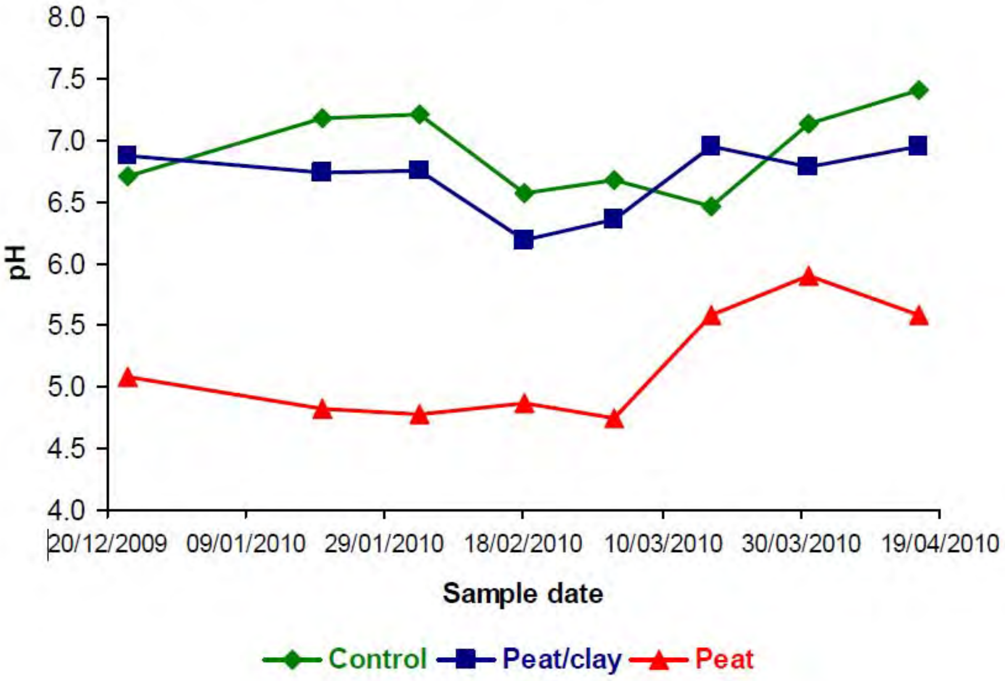
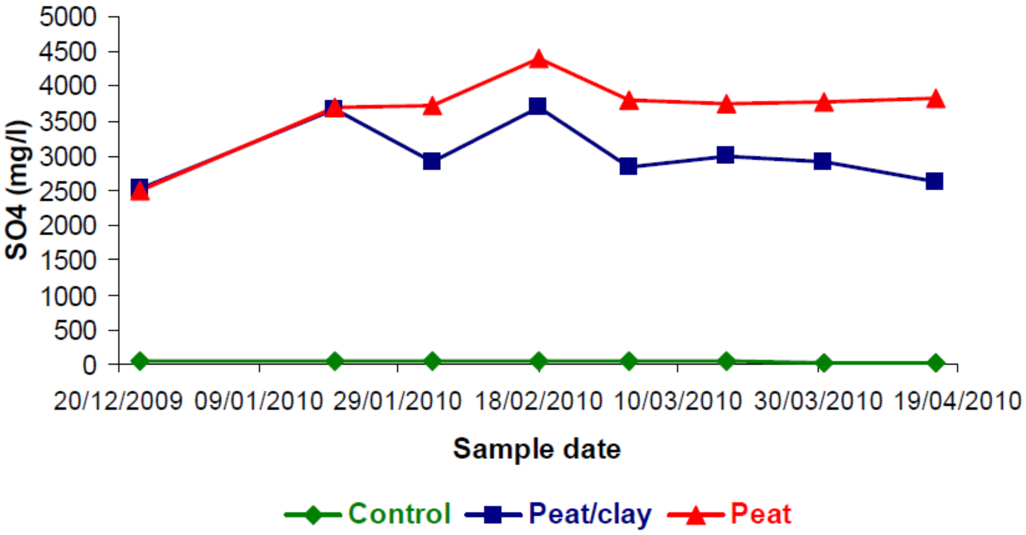


Figure 4. The pH of drainage water leaching below 90cm following incorporation of peat materials at Sizewell.



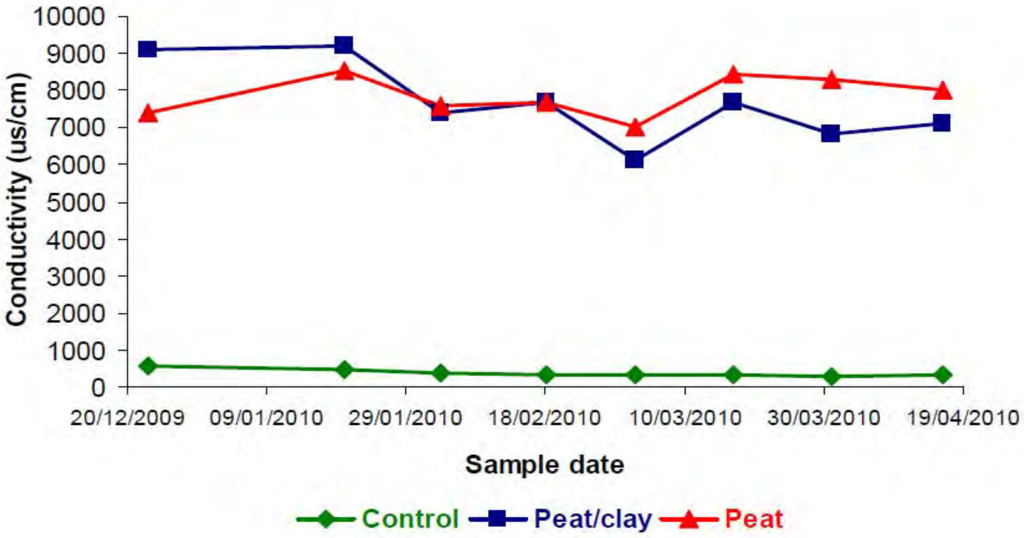
Sulphate

Figure 7. Sulphate concentrations of drainage waters leaching below 90cm following incorporation of peat materials at Sizewell.



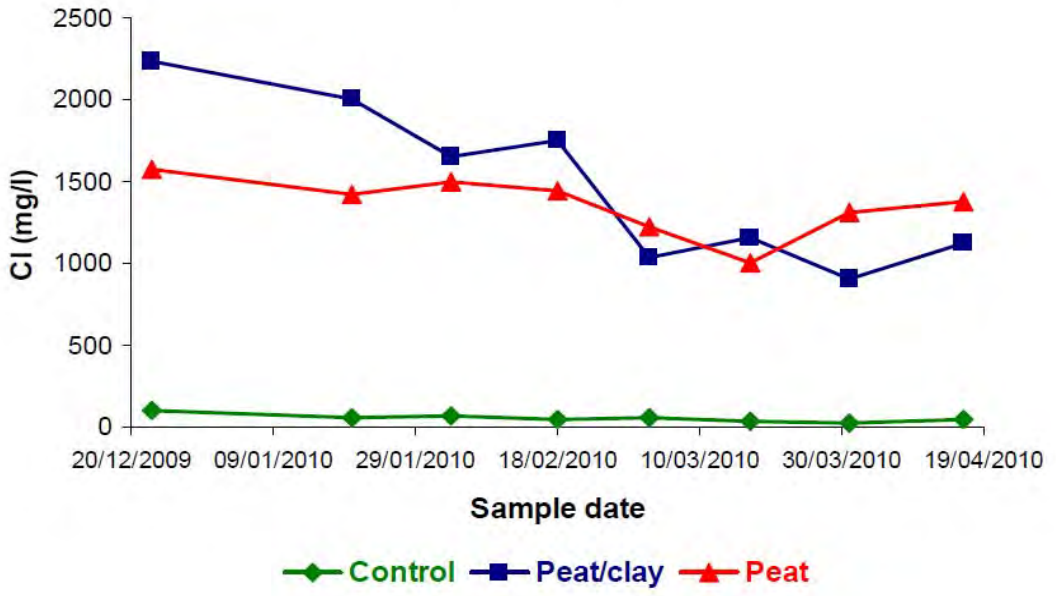
Electrical conductivity

Figure 5. The conductivity of drainage waters leaching below 90cm following incorporation of peat materials at Sizewell.



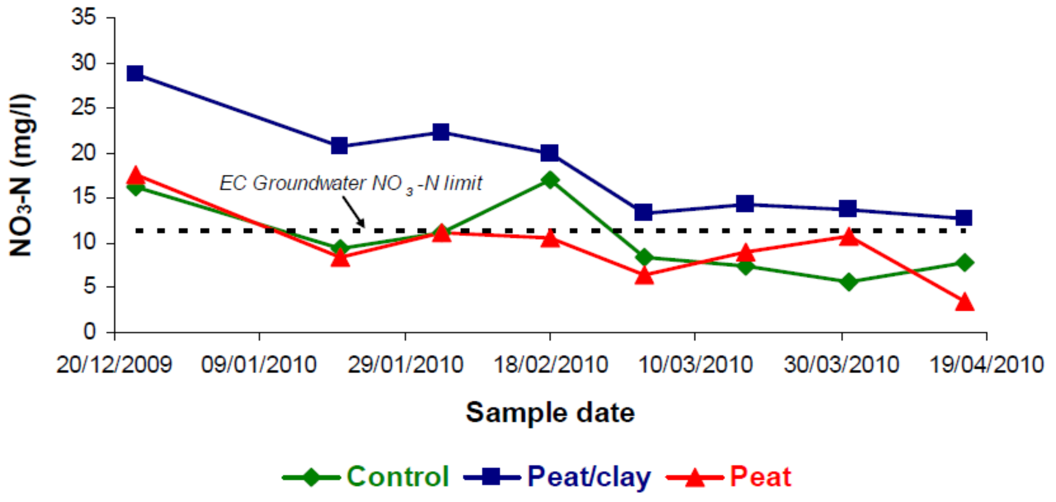
Chloride

Figure 6. Chloride concentrations of drainage waters leaching below 90cm following incorporation of peat materials at Sizewell.



Nitrate

Figure 8. Nitrate-nitrogen concentrations of drainage waters leaching below 90cm following incorporation of peat materials at Sizewell.



Appendix H
Suitability of Lime Stabilisation

Suitability of Lime Stabilisation

1 Introduction

1.1 Purpose of Report

The purpose of this report is to assess the viability of proposals to utilise lime treatment in order to modify and improve the properties of alluvial materials excavated from the proposed location of the Sizewell 'C' power plant for use as backfill to borrow pits excavated to win Norwich Crag material.

The report will assess the proposals that were put forward by Costain as part of the constructability study, as well as carry out a review of the technical guidance that exists for the process, in terms of the different levels of lime treatment, and the viability of its application to the excavated materials.

Consideration will also be given to the Environment Agency's views on the proposals, and whether they fall into the requirements of the CL:AIRE guidelines (Contaminated Land: Application in Real Environments).

A separate note also been included on the implications of lime stabilisation to drainage from the alluvium and any implications for the groundwater risk assessment.

1.2 Background

The development of the proposed Sizewell C power station will involve an excavation which may generate approximately 1.1 million cubic metres of alluvium (recent deposits comprising a mixture of clay, silt, organic clay, sand and peat). As this material is not suitable for engineering fill within the power plant footprint, it is proposed to use these materials as backfill to borrow pits which are to be excavated in order to win Norwich Crag deposits for re-use as engineering fill.

The borrow pits will be excavated in the area known as the western borrow pits (Sites 1-3) where an excavation depth of 8-9m is proposed in order to win approximately 1 million cubic metres of Norwich Crag sand. It was initially also proposed to use the backfilled borrow pits as an interim stockpiling area for fill materials that will be used in the development; this is now no longer the case and the area will be capped with up to 3m of overburden to allow re-profiling and restoration to farmland or acid grassland, depending on plot ownership.

A review of the geotechnical characteristics of the material has been carried out by Wood (previously Amec Foster Wheeler Environment & Infrastructure UK Limited) and this concluded that the material may be expected to exhibit high liquid and plastic limits which may cause difficulties in relation to trafficability, workability and compaction; and as such the material will require careful management and handling in order to be placed and compacted effectively within the borrow pit excavations. In addition, a review of previous ground investigation data indicates that the material is highly compressible and t the proposed use of the backfilled borrow pits as a stockpiling area for engineering fills would be expected to result in considerable settlement and potentially bearing failure.

As part of a constructability study for the site, it was proposed that lime treatment (lime Improvement, using Quicklime) would be used to modify and improve the properties of the alluvium, therefore increasing its workability and enhancing the safety of plant working in the borrow pit.

EDF Energy has commissioned Wood to produce a report appraising Costain's proposals and to comment on the viability of lime treatment, in terms of geotechnical suitability and compliance with CL:AIRE guidelines.

2 Document Review

2.1 Costain Proposals

In February 2015 Costain undertook a constructability study for the Sizewell C, including a study of the borrow pit and potential material stockpiling area.

The report notes that the peat and clay materials cannot be trafficked by conventional earthworks plant due to their soft consistency. It was proposed to pre-drain the alluvium in the Main Construction Area (MCA) as much as possible, either by installing stone columns or digging drainage trenches through it prior to removal. Nonetheless, it is still expected that the alluvium will be wet on excavation, as it has poor drainage properties. It will not be possible to dry the material out in the borrow pits as the Environment Agency (EA) has identified that this could lead to the generation of acidic leachate.

As a result, it was considered that the nature of the material and its inability to support conventional earthworks plant represented a significant constraint and a health and safety hazard; and therefore carried out an options appraisal for different methods of placing the material as backfill. The following options were considered:

2.1.1 Filling with Untreated Peat

This option would involve end tipping of the alluvium into the borrow pits and leaving it to settle over time. Periodically long reach excavators could push the material out towards the middle of the pit. However, this would not be sufficient to get material to the centre of the borrow pit and therefore this option was rejected.

2.1.2 Causeway Method

A variation on the above method where causeways of original in-situ material would be left in place, effectively creating a series of 40m wide trenches, rather than a large single excavation. The material could then be tipped and spread more effectively. However, this option was also rejected as it would significantly reduce the amount of Norwich Crag material that could be won, and consequently the available void space for alluvium would similarly be reduced.

2.1.3 Conveyor System

In this option, a detailed network of travelling tripper conveyors and / or radial stackers would be used to place the material. However, this option would be costly and there could be no guarantee as to whether the system could reliably handle the very soft and wet alluvium. Therefore this option was also rejected.

2.1.4 Cell Method

This option would involve placing up to 3m of material by pushing with a dozer. Then this base would be capped with a platform comprising Norwich Crag material and geo-grids. Bunds would be formed to prevent lateral spread of the alluvium. This would form a number of cells across the borrow pit. This would allow tracking of smaller plant but this would still require careful management and monitoring. This process could be repeated until backfilling is complete, with a final platform formed which would allow a stockpile to be placed.

Whilst the Norwich Crag cells would aid consolidation and drainage of the alluvium, it may increase the rate of leachate, which may not be acceptable to the Environment Agency. Other disadvantages include the sterilisation of some of the Norwich Crag resource and subsequent loss of volume capacity, and therefore this option was rejected.

2.1.5 Lime Treatment

In this option, *ex situ* treatment would be undertaken which would modify the clay components absorbing water during the hydration process, effectively stiffening the material. The lime will have little effect on the properties of peat within the alluvium, although the rotovation process will help to break these down. The treatment will have to be carefully managed, and areas that are not sufficiently improved will require further treatment, capping or removal. The process of lime treatment will allow the alluvium to be trafficked and compacted, which will also aid in the site being suitable for stockpiling. The amount of leachate will be minimised. However, this process is expensive and requires careful management to minimise environmental impact (lime dust).

Overall, the report concluded that this option would be the most preferable in terms of meeting EDF Energy's requirements, and that the process to be used would be Lime Improvement using Quicklime.

2.1.6 Methodology

Costain proposed to treat the material by adding 1-2% of lime (by mass), although this may have to increase to approximately 4% for certain materials (Section 3.2).

It is proposed that the material will be treated in the borrow pits, to reduce the spread of dust over the surrounding area. Alluvium will be tipped at the base and spread out in approximately 300 mm thick layers using a bulldozer. The lime spreader and mixers will then travel over the placed alluvium, the intent is also that the mixing process helps to incorporate any peat pockets within the rest of the material.

Treated material will be left to hydrate for approximately 24 hours, whilst further material is placed and treated in other areas of the pit. It was considered that the area of floor space available would allow for material to be spread for 6 days before any areas need to be overlaid. As the treatment cycle lasts two days this allows sufficient time to compact treated layers and identify any soft spots requiring further treatment. Notwithstanding this, it was also proposed that a reserve a back-up treatment area in the Temporary Contractors Area (TCA) may be required.

Soft spots can be treated in one of four ways:

- Retreat the area with further lime;
- Cement treatment;
- Cap or cover with successfully treated material; and
- Remove and mix with predominantly clay material.

EDF Energy consider that once the borrow pit has been filled it will be available for stockpiling and will provide a good platform to support stockpiling.

2.2 Technical Reports / Specifications

A number of technical papers and specifications exist for the application of lime treatment, which have been reviewed as part of this assessment. These were reviewed with particular emphasis on the feasibility of its use with soft and wet alluvial materials. Many of the documents make the distinction between lime stabilisation, and lime improvement / modification, which is the desired effect required in this case.

2.2.1 Lime Stabilisation Manual[5]

This is a guidance document published by the British Lime Association. In Chapter 3 "mechanism of Lime Stabilisation" the following is stated:

The addition of lime to a fine grained soil initiates several reactions:-

a. *Drying out by absorption and evaporation. The reduction in the moisture content of the soil can be substantial and care must be taken to ensure that it does not become too dry.*

b. *Rapid physico-chemical reactions between the lime and clay minerals produce immediate changes in soil plasticity, bringing many benefits. This is known as lime modification.*

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[5] British Lime Association (1990): Lime Stabilisation Manual – 2nd Edition

c. *Long-term soil-lime pozzolanic reactions result in the formation of cementing agents which increase mixture strength and durability. This is known as lime stabilisation.*

As well as the drying effect caused by the addition of lime (the effect is increased if quicklime is used as the additive), the initial reactions cause a significant changes in the engineering properties of the soil. These changes usually occur at lime contents of 2% to 4%, although this also depends on the efficiency of mixing:

- Plastic Limit increases, making the soil appear drier. In clay dominant soils the Liquid Limit also reduces, but increases in silt dominant soils. Due to the silt/clay mixtures typical of soils in the UK there is often little net change in the Liquid Limit;
- Clay clods become easier to break down and the soil becomes more loose and friable, improving workability;
- The Optimum Moisture Content (OMC) increases;
- Maximum Dry Density (MDD) is reduced for a given compactive effort;
- Compaction curve becomes flatter, meaning that good densities can be achieved across a wider moisture content range;
- Undrained shear strength and CBR increase;
- Soil becomes less susceptible to moisture softening and shrink/swell.

The above effects all combine to aid bulk earthworks of soft, plastic, cohesive soils. As well as increasing the mobility of plant, the stability of the soil will increase and will be less vulnerable to weather conditions.

2.2.2 HA 74/07

The Highways Agency Design Manual for Roads and Bridges includes a section on Lime Treatment[6]. The document also draws the distinction between lime improvement and lime stabilisation, and states that all cohesive material can be improved, but not all cohesive material can be stabilised. The document points out that lime improvement can render Class U1A unacceptable materials, acceptable as Class 1, 2 or 3 material.

Soils with high levels of sulphate may undergo some expansion but this is more of a concern in lime stabilisation for capping materials, rather than improvement of soils for general fill uses. High organic content can hinder the stabilisation process, but not soil improvement.

HA 74/07 states that quicklime is best used for wet soils, such as at Sizewell, as it requires a large amount of water to hydrate. The hydration of the lime is an exothermic reaction, which drives off some of the moisture content. The hydration also causes clay particles to flocculate, hence increasing the Plastic Limit and thereby reducing the plasticity index. This document also refers to the increased OMC and flatter compaction curve caused by lime improvement.

Whilst the document recognises that the amount of quicklime to be added is difficult to specify given the nature of the process but it states that normally only 1% to 2% by dry weight of available lime is required for rendering of general fill materials. By contrast, stabilisation requires a higher percentage of lime to produce cementitious products which bind the soil together. The amount of lime required for this effect is termed the 'fixation level'.

2.2.3 Aggregates Advisory Service

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[6] Highways Agency (2007): Design Manual for Roads and Bridges Volume 4 (Geotechnics) Section 1 (Earthworks): Part 6 HA 74/07 – The Treatment of fill and capping material using either lime or cement or both

The AAS produced a short guidance note on Lime Stabilisation in 1999[7]. Similarly to other documents this guidance note specifies the importance of field trials and laboratory based testing to ascertain the suitability of the soil and to define appropriate dosage rates. The document specifies that soil should have a Plasticity Index of above 10% and a relatively low sulphate and organic material content. The document states that peat is not suitable for treatment.

2.3 Case Studies

Case studies for lime improvement are difficult to find, although numerous case studies for lime stabilisation are available.

Otoko & Blessing[8] present a study of cement and lime stabilisation of Nigerian Marine clay and peat in the Niger Delta region. With respect to lime stabilisation, standard Proctor Compaction tests, and unconfined compression tests were carried out on untreated samples, and samples treated with lime added to the soil at percentages of 10%, 30% and 50% to soil mass.

The results showed that the unconfined compressive strength and maximum dry density increased with increase in lime content, although in contrast to lime improvement the optimum moisture content was found to fall with the increase in lime content.

Quigley[9] discussed the advantages of using lime and cement to modify low strength soils in Ireland. Lime treatment has been carried out sporadically in Ireland since the 1980's but has increased in its application since a stabilisation trial at Dublin Airport in 1987 showed that quicklime was very effective in increasing the strength and CBR of 'brown boulder clay'. In addition lime improvement modified unacceptable Class U1 material to produce an acceptable Class 2C material, and it was understood that the addition of 1% to 2% lime had caused the modification.

At a proposed industrial development at Brownsbarn, a stockpile of approximately 100,000m3 of stockpiled brown boulder clay was intended for use as fill material to support foundations. Geotechnical testing indicated that in its natural state, the clay was significantly wet for optimum moisture content and had variable California Bearing Ratio (CBR) and MCV values. Lime was added at a dosing rate of 1% to 2% and following this mean CBR values of 12.7% were obtained, whilst plate bearing tests recorded settlements of 2-4mm at a load of 100kPa.

3. Appraisal

3.1 Acceptability under CL:AIRE (DoWCoP)

Following the constructability study, advice was sought by EDF Energy from the Environment Agency (EA) as to whether the lime stabilisation of the alluvial soils would result in the material being classified as waste under the CL:AIRE guidelines (DoWCoP).[10]

The document sets out 4 main factors that can be used to determine whether material can be used as non-waste, and it is the document that the EA refer to in making the decision whether to classify material as waste. If the material is classified as a waste material, then an environmental permit would be required to dispose of it in the borrow pits.

The factors to be considered are as follows:

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[7] Aggregates Advisory Service (1999): Improving Poor Ground Conditions – Lime and Cement Stabilisation of Weak Clay Soils

[8] Otoko G.R & Blessing O.C (2014): Cement and Lime Stabilisation of a Nigerian Deltaic Marine Clay (Chikoko) in European International Journal of Science and Technology Vol. 3 No.4 *pp* 53-60

[9] Quigley P. (2006): Modification / Stabilisation of Low Strength Cohesive Soils under Foundation and Floor Slabs

[10] CL:AIRE (2011): Definition of Waste – Development Industry Code of Practice (DoWCoP)

- Protection of Human Health and the Environment;
- Suitability for use, without further treatment;
- Certainty of use; and
- Quantity of materials.

Factor 1 – Protection of Human Health and the Environment

This is the primary aim of the Waste Framework Directive and as such, needs to be met. Therefore, in cases where measures are included to protect Human Health and the Environment these are likely to be acceptable. Conversely, if the re-use of the material was likely to cause an unacceptable risk to Human Health and the Environment it would be considered as waste.

Factor 2 – Suitability for use, without further treatment

This means that a material must be suitable for its intended use in all respects (i.e. both chemical and geotechnical). In cases where treatment is needed to make the material ready for use it will be waste but may cease to become waste once the treatment has been successfully completed.

Factor 3 – Certainty of Use

In order to meet this criteria it must be demonstrated that the material will certainly be used. Out of specification material will be classed as waste.

Factor 4 – Quantity of material

Material should only be used in the quantities that are necessary for the intended use. Any excess material would be regarded as waste being disposed of.

The accepted method of demonstrating the four factors is by the production of a Materials Management Plan.

In considering the suitability of lime stabilisation of the alluvial soils under the DoWCoP, the EA acknowledged that the main driver for its use was to ensure health and Safety on the site (i.e. not required on environmental grounds) and that lime stabilisation is a standard process used on many sites. EA referred to Paragraph 8.1.6 in Appendix 8 of the DoWCoP which states that construction activities carried out on uncontaminated soils solely for the purpose of improving geotechnical properties are not generally regarded as waste treatment operations and do not require a permit. Lime / cement stabilisation is specifically mentioned as one of these activities and therefore the EA was content that the proposal fell within CL:AIRE guidelines.

The EA was also asked about the possibility of placing material excavated from the cut-off wall excavation in the borrow pit. The EA initially had concerns about the possibility of bentonite being incorporated into these materials and stated that bentonite does not meet the definition of excavated material that the DoWCoP relates to, which included parent material and underlying geology.

However, the EA has since confirmed that, in their professional view, bentonite can be considered to fall under CL:AIRE DoWCoP by virtue of material type. Bentonite is essentially a special type of clay which is a natural material (i.e. soil based and of natural origins). The material will be remaining within the site boundary and so would not be considered a disposal activity. Therefore the inclusion of bentonite in borrow pit backfill providing that the bentonite does not contain any hazardous additives. If this is not the case then further discussions will be needed.

3.2 Viability of Lime Treatment

As part of the constructability study, the proposed process to treat the alluvial soils would be lime improvement using quicklime. This is a recognised method and is considered to be the most applicable to wet soils, such as the materials expected to be excavated at Sizewell.

Lime improvement using quicklime is best used on wet soils and improves the moisture and plasticity properties of soil in two ways: Firstly, the heat generated by the hydration of the lime drives off moisture within the soil, and secondly the hydration causes the clay particles to flocculate, resulting in an increase in Plastic Limit (and therefore a reduction in Plasticity Index). This improvement starts to take place almost immediately and continues for up to 72 hours. The material becomes more workable and more amenable to adequate compaction, due to a flattening of the compaction curve for the soil.

Conversely, lime stabilisation is a more long-term reaction which produces a cementitious gel which binds the soil together and relies on an increase in the soil pH level.

Whilst lime stabilisation can be affected by the presence of organic material, meaning that more lime has to be added, it does not affect the improvement process.

It is noted that peat material in itself will not be greatly improved by the process, although the heat caused by the hydration process will reduce its moisture content. The process of rotovation will, however, help to break up the peat and mix it into the rest of the soil mass. It would also be prudent to allow for some observation of the materials as they are excavated in order to ensure that large bodies of peat are not placed in one area.

In addition, the lime treatment will reduce the amount of leachate generated by the alluvial backfill material as it will be absorbed by the lime during the hydration process. Any remaining leachate will be reduced in pH which would be beneficial given the naturally acidic nature of the leachate that would be produced.

The proposal is to use combined spreader mixer units to minimise the potential for dust generation.

The constructability study envisaged that a dosing rate of 1-2% would be sufficient to render the bulk of the alluvial material, although up to 4% may be required for specific material batches. This is broadly in accordance with the recommendations in the Lime Stabilisation manual and HA74/07. It will however be necessary to confirm this in dosing trials but in any case the amount should be well below the lime fixation level at which lime stabilisation would occur.

It was proposed to carry out the lime stabilisation in the borrow pits themselves, as this will minimise the spread of airborne dust from the backfilling operation. The material will be placed and treated in panels, so that it can be left to hydrate whilst other panels are placed and treated. It was estimated that material can be spread over the borrow pits for 6 days before any areas need to be overlaid. The treatment cycle is two days so this allow plenty of time for additional work to deal with residual soft spots. It was also proposed to reserve a back-up treatment area in the TCA should any problems arise.

Subject to material management and monitoring to avoid the placement of large bodies of peat in one area, it is Wood's belief that the proposed proposals are robust and represent the most efficient method of backfilling the borrow pits with alluvium from the main platform excavations.

3.3 Stockpiling

On completion of infilling the borrow pits, EDF Energy propose to temporarily stockpile granular material over the borrow pits. The maximum height of the stockpile would be 5 m and would be in place for up to 8 years.

The risk assessment presented in Section 8.4 indicates that the impact on water quality from stockpiling over the borrow pits is mainly associated with the initial squeezing out of pore water over a relatively short time scale (~5 years) and reduces with stockpile height. The predicted concentrations are unlikely to impact on water receptors.

The initial settlement calculations were based on the placement of untreated alluvial material, and it could reasonably be surmised that the settlement of lime improved soils would be much less, given their improved workability and suitability for compaction, and that leachate levels would be reduced, and this possibility was raised by Costain in their constructability study. In order to revise the risk assessment it will be necessary to carry out some further investigation and field trials to allow a revised assessment of likely settlements to be carried out.

4. Concluding Remarks

4.1 Conclusions

Costain propose to utilise lime improvement techniques to render the alluvial materials suitable for re-use as backfill materials to the proposed borrow pits at Sizewell. It is considered that, based on the points outlined within this report, that this would be a suitable option and would allow the greatest volume of the borrow pits to be used for the purpose of backfilling, and will also be beneficial on Health and Safety grounds as plant will be able to traffic on the newly placed material (once the improvement process is complete) and it will also be an acceptable use of the material under the CL:AIRE DoWCoP guidelines, as confirmed by the EA.

Material containing bentonite can be placed in the borrow pits under CL;AIRE guidelines, providing it does not contain hazardous additives.

4.2 Recommendations for Trials (for discussion, and recommendations can be provided separately)

At this time it is not fully known how the materials are likely to behave on excavation and placement in the borrow pits, in previous investigations compressibility testing has been carried out on samples described as either peat or clay, recovered from boreholes. To date, no samples have been taken of mixtures of the different types of alluvium, which would be more representative of the soil being excavated and brought to the borrow pits *en masse*. Furthermore, we have no knowledge of how much the lime improvement of the material will change the soil's behaviour in terms of bearing capacity and settlement under surcharge loading of stockpiles.

As part of any lime improvement programme it would be recommended to carry our field trials in order to assess the efficacy of the process and to define the optimum lime dosing rates. This can be done either in the laboratory on recovered samples of material (with the addition of lime being carried out in the laboratory), or in a demonstration area on site, prior to the bulk earthworks operations.

Tests should be carried out on untreated mixtures of the alluvium, and on lime improved material in order to determine the efficacy of the process, and to assess the settlement characteristic likely to be exhibited by the treated material.

The testing should include, but not necessarily be limited to the tests listed in Table 4.1 below:

Table 1 Recommended Laboratory Testing

Test Description	BS 1377[11] Reference	Clause No.
Natural Moisture Content	Part 2	Clause 3
Atterberg Limits	Part 2	Clause 4 & 5
Dry Density / Moisture Content Relationship	Part 4	Clause 3.3

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[11] BSI (1990) – BS1377: Methods of test for soils for Civil Engineering Purposes Parts 1-9

Test Description	BS 1377[11] Reference	Clause No.
Moisture Condition Value / mc calibration (MCV)	Part 4	Clause 5
1-Dimensional Consolidation	Part 5	Clause 3
Unconsolidated Undrained Triaxial Compression	Part 7	Clause 8

4.3 Material Management

Careful management of material will be required in order to ensure that large bodies of peat are not deposited in the borrow pits. Peat does not undergo any appreciable improvement under lime treatment, although the act of rotovation will help to break down clods and mix it into the rest of the material. A large body of peat will be susceptible to large settlements, especially if placed close to the surface, and therefore large amounts of peat should not be deposited together (i.e. a lorry load of peat with no clay or silt) and consideration should therefore be given to reserving a segregation area for peat (either at the excavation site or at the borrow pits, where large bodies of peat can be stored and then mixed gradually into the material as backfilling progresses).

Therefore it will be important to observe and monitor the make-up of the alluvium as it is excavated, to identify loads that are predominantly made up of peat and to avoid placement of significant quantities of peat in a particular area, otherwise there is a potential for significant settlement above that area, due to self-weight settlement and surcharge loads imparted by the overburden capping. The amount of settlement would depend on a number of factors:

- Inherent compressibility of the peat;
- Moisture Conditions;
- Depth below surface of the placed peat; and
- Organic Content

The differential settlement realised at the surface may result in the formation of depressions, which may encourage accumulations of water unless the area is reprofiled on completion of infilling.

The infilling operation will need to be supported by a materials management strategy to ensure that peat is distributed through the mass of fill.

4.3 Acceptability Testing

Compliance monitoring and testing forms an integral part of lime improvement / stabilisation projects. A specification / CQA plan will be required to define the types and frequencies of acceptability and validation testing to be undertaken during the backfilling operation.

HA74/07 recommends that MCV testing is used as a means of controlling moisture content of cohesive materials, immediately before compaction. This is because the MCV is a constant measure as the optimum moisture content increases with time.

Consideration should be given to the following tests to validate the treated material:

- Lime spread checks – to ensure that dosage is at correct level;
- MCV / Moisture Content;
- CBR Values; and

- Plate Bearing Tests.

Appendix A Lime Stabilisation and Groundwater Risk Assessment

As part of the assessment of the feasibility of infilling the borrow pit void with alluvium, a controlled waters risk assessment[12] has been carried out by Wood (previously Amec Foster Wheeler Environment and Infrastructure UK Ltd) in order to determine the potential effects on groundwater and surface water resources and other relevant receptors. The results of the assessment were presented to the Environment Agency and showed:

- No risk of a breakthrough of hazardous metals at the water table (based on pH buffering calculations);
- No impact from ammonium, iron and phenanthrene on groundwater;
- No exceedences of water quality standards (Drinking Water or Environmental Quality Standards) by chloride, sulphate, sodium and iron in groundwater or in surface water receptors at the 50% and 95% percentile predictions;
- Increase in concentrations of chloride, sodium and sulphate in groundwater down gradient of the borrow pits, but no exceedences of relevant water quality standards;
- No impact on surface water (and therefore the dependent habitats) from sodium and chloride as concentrations in groundwater discharge are within the baseline range for surface water; sulphate concentrations in groundwater (58-73 mg/l) discharging to surface water are likely to be above the baseline, but are below 400 mg/l (EQS) and below peak concentrations in surface water. The groundwater discharge will also be diffuse (over an area) and therefore any change in surface water quality is very unlikely to be measurable.

Lime stabilisation will result in a change in the physical and chemical characteristics of the alluvium and a change in the volume and quality of drainage to groundwater. Therefore an initial review has been undertaken to assess whether lime stabilisation could change the findings of the controlled water risk assessment.

Lime stabilisation has been undertaken as part of the treatment and stabilisation of contaminated soils. The Environment Agency[13] has published a literature review which is relevant to this study. This report provides a useful summary of the changes to the physical and chemical characteristics of soils arising from the addition of lime.

Based on a review of this document it is concluded that overall lime stabilisation will result in a reduced risk to groundwater for the following reasons:

- The hydration process will result in a reduction in the volume of pore water that could be leached. Water is taken up as part of the reaction process and may also be lost as evaporation as the process is exothermic as illustrated by the following reaction;

  $$CaO + H_2O \rightarrow Ca(OH)_2 + \text{heat} \uparrow$$

- Whilst the addition of lime may result in a short term increase (days) in the permeability of alluvium, the precipitation of a cementitious gel in pore spaces will result in a decrease in permeability and a decrease in drainage rates in the longer term;

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[12] Wood (previously Amec Foster Wheeler) 2014. Peat and Alluvium as Backfill for Borrow Pits. Groundwater, Surface Water & Ground Gas Risk Assessment. September 2014.

[13] Environment Agency, 2004. Review of scientific literature on the use of stabilisation/solidification for the treatment of contaminated soil, solid waste and sludges. Science Report SC980003/SR2.

- Rotovation of lime into the alluvium will result in further mixing of this material and a break up of more permeable peat pathways (see comments in Sections 3.2 and 4.3);
- The stabilisation process will result in an increase in the mechanical strength of the alluvium and a reduction in the volume of water released by settlement (See Section 3.3);
- The addition of lime will result in an increase in pH to 10 to 11 and a reduction of mobility of contaminants (e.g. metals).

The review has identified the potential for the addition of lime to result in an increase in pH (to between 10 and 12) which can:

- Increase the solubility of amphoteric[14] metals (e.g. zinc, lead, and chromium), albeit these metals would also be mobilised at low pH suggesting no net increase in risk to groundwater;
- Lead to the potential for solubilisation of humic and fulvic acids and a potential for an increase in the mobility of PAHs albeit the concentrations of these compounds in previous leaching tests was low. Any change would need to be considered in terms of the likelihood for lower drainage rates.

It is recommended that the laboratory trials proposed in Section 4.2 should also include leaching tests to provide confirmation that the addition of lime does not result in the leaching of PAHs at concentrations of concern with respect to control waters.

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[14] Amphoteric metals form compounds which are soluble in both low pH (acidic) and high pH (basic) conditions

Appendix I
Geotechnical Risk Register

Geotechnical Risk Register GRR 01 *Wood E&IS UK*

Project Number: 41828

Project Title: Sizewell C Development

Stage: Re-use of Alluvium as Borrow Pit Backfill - Lime Improvement

Compiled by: DG 31/07/2019 Reviewed by:

The risk register is a means of documenting perceived risks and their importance and recording actions taken to manage them. The key elements of a geotechnical risk register are as follows:

1. Identify the geotechnical risks.
2. Identify the methods of construction that may be incorporated into the project.
3. Scale the risks according to probability and impact.
4. Based on the severity of each risk, decide on the type of action.
5. Identify how each risk should be managed.
6. Record the actions taken to manage the risk.
7. Reassess the severity of each risk after action has been taken.
8. Review the risk register at regular intervals and communicate.

The risk register is a live document and should be reviewed on a regular basis and at the end of each stage of the project.

The probability (P) that a given event will occur is given by the following:

Scale	Likelihood	Chance per section of work (Amend to suit local conditions and to be agreed with the Client)
1	Negligible	< 1 in 100
2	Unlikely	1 in 100 to 1 in 10
3	Possible	1 in 10 to 1 in 5
4	Probable	1 in 5 to 1 in 2
5	Almost certain	> 1 in 2

The impact (I) of a given event is given by the following:

Scale	Effect	Increase in cost or time (% increase) (Amend to suit local conditions and to be agreed with the Client)
1	Negligible	< 1%
2	Very low	1% to 4%
3	Low	4% to 8%
4	High	8% to 15%
5	Very high	> 15%

The risk after the application of risk control measures should be reviewed in the light of the following table:

Degree of Risk	Risk Level	Action Required
1 - 4	Trivial	None
5 - 9	Tolerable	Consider more cost-effective solutions or improvements
10 - 15	Substantial	Work must not start until risk has been reduced
16 - 25	Intolerable	Work must not start until risk has been reduced. If risk cannot be reduced, project should not proceed.

The risks and their potential impacts may vary between the various stages of the project, such as the risk to and from buried services, where the impact can be much higher during a ground investigation than during a desk study.

Appendix J
Proposed Monitoring Programme

1. Introduction

To ensure the groundwater environment in the vicinity of the borrow pits is adequately protected from infilling the borrow pits a groundwater monitoring programme is proposed. This section provides an outline of the proposed principles for monitoring and defines levels upon which actions are to be implemented, if required. This monitoring scheme will be updated once the final option for backfilling has been determined.

1.2 Proposed Monitoring Locations

The monitoring network will comprise the following:

- One upgradient borehole to define background quality;
- Up to six compliance boreholes located on the site boundary (within 50 m of the edge of the borrow pits);
- Two to three downgradient boreholes to determine downgradient quality; and
- Two to three surface water monitoring points located at the western edge of the SSSI.

Existing monitoring boreholes will be used if located in an appropriate location.

1.3 Frequency of Sampling and Analytical Suite

The proposed monitoring frequency is set out in **Table 1.**

Table 1 Proposed frequency of groundwater and surface water monitoring

Location	12 months prior to infilling	During infilling and stockpiling	After restoration and stockpiling
Groundwater			
Upgradient	Quarterly	Quarterly	Quarterly for first 4 years and then reviewed
Boundary of borrow pits	Quarterly	Monthly	Quarterly for first 4 years and then reviewed
Downgradient	Quarterly	Quarterly	Quarterly for first 4 years and then reviewed
Surface Water			
	Quarterly	Quarterly	Quarterly for first 4 years and then reviewed

The proposed monitoring suite will comprise pH, electrical conductivity, sulphate, chloride, sodium, iron, ammoniacal nitrogen and PAHs.

During infilling and stockpiling the results will be reviewed monthly to assess any potential impacts on groundwater quality. A summary report will be prepared every 6 months and provided to the planning authority and the EA. After restoration and stockpiling the results will be reviewed annually and a summary report prepared. After 4 years the report will set out recommendations for monitoring in the long term.

1.3 Action levels

Monitoring of the borrow pits boundary (compliance) boreholes is intended to assess the impact of infilling the borrow pits and subsequent stockpiling on groundwater quality and whether this is consistent with the results of this risk assessment. Action levels are proposed which if exceeded will require actions to be undertaken as detailed in **Table 2**. Action Level 1 will be defined as the 95%ile concentration from the

LandSim modelling results (to be confirmed). Action Level 2 has been defined as the lower of either the drinking water standard or EQS. The action levels will be updated once the final option for backfilling has been determined. The monitoring data for the downgradient groundwater and surface water monitoring points will also be reviewed and used to inform any update of the conceptual model and risk assessment.

Table 2 Proposed Action Levels

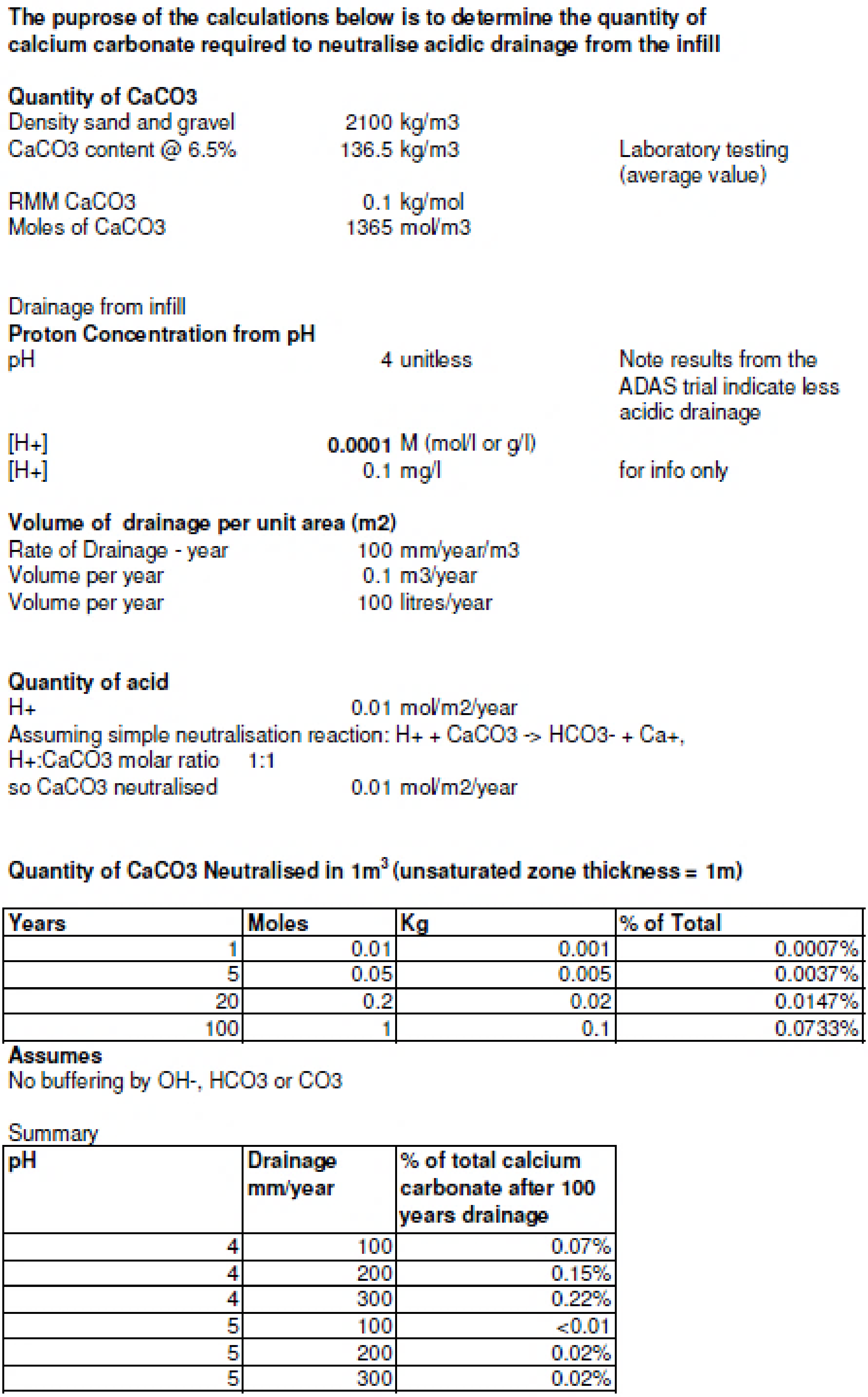
Action Level		**Action to be taken**
Action Level 1 One exceedence of Action Level 1	Sulphate, chloride as 95%ile concentration from the LandSim modelling results (to be confirmed).	Check with laboratory to confirm the result Check recent groundwater quality trends and historical data. Repeat sampling if result confirmed and historical data indicate upward trend
Action Level 1 Three consecutive exceedences of Action Level 1	Sulphate, chloride as 95%ile concentration from the LandSim modelling results (to be confirmed).	Check with laboratory to confirm the result Inform the planning authority and EA Check recent groundwater quality trends and historical data. Review operations to identify cause(s) of exceedance Review conceptual model and risk assessment to determine need for further actions (if assessment confirms that Action Level 2 is unlikely to be exceeded then implement then continue monitoring and provide report to planning authority and EA) If risk of exceedance of Action Level 2 develop action plan and agree with planning authority and EA Provide report to planning authority and EA
Action Level 2 One exceedence of Action Level 2	Sulphate 250 mg/l Chloride 250 mg/l	Check with laboratory to confirm the result Confirm the analysis by repeat sampling (if laboratory confirms the result) Inform the planning authority and EA Review conceptual model and implement action plan if required Provide report to planning authority and EA

1.4 Action Plan

An action plan should be developed and agreed with the planning authority and the EA. This action plan should take account of site operations and the observed and predicted impact on groundwater quality with the objective of implementing measures to reduce the impact and improve groundwater quality. Actions to be considered could include:

- Changes to site backfilling operations;
- Changes to surface water management; and
- Implementation of remediation measures such as groundwater abstraction.

Appendix K
pH Buffering Calculations



The puprose of the calculations below is to determine the quantity of calcium carbonate required to neutralise acidic drainage from the infill

Quantity of CaCO3

Density sand and gravel	2100 kg/m3	
CaCO3 content @ 6.5%	136.5 kg/m3	Laboratory testing (average value)
RMM CaCO3	0.1 kg/mol	
Moles of CaCO3	1365 mol/m3	

Drainage from infill

Proton Concentration from pH

pH	4 unitless	Note results from the ADAS trial indicate less acidic drainage
[H+]	**0.0001** M (mol/l or g/l)	
[H+]	0.1 mg/l	for info only

Volume of drainage per unit area (m2)

Rate of Drainage - year	100 mm/year/m3
Volume per year	0.1 m3/year
Volume per year	100 litres/year

Quantity of acid

H+ 0.01 mol/m2/year

Assuming simple neutralisation reaction: H+ + CaCO3 -> HCO3- + Ca+,

H+:CaCO3 molar ratio 1:1

so CaCO3 neutralised 0.01 mol/m2/year

Quantity of CaCO3 Neutralised in 1m^3 (unsaturated zone thickness = 1m)

Years	**Moles**	**Kg**	**% of Total**
1	0.01	0.001	0.0007%
5	0.05	0.005	0.0037%
20	0.2	0.02	0.0147%
100	1	0.1	0.0733%

Assumes

No buffering by OH-, HCO3 or CO3

Summary

pH	**Drainage mm/year**	**% of total calcium carbonate after 100 years drainage**
4	100	0.07%
4	200	0.15%
4	300	0.22%
5	100	<0.01
5	200	0.02%
5	300	0.02%

Appendix L
Risks posed by lime stabilisation to Sizewell and Minsmere Marshes SSSI

Peat and Alluvium as Backfill for Borrow Pits:
Risks posed by lime stabilisation to Minsmere Marshes SSSI

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1. Introduction

The purpose of this technical note is to assess whether the use of lime to stabilise fine grained soils within the borrow pits associated with the proposed Sizewell C development will pose a risk to downgradient surface water receptors, specifically from a potential increase in alkalinity. Groundwater beneath the borrow pits flows towards, and discharges into, groundwater dependent terrestrial ecosystems (GWDTEs) of the Minsmere-Walberswick Heaths & Marshes Site of Specific Scientific Interest (SSSI) approximately 450 m downgradient of the borrow pits. A change in the chemistry of groundwater entering the marshes could lead to a change in surface water chemistry which has the potential to adversely affect the ecology within the marshes.

Lime addition (lime modification) of the backfill materials is proposed to improve their geotechnical properties, making them more amenable to placement and compaction. The addition of lime will result in increased pH and alkalinity within porewater and leachate within the pits. Some of this may move vertically downwards to contribute to an increase in alkalinity in groundwater beneath the pits that may flow towards, and discharge into the marshes.

2. Objectives

For alkalinity to significantly affect the GWDTE then it must:

- Be mobile and capable of being released to porewater / infiltrating recharge at elevated concentrations and in large mass;
- Have sufficient mass flow rates to raise the baseline alkalinity of groundwater beneath the site after dilution and mixing;
- Not undergo attenuation through processes such as mineralisation that reduce the concentration arriving at the discharge location; and
- Have sufficient mass that the discharge into the GWDTE is capable of affecting the baseline chemistry of the marshes.

This Technical Note investigates the potential for there to be a significant adverse impact from the use of lime stabilisation through consideration of the above points.

3. Approach

The approach has been to:

- Review site monitoring data to understand baseline conditions in groundwater and the marshes;
- Review literature on lime modification, focussed on studies of leaching behaviour to derive a likely source term concentration;
- Undertake an assessment of the effect of leaching of alkalinity on groundwater and surface water chemistry;
- Assess the results to consider whether the effects are likely to be significant.

4. Results

4.1 Baseline Condition

Groundwater

Groundwater around the proposed borrow pits has alkalinity (expressed as mg/l $CaCO_3$) that varies between 32 mg/l (BP28) and 567 mg/l (GW9S) with an average of 236 mg/l. Alkalinity in monitoring boreholes immediately downgradient of the borrow pits (at CPB13 and CPB14) average 190 to 210 mg/l. A representative value for alkalinity is therefore in excess of 200 mg/l.

Surface water

Surface water has been sampled in the Minsmere-Walberswick SSSI at the following sample points:

- SW11 (Leiston Drain),
- SW14 (South of Minsmere - Drain entering Minsmere to the east of Ash Wood Cottages); and
- G8 (Drain on the eastern most edge of Minsmere - possibly draining north to sluices)

These have average alkalinity values of

- SW11 336 mg/l;
- SW14 264 mg/l; and
- G8 393 mg/l

Other surface water sampling locations in Sizewell Marshes, to the south of the borrow pits, had alkalinity of approximately 275 to 400 mg/l.

The data suggest that baseline groundwater and surface water are both relatively alkaline and are, therefore, unlikely to be sensitive to changes (increases) in alkalinity.

4.2 Literature Review

The literature was reviewed to identify the likely source term in terms of alkalinity and / or pH following lime addition to soils.

Most of the literature on lime stabilisation of soils is focussed either on the improvement of geotechnical properties or on prevention of leaching of heavy metals. No specific literature on the risks of increased alkalinity to sensitive receptors could be found, suggesting that it is not generally a significant concern.

There are a small number of studies on leaching behaviour. However, lime modification is used in remediation of contaminated soils to reduce leaching of heavy metals and these leaching results are generally only reported for the metals of concern. Some general studies considered the fate of lime when added to soils.

Lime modification is typically used to allow soils to be used as construction fill by allowing them to be worked and compacted even when wet. The main effect is chemical alterations at the clay particles surface which decrease the volume change potential of the clay minerals (Beetham et al, 2015). This effect occurs rapidly over a period of hours to days. At high lime addition rates cementious (pozzolanic) reactions between lime and clay can result in substantial long-term enhancement of engineering properties, including strength, durability and frost resistance. Pozzolanic reactions occur slowly over months and even years (Beetham et al., 2015) and are therefore not considered here.

When dry, powdered lime is added to wet soils and is hydrated, calcium hydroxide enters the soil water solution. This partially dissociates to calcium (Ca2+) ions and hydroxyl groups, which then react with the clay-soil system. The hydroxyl groups elevate pore water pH to a maximum possible value of approximately 12.45 (Beetham et al. 2015).

Clays and silts are typically rich in alumino-silicates and on addition of lime reaction products form, including calcium silicate hydrates, calcium aluminate hydrates and calcium aluminate silicate hydrates. The composition of the reaction products formed by the lime-clay soil reaction is dependent on timing of reactant availability.

Calcium and hydroxyl ions move through the soil primarily by chemical diffusion from areas of high to low concentration so that they are rapidly distributed through the soil (Beetham et al. 2015). Advection is increasingly influential with soil increased permeability, i.e. with permeability greater than 1x10-9 m/s.

Following movement of Ca2+ ions and hydroxyl groups into place, the subsequent development of pozzolanic reactions throughout the clods can occur. The lime improvement process is usually complete within 24 hours, but subject to clay mineralogy and content may require up to 72 hours.

There are few published data on leaching from lime treated soils from which to understand the likely source term. One investigation by Chittoori et al. (2011) undertook leaching tests on a series of soils treated with 6 to 8% lime (higher than would be used at Sizewell). Leachate was analysed for calcium, rather than alkalinity. The tests were run for an amount of infiltration equivalent to 5 years at an assumed effective rainfall rate of 266 mm/yr. For comparison the rainfall at Sizewell in 2014/15 was 642 mm/yr and the long-term effective rainfall through the borrow pits has been estimated to be approximately 30 mm/yr. This found that:

- Calcium concentrations were highest in initial leachate (up to 700 mg/l) and declined over time;
- Calcium concentrations were higher for soils dosed with higher amounts of lime, i.e. the calcium concentration correlates to the amount of lime added;
- Average leachate concentration of calcium for the 6% lime stabilised soil were 430 mg/l over 14 leaching cycles compared to 589 mg/l for 8% lime addition.

The study found that only a small proportion of the total available calcium was leached (less than 1%) after the 5 years equivalent leaching implying that it would take many decades for full leaching.

Although alkalinity was not measured, assuming that the leachate was calcium bicarbonate, by stoichiometry the peak alkalinity would be 1750 mg/l and the average alkalinity for the 6% lime stabilised soil leachate would be 1100 mg/l.

The likely lime addition at Sizewell is lower (estimated to be 1 to 2 %) and the results form Chittori et al., (2011) suggest that the concentration of calcium is proportional to the amount of lime added so a lower alkalinity is anticipated for the borrow pits. Assuming a linear relationship between the amount of lime added and the alkalinity generated suggests that the peak suggests that at 2% addition, the peak and average concentrations of alkalinity would be 582 and 360 mg/l respectively. The Average alkalinity is not significantly above background concentrations.

4.3 Assessment

Leachate generation

The rate at which leachate is generated will highest in the first 2 to 3 years immediately after placement due to the effects of consolidation that will lead to expulsion of porewater. This leachate will also have the highest alkalinity concentration. Consolidation will be relatively rapid and at the same time the alkalinity concentration will also fall. In the long-term, the rate of leachate generation will be low due to the low predicted infiltration rate of 30 mm/yr, in addition the long-term concentration of alkalinity will also be low.

The risks of an increase in alkalinity will therefore be greatest in the first few years following backfilling and will rapidly diminish. The relatively rapid displacement of high alkalinity porewater represents a slug that will be subject dispersion within groundwater as it travels in the direction of groundwater flow. The effect of dispersion will be to reduce peak concentrations.

Travel times in the aquifer to the wetland over a distance of 450 m can be estimate from the distance, the hydraulic conductivity, K, estimated as 12.5 m/d the hydraulic gradient of 0.00145 and the estimated porosity (20%). This calculation suggests that it will take 14 years for groundwater to reach the receptor. Over this time, dispersion will significantly reduce the concentration arriving at the marshes and the concentration that does arrive will be closer to the average (360 mg/l) than the peak concentration (582 mg/l).

Groundwater flowing beneath the site forms only a small part of the potential groundwater discharge to the Minsmere and Walberswick Marshes, which extend 3 km from south to north. The marshes also receive surface water runoff from the Minsmere River and its tributaries which will dilute groundwater inflows.

4.4 Assessment

Based on the literature, the alkalinity source concentration leaching from lime stabilised soil was conservatively estimated at 1311 mg/l. This values was derived for a 6% addition of lime, whereas current proposals are for 1 to 2%, which is estimated to have an average concentration of 360 mg/l.

The peak alkalinity concentration will be reduced by reaction with acidity generated by the oxidation of pyrite during the excavation, transport and placement of the infill material. The release of alkalinity will be greatest in the first two to three years due to consolidation of soils squeezing out porewater. The rate of release will rapidly diminish as consolidation reduces and concentration will also reduce in line with the behaviour identified in the leaching tests by Chittoori et al. (2011).

Based on the likely average alkalinity calculation, the limited time over which alkalinity will be released at elevated concentrations and the long travel time to receptors, it is anticipated that maximum concentrations reaching the marshes will represent a small increase above baseline and in the long-term will be similar to the baseline. As groundwater and the marshes are characterised by elevated alkalinity this is unlikely to represent

5. Conclusions

It is proposed to stabilise soils in the borrow pits by lime modification to enable them to be worked and compacted. The use of lime potentially poses a risk to downgradient receptors.

An assessment has been undertaken to evaluate the likely impact of lime modification on downgradient receptors using conservative assumptions. This assessment has found that there is likely to be an increase in groundwater alkalinity beneath and downgradient of the borrow pits. However, concentrations in groundwater are unlikely to rise significantly above the baseline. It is therefore concluded that lime modification will not adversely affect surface water quality in the Minsmere & Walberswick Heath Marshes.

6. References

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Chittoori S,Pedarla A,Puppala A. J, Hoyos L. R, Nazarian S and Saride S. 2011. Leachate Studies on Lime and Portland Cement Treated Expansive Clays. In Geo-Frontiers Congress 2011 Advances in Geotechnical Engineering, Han J and Alzamora D E (Eds)

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Appendix M
Settlement Calculations

Peat and Alluvium as Backfill to Borrow Pits at Sizewell – Settlement Calculations

1. Introduction

1.1 Background

EDF Energy is undertaking studies into the feasibility of constructing a new nuclear power station at Sizewell in Suffolk, henceforth referred to as Sizewell C (SZC).

Bulk excavations will be required to enable the foundations and underground structures of the power station to be constructed. The excavations will be undertaken primarily within a hydraulic containment cut-off wall. Ground conditions within the cut-off wall area comprise Made Ground (comprising sand with demolition material including concrete and brick) overlying Alluvium (peat, peaty clay and clay/silt) and Norwich Crag Sand.

The excavation of the area within the cut-off wall of the Sizewell C main site may generate approximately 1.1 million m^3 of recent deposits, comprising a mixture of peat, peaty clay and clay/silt[1]. EDF considers that this material is not suitable as engineering fill around power station structures. It is understood that EDF is considering options for winning a similar volume of Norwich Crag sand material from a borrow pit to be located within the wider SZC development site for use as engineering fill.

A preliminary study has been undertaken to assess the option of using the excavated peat, peaty clay and clay/silt materials as backfill to the borrow pit (AMEC, 2014) which included a review of the geotechnical characteristics of the alluvium. The material is generally characterised by high liquid and plastic limits which indicates that consideration will need to be given in handling and management of the material during excavation, placement and compaction.

The backfilled borrow pit also provides a potential site for stockpiling granular material during the SZC construction phase. Creation of the temporary stockpiles has the potential for settlement of the infill material which may result in squeezing out of pore water and a potential impact on groundwater in the short term.

This technical note describes the assessment undertaken by AMEC to assess the likely settlement of the backfill material caused by the stockpiling of materials. This note should be read in conjunction with the previous AMEC report 'Peat and Alluvium as Backfill for Borrow Pits Groundwater, Surface Water & Ground Gas Risk Assessment' (Ref. 34678r001i5 – dated June 2014).

Although the calculation of likely settlements has been carried out and presented within this note, there is the potential for bearing capacity failure of the backfilled material once subjected

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[1] P Judge Note – Borrow Pit Options for Discussion with AMEC (9/10/13)

to the stockpile loadings and further work would be needed to assess this risk and the need for geotechnical measures to prevent failure.

1.2 Scenario

The proposed borrow pit would be excavated to 2m above the water table with a typical depth of excavation of approximately 8 m below current ground level. The excavations will cease within sand and gravels, a medium dense to dense brown silty sand with inclusions of clay and shell fragments. These deposits are underlain at approximately 10m bgl by the Norwich Crag which has similar properties.

The borrow pits will be backfilled with a mixture of peat, peaty clay and clay/silt . The backfilled borrow pit may then be used for the interim storage of fill materials. The preferred option would be to create stockpiles up to 14m height. The infill materials are compressible with the likelihood that stockpiling will result in settlement.

The stockpiles are likely to be in place for 4 to 5 years, with material being progressively removed for construction purposes.

2. Methodology and Scope

2.1 Scope

Calculations have been undertaken to estimate the ranges of total settlement likely to be caused by the placement of stockpiles of varying height, over the backfilled borrow pit. The settlement experienced by both the backfill material and the underlying sand and gravels has been calculated. In addition, the amount of settlement at yearly intervals (to a maximum of 5 years) after placement has been calculated, as it is expected that the stockpiles will have been removed by this time.

The estimated rebound of the backfill materials on removal of the stockpiles has also been calculated.

2.1.1 Basis of Calculations

A number of variables have been considered, as follows:

- Calculations have been carried out for stockpiles of 14 m, 7 m and 3.5 m in height.
- Due to the variable compressibility of the mixed unsuitable material, settlement calculations have been carried out using worst case, best case and average case compressibility parameters as determined from analysis of in-situ soils (Structural Soils, 2009).
- Although some variability is expected in the co-efficient of consolidation, yearly settlements have been calculated using average case parameters, but a range in values (Table 3.1) have also been used for ‘best’ and worse ‘case’ scenarios (Section 3.1.1).
- The calculations have been carried out using parameters obtained from interpretation of geotechnical testing on in situ soils (Structural Soils, 2009). Excavation, transport and

placement of the soils will result in a change in the properties of the materials, with the potential for a higher amount of settlement.

2.2 Calculation Methodologies

The settlement of the backfill material was carried out using the method outlined by Tomlinson[2], whilst the rate of settlement is calculated using the Janbu, Bjerrum and Kjaernsli method quoted by Simons and Menzies[3].

The settlement of the sand and gravels/Crag sand was carried out using the Burland and Burbidge[4] method.

These methods are all well established and widely used in geotechnical engineering practice.

2.3 Assumptions

In undertaking the settlement calculations the following assumptions have been made:

- Stockpiles to be on site for up to 5 years;
- Assumed width of stockpile is 50 m.
- Therefore, base of influence (z1 - within which 75% of settlement takes place) = 20m bgl (Burland and Burbidge)
- Length of stockpile assumed to be 200 m.
- Settlement of underlying sand and gravels/Norwich Crag will take place in short term.
- Unit weight of stockpiled material = 20kN/m^3.

The above dimensions are an underestimate of the actual stockpile footprint, but this would not be expected to affect settlement calculations for the fill, but would have a small influence on settlement of the underling sand and gravels.

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[2] Tomlinson M.J (2001): Foundation Design and Construction 7th Edition

[3] Simon N. & Menzies B. (2005): A short course is Foundation Engineering 2nd Edition

[4] Burland J.B. &Burbidge M.C (1985): Settlement of foundations on sand and gravel – Proceedings of the Institution of Civil Engineers pp 1325-1381.

3. Settlement Calculations

3.1 Parameters

3.1.1 Backfill Material

The geotechnical parameters for the backfill material have been derived from data from the ground investigation carried out by Structural Soils in 2009. The parameters values used are as follows:

- Co-efficient of volume compressibility (m_v) – this is used in the calculation of the total settlement and is derived from values obtained in oedometer testing in the laboratory. The value of m_v varies depending on the applied load, and is expressed as m^2/MN.
- Co-efficient of consolidation (cv) – this is used to calculate the ‘time factor’ which is required to calculate the rate of settlement. This also varies depending on the applied load and is expressed as m^2/year.
- Geological Correction factor (µg) – a dimensionless factor which is applied to total settlement calculations. The value depends on the type of clay. Sensitive clays (e.g. alluvial/estuarine clays)) have a µg of between 1.0 and 1.2, so these are incorporated in the worst case, best case and average case scenarios accordingly.

The parameters are summarised in Table 3.1 below:

Table 3.1 Geotechnical Parameters – Backfill Material

Scenario	**3.5m stockpile (75kPa)**		**7m stockpile (140kPa)**		**14m stockpile (280kPa)**		**Geological correction factor µg**
	M_v (m^2/MN)	**C_v (m^2/year)**	**m_v (m^2/MN)**	**c_v (m^2/year)**	**m_v (m^2/MN)**	**c_v (m^2/year)**	
Worst Case	**3.5**	**5.0**	**2.10**	**2.75**	**1.20**	**2.10**	**1.2**
Average Case	**1.90**		**1.40**		**0.85**		**1.1**
Best Case	**0.66**		**0.56**		**0.31**		**1.0**

Based on *in situ* soil properties with limitations as discussed in Section 2.2

It should be noted that the worst case scenario combines 4 case parameter values and therefore the calculated settlement values (1 in 256 case) may represent an extreme case, but has been included for illustrative purposes.

3.1.2 Sand and Gravels/Norwich Crag

As a granular deposit, the Burland and Burbidge method has been used to calculate settlement of the Sand and Gravels/Norwich Crag. The method uses a compressibility factor (Ic) in the calculation, which is derived from ‘N’ values obtained in Standard Penetration Tests. Based on the results of the recent ground investigation carried out by Structural Soils in 2014, the following parameters have been derived:

- Representative SPT ‘N’ value for Sand and Gravels/Norwich Crag (below 8m bgl) = 30
- Burland & Burbidge Compressibility Factor (Ic) = 0.015

3.2 Results

The settlement results are summarised in Table 3.2 below:

Table 3.2 Estimated Settlements

Height of Stockpile (m)	Case Parameters	Total Settlement of Backfill (mm) (assuming stockpile in place indefinitely)	Sand gravel Settlement (mm)	Backfill Settlement after placement (mm)					Estimated Rebound (mm)
				1 Year	2 years	3 years	4 years	5 years	
14 (280kPa)	Best	700-800	100-150	280-320	400 - 460	480 - 550	525-600	560-640	250-300
	Average	2000-2500		800 - 1000	1160-1450	1380-1730	1500-18750	1600-2000	
	Worst	3000-3500		1200-1400	1740-2030	2070-2420	2250-2630	2400-2800	
7 (140kPa)	Best	600-700	50-75	270-320	390-460	440-510	490-570	530-620	275-325
	Average	1500-2000		680-900	980-1300	1100-1460	1230-1640	1320-1760	
	Worst	2500-3000		1130-1350	1630-1950	1830-2190	2050-2460	2200-2640	
5 (100kPa)	Best	500-600	50-75	350-400	450-500	500-550	550-600	550-600	200-250
	Average	1500-2000		1000-1300	1200-1500	1400-1700	1500-1800	1600-1900	
	Worst	3000-3500		2000-2300	2500-2800	2900-3200	3100-3400	3200-3500	
3.5 (70kPa)	Best	350-450	25-50	220-280	270-350	320-410	330-430	340-440	150-200
	Average	1000-1500		630-950	780-1170	900-1350	950-1380	980-1470	
	Worst	2000-2500		1260-1580	1560-1950	1800-2250	1900-2380	1960-2450	

4. Conclusions

4.1 Summary of Findings

The calculations have shown that stockpiling would result in settlement of the backfill. Using most likely or average values the amount of settlement for a 14m stockpile is estimated at between 1.6m and 2m over a 5 year period. For a 3m stockpile, the predicted settlement is between 0.98 and 1.47m, with best case predictions of 0.34 to 0.44m.

The calculations are sensitive to the stockpile height and to the properties of the peat and clay. The property values are based on laboratory testing of undisturbed materials and do not take account of changes in properties as a result of excavation, handling and placement of the material which will also result in a mixed material. The design of backfill operations will need to consider how materials are best handled and managed to achieve facilitate compaction. t

The calculations also show that a significant amount of the total settlement (80 to 98%) will occur over a 5 year storage period assuming no removal of the material during this period.

The actual settlement experienced will also largely depend on the amount of time it takes for the stockpile to be built up, and then removed as the fill is used in the construction of the power station.

An additional factor that will need to be taken account in the construction of the stockpiles is that the undrained strength of the materials is low with the potential risk of bearing failure of the fill which could affect the stability of the stockpiles as well as plant movements during placement and removal of the stockpiles. This will need to be considered as part of the design of the works.

4.2 Recommendations

The calculations have been carried out using a range of geotechnical parameters derived from a detailed review of laboratory test results on the clay and peat material expected to form the backfill material. However, each of the tests has been carried out on discrete materials as encountered in exploratory boreholes. In the event, the material will be a mixture of clay, peat, peaty clay and silt formed as a result of mass excavation, transport and placement.

Geotechnical testing of samples of blended material at varied states of compaction would serve to provide geotechnical parameters more representative of the mass material, which may also allow for more accurate calculations of settlement.

5. References

Amec, 2014. Peat and Alluvium as Backfill for Borrow Pits. Groundwater, Surface Water & Ground Gas Risk Assessment. RR001i5.

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Structural Soils, 2014. Factual Report on 1st Phase Ground Investigation on SZC Construction Site Area and Associated Development

Tomlinson M.J (2001): Foundation Design and Construction (7^{th} Edition).

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Appendix N
LandSim Model Input Parameters

The LandSim model input parameters are listed in **Tables O1 to O3**. For the majority of parameters, a triangular distribution (Environment Agency, 2001) has been used based on plausible, minimum, most likely and maximum values. Where data are of limited quality, a uniform distribution has been used. In some cases, a log normal distribution has been used where the data show this is appropriate. A summary of the main input parameters is discussed below.

Table O1 LandSim input parameters: site geometry, unsaturated pathway and saturated pathway

Description	**Distribution**				**Justification**
	Unit	**Min**	**Mean**	**Max**	
Site Geometry					
Site geometry – Top area	ha	19.9 (single value)			Revised from 2016 risk assessment to reflect revised potential borrow pits areas. Measured from Figure 3.1.
Site geometry – Base area	ha	15.97 (single value)			Revised from 2016 risk assessment to reflect revised potential borrow pits areas. Assumed 80% of top area based on 1 in 2.5 side slopes.
Backfill thickness	m	8 (single value)			Revised from 2016 risk assessment to reflect revised potential borrow pits areas. Average backfill thickness for Areas 1, 2 and 3. Estimated from comparison of topographic levels (Figure 4.1) and maximum groundwater levels (as defined in Section 4.4) plus allowance for a minimum of 2 m unsaturated zone.
Infiltration					
Infiltration backfilling	mm/yr	30 20*	90 60*	150 100*	No change from 2016 risk assessment. Assumed conservatively to be a factor of 3 times higher the average long-term drainage rate (10, 30, 50 mm/yr below) to account for settlement and higher infiltration over the backfill area and these rates have been assumed to occur over a period of 2 years. *Lime treatment assumes backfilling drainage rate of 20-60-100 mm/yr during 3 years (see text below)
Infiltration restored	mm/yr	10 5*	30 15*	50 25*	No change from 2016 risk assessment. Drainage rates after the site has been restored are considered to be controlled by the permeability of the infill to give an average drainage rate of 30 mm/year (assuming a mass permeability of 10^{-9} m/s) and a range of 10 to 50 mm/year. *Lime treatment assumes restored drainage rate of 5-15-25 mm/yr (see text below)
Backfill hydraulic conductivity	m/s	$1x10^{-9}$	-	$1x10^{-7}$	No change from 2016 risk assessment. Testing of alluvial material (Jacobs, 2011)
Backfill porosity	%	60 (single value)			No change from 2016 risk assessment. Testing of alluvial material (Jacobs, 2010)
Backfill Dry density	kg/m^3	600 (single value)			No change from 2016 risk assessment. Testing of alluvial material (Jacobs, 2010)
Backfill field capacity	%	10 (single value)			No change from 2016 risk assessment. Testing of alluvial material (Jacobs, 2010)
Lining System					

Description	Distribution				Justification
	Unit	**Min**	**Mean**	**Max**	
Type	No liner				
Head of leachate	m	0.001 (single value)			No change from 2016 risk assessment. Adjusted to ensure drainage rate equals infiltration rate, set at 0.001 m.
Unsaturated Pathway (Crag)					
Flow Model	-	Porous medium			No change from 2016 risk assessment. Intergranular system
Pathway length	m	2.0	4.8	7.7	Revised from 2016 risk assessment to reflect revised potential borrow pits areas. A minimum depth of 2 m of unsaturated thickness assumed. The site investigation shows that an excavation depth of 6.7 to 8.3 m will provide a minimum unsaturated thickness of 2 m.
Matrix Hydraulic conductivity	m/s	2x10^{-5}	2.16x10^{-5}	2.3x10^{-5}	No change from 2016 risk assessment. See Section 4.4 (1.7 to 2 m/d).
Moisture Content	-	0.08	0.10	0.13	No change from 2016 risk assessment. Assumed value for intergranular aquifer.
Density	Kg/l	2.1 (single value)			No change from 2016 risk assessment. Testing of alluvial material (Jacobs, 2011)
Organic carbon content	-	0.001 (single value)			No change from 2016 risk assessment. 0.001 from Environment Agency (1999). Field testing indicates a value of 0.0006 but value of 0.001 considered to be appropriate.
Longitudinal Dispersivity	m	10% of pathway length			No change from 2016 risk assessment. EA, 2003a.
Aquifer Pathway (Crag)					
Pathway length	m	50, 250 and 450			Re-assessed but no change from 2016 risk assessment. Based on distance to nearest groundwater and surface water receptors (see Section 8.3)
Width	m	450 (single value)			Revised from 2016 risk assessment to reflect revised potential borrow pits areas. Width of site perpendicular to flow.
Mixing zone thickness	m	35 (single value)			No change from 2016 risk assessment. Typical saturated thickness of Crag below borrow pits (see cross sections in figures 4.4 to 4.6).
Hydraulic gradient	-	0.0013	-	0.0016	No change from 2016 risk assessment. Hydraulic gradient based on observed data for March 2015 (date of maximum observed groundwater level; see Section 4.4)
Hydraulic conductivity	m/s	6x10^{-5}	1.45x10^{-4}	3.5x10^{-4}	No change from 2016 risk assessment. Values based on site investigation. Testing of boreholes (Table 4.1) indicates hydraulic conductivity in the range 4 to >21 m/d. Pumping tests in the wider area indicate that hydraulic conductivity can exceed 50

Description	Distribution				Justification
	Unit	Min	Mean	Max	
					m/d. For this reason a hydraulic conductivity of 5 to 30 m/d, equivalent to $6x10^{-5}$ and $3.5x10^{-4}$ m/s (average 15 m/d equivalent to $1.45x10^{-4}$ m/s) has been used.
Porosity	-	0.2 (single value)			No change from 2016 risk assessment. Literature values (see Section 4.4)
Density	kg/l	2.1 (single value)			No change from 2016 risk assessment. Testing by Jacobs (2011).
Organic carbon content	-	0.0006 (single value)			No change from 2016 risk assessment. 0.001 from EA (1999). Field testing indicates a value of 0.0006 but value of 0.001 considered to be appropriate.
Longitudinal Dispersivity	m	10% of pathway length			No change from 2016 risk assessment. EA, 1999.
Transverse Dispersivity	m	3% of pathway length			No change from 2016 risk assessment. EA, 1999.

Table O2 LandSim input parameters: infill source term parameters

Description	Unit	Concentration [a]	Kappa Value	K_d	K_{oc}	Half-life	Justification
		Min-Mean-Max	(kg/l)	(l/kg)	(l/kg)	(years)	
Ammoniacal-Nitrogen	mg/l	15-22.5-30 Triangular distribution	m=0 c=0.59	0.05-0.5	-	1 to 5	No change from 2016 risk assessment. Kd and aquifer half-life (EA, 2003b) Kappa (LandSim default)
Chloride	mg/l	30-1 900-4 100 Log Triangular distribution	m=0.0298 c=0.2919	0	-	10^9	No change from 2016 risk assessment. Kd (LandSim default) Half-life (conservative substance) Kappa (LandSim default)
Sulphate	mg/l	1 858-2 800-3 750 *1 394-2 100-2 813 Triangular distribution	m=0.1 c=0.1209	0-0.25	-	10^9	No change from 2016 risk assessment. Initial concentration based on ADAS trial for peat/clay. * Lime treatment (see text below) Kd (see text below) Half-life (conservative) Kappa (see text below)
Iron	mg/l	0.1-1.4-9.6 Log triangular distribution	m=0.1 c=-0.12	1-10 000	-	10^9	No change from 2016 risk assessment. Kd (LandSim default, literature) Half-life (conservative) Kappa (assumed)
Sodium	mg/l	1020 or *765 (mean) 1610 or *1208 (standard deviation)	m=0.0298 c=0.2919	0	-	10^9	No change from 2016 risk assessment. * Lime treatment (see text below)

		Log normal distribution					Kd (LandSim default) Half-life (conservative) Kappa (assumed same value as for chloride from LandSim default)
Phenanthrene	ng/l	11-30-230 Log triangular distribution	m=0 c=0.59	13.9 ^{b}	23 200	10	No change from 2016 risk assessment. Koc (ConSim) Half-life in unsaturated zone and aquifer (ConSim) Kappa (assumed same value as for ammoniacal-N from LandSim default)

Notes: a) Concentration derived from site data. b) Kd calculated as Kd=Koc.foc, where foc is the assumed organic carbon content of the Crag (0.0006) and Koc is the organic carbon-water partition coefficient for phenanthrene (23 200 l/kg).
* Sensitivity analysis

Table O3 LandSim input parameters: background groundwater quality

Substance	Unit	Background Groundwater Concentration			Notes
		Min	Mean	Max	
Chloride	mg/l	27	68	90	Based on monitoring data excluding two concentration spikes (120 and 180mg/l) at borehole BP27 in April and July 2016 which appear anomalous compared to data across the borrow pits including adjacent borehole BP28 (see water quality plot in Appendix D of this document).
Sulphate	mg/l	27	67	99	Based on monitoring data excluding concentration spike (120 mg/l) at borehole SD3 in October 2015 which appears anomalous compared to data across the borrow pits including adjacent borehole BP9 (see water quality plot in Appendix D of this document).
Ammoniacal nitrogen	mg/l	0.008	0.13	0.72	Based on monitoring data excluding six outliers (1.0 to 7.2mg/l) which appear anomalous (see water quality plot in Appendix D of this document).
Sodium	mg/l	10	24	50	Based on monitoring data excluding concentration spike (73mg/l) at borehole SD3 in October 2015 which appears anomalous compared to data across the borrow pits including adjacent borehole BP9 (see water quality plot in Appendix D of this document).
Iron	mg/l	0.02	0.29	0.409	Data shows some variability. Maximum concentration set as 95th percentile (see water quality plot in Appendix D of this document).
Phenanthrene	mg/l	0	0	0	Observed concentrations typically below detection limits (<0.01 µg/l)

Notes: Groundwater quality data for November 2014 to June 2019 and boreholes within and near the potential borrow pit locations (BP6, BP7, BP9, BP12, BP27, BP28, C7, CPB11, CPB13, CPB14, SD3, SD6, SD7 and SD8) has been used to define background conditions for the LandSim model.

Borrow Pits

The area and approximate depth of excavation of the borrow pits for each of the options being considered is given in **Table 2.1** and **Table O1**. The base and sides of the excavation will be unlined and restoration will comprise reprofiling of the final landform to facilitate surface water drainage and replacement of topsoil to allow the land to be returned to agriculture or heathland. Excavation of the Crag to 8 m will leave an unsaturated zone thickness of 2 m (above maximum groundwater levels).

The LandSim assessment has been based on the assumption of a minimum thickness for the unsaturated zone of 2m.

Drainage Source Term

The backfill operation will comprise excavation of the alluvium and transport to the borrow pits. The scheme is likely to comprise placement of the alluvium in layers, lime will be added and rotavated into the fill and left before the next layer of fill is spread. This procedure may result in limited aeration of the alluvium and oxidation of pyrite, albeit as each layer is placed, exposure to the atmosphere to the mass of the fill will reduce. The reaction with lime will result in utilisation of pore water (hydration) and/or rainwater plus some evaporative loss due to a rise in temperature caused by hydration. The creation of calcium and sulphate hydrates will also limit the loss of these ions through leaching and drainage. The generation of ground gas may also result in an oxygen poor environment which will limit further oxidation of pyrite.

Based on the review of information for the alluvium backfill (Section 5.3) the source term has been defined as follows:

Chloride. Soils testing indicates soluble chloride concentrations in clay and peat are likely to about 1 900 mg/l (range 30 to 4 100 mg/l) (**Appendix F** of this document) which is consistent with the observations during the heathland trials. It is noted that chloride concentrations for peat/ clay excavated from the western part of the SZC development area is likely to be lower and therefore material from this area could be characterised by a lower strength source term. For chloride a triangular distribution[15] (Environment Agency 2001) was used (**Table O2**). The addition of lime is unlikely to affect chloride concentrations, but is likely to reduce the volume and rate of drainage.

Sulphate. Under anaerobic conditions the concentration of sulphate in leachate is likely to be low (<100 mg/l) as demonstrated by leaching tests (Section 5.3) and this is likely to be the case in the longer term as conditions within the fill will be anaerobic. In the short term, excavation and placement of the material may result in oxidation of pyrite and higher sulphate concentrations (~3 000 mg/l) in any drainage. For the LandSim source term an initial high concentration was conservatively assumed based on the heathland trials. This was then allowed to decline to represent from a change from aerobic to anaerobic conditions as discussed below. The initial source term is considered to be highly conservative as it is based on data from trials that would have maximised the potential for exposure of peat to the atmosphere. For sulphate a log normal distribution was used (**Table O2**).

Lime added to the alluvium will react with pyrite (oxidation of pyrite), however the sulphate released is likely to form sulphate hydrates which will be precipitated within the mass of alluvium, and therefore it is considered that the addition of lime is likely to result in decrease in the sulphate source term.

Sodium. Soils testing indicates sodium concentrations in the alluvium is likely to about 1,000 mg/l (range 300 to 6,800 mg/l) (**Appendix F** of this document) which is consistent with the observations during the heathland trials. For sodium a log normal distribution was used (**Table O2**).

The addition of lime (CaO), may result in ion exchange of sodium for calcium, and a potential for an increase in sodium concentrations in the drainage albeit precipitation of sodium hydrates within the alluvium is more likely to result in a decrease in sodium concentrations in drainage water.

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[15] For the LandSim model parameter values were described using a uniform, triangular, log triangular or log normal distribution (Environment Agency 2001). The type of distribution was determined based on the available data, for most parameters a triangular distribution was used.

Iron. Under acidic conditions the iron concentration of drainage is likely to be high, but concentrations are likely to decrease rapidly due to the buffering capacity of the Sand and Gravel/Crag with precipitation of iron in the unsaturated and saturated zone. Monitoring for the heathland creation trials, showed that drainage from peat/clay had iron concentrations below 0.1 mg/l and in the range 0.4 to 9.6 mg/l for the peat trial. A triangular distribution has been used in the risk assessment (**Table O2**).

Ammonium and nitrate. Limited data are available on ammonium concentrations in the alluvium. Soil testing indicates soil concentrations of 50 to 320 mg/kg (**Appendix F** of this document). Monitoring of drainage during the heathland trials showed that drainage was initially characterised by high concentrations of nitrate (70 to 120 mg/l as NO_3), indicating that any ammonium present was rapidly transformed to nitrate on exposure to the atmosphere. Over the 5-month trial, concentrations fell to less than 60 mg/l as NO_3. These nitrate concentrations are lower than baseline groundwater for the Crag aquifer suggesting that nitrate is not a significant issue. To represent the scenario where the backfill remains anaerobic, the nitrate concentrations measured in the heathland trials have been back calculated to give an ammonium source term (~30 mg/l ammonium as N) and this has been used as input to the LandSim model (**Table O2**).

PAHs (phenanthrene). Leachate tests have indicated the potential for low concentrations of PAHs (<0.25 µg/l, but are more typically less than 0.03 µg/l or below detection limits) to be leached from the material (albeit the PAHs may be naturally occurring), therefore phenanthrene has been included in the assessment (Table 8.8) as this PAH yielded the highest concentrations in leachate tests (Table 5.7). These low concentrations are consistent with soil analysis which indicate concentrations are below detection levels (<100µg/kg).

The addition of lime is unlikely to affect the iron and ammonium concentrations. However, potential for solubilisation of humic and fulvic acids and a potential for an increase in the mobility of PAHs may exist albeit the concentrations of these compounds in previous leaching tests were low. Any change would need to be considered in terms of the likelihood for lower drainage rates. A potential for an increase in the concentrations of PAHs has been considered as part of the sensitivity analysis

In summary the main influence of addition of lime will be to reduce the rate of drainage. The concentrations of chloride, sulphate, iron and ammonium are unlikely to be affected and in the case of sulphate lower. There is a potential for an increase in sodium and PAH concentrations and this has been investigated as part of the sensitivity analysis.

The material that will used for reprofiling the borrow pits will be sourced from Crag excavated from the SZC excavation and/or material excavated from the borrow pits. Groundwater quality monitoring data for boreholes located in the SZC area indicates that groundwater is characterised by elevated chloride (50 to 4,300 mg/l) and sodium (50 to 1,100 mg/l) concentrations (although concentrations are lower than for the alluvium) and low sulphate concentrations (<100 mg/l). Drainage from this material has conservatively been assumed to fall within the source term defined for the alluvium.

A conservative approach has been taken in definition of the source term as this is considered to present the key variable for the risk assessment. This is illustrated by the use of data from the heathland trials which are considered to represent a 'worst' case in terms of generating poor quality water draining from the backfill (e.g. exposure to the atmosphere will be maximised and where the material used in the trials was either 100% peat or 50% peat and 50% clay). In practice peat is anticipated to represent about 38% of the backfill material as a whole.

This same source term has been used for the granular profile material (assuming this material is sourced from the SCZ main excavation) and the lime treated alluvium and is considered to be a conservative assumption.

Change in Source Term

The concentrations of the above parameters have been assumed to decrease with time as a result of flushing by infiltration through the infill material and this has been determined based on infiltration rates, the thickness and moisture content of the backfill and the use of appropriate Kappa values (Environment Agency, 2003a). For sulphate, there is the likelihood that as conditions within the backfill become anaerobic the concentrations will decrease to less than 200 mg/l based on the results of leaching tests. No relevant data or literature could be identified to define the likely period for this decline. For the purposes of this assessment sulphate concentrations have been assumed to decline to 500 mg/l in 10 years and 100 mg/l in 15 years. This has been investigated further through sensitivity analysis (Section 8.4.7). It is noted that the peat trials undertaken by the University of East Anglia indicated that sulphate concentrations showed a much more rapid rate of decline indicating a finite capacity for the generation of high sulphate concentrations in drainage even under aerobic conditions. Groundwater monitoring data for the SZC development area (Section 4.3), also demonstrate that under anaerobic conditions (which are likely to exist in the backfill), low sulphate concentrations would be expected.

In the longer term the environment within the mass of the backfill is expected to be anaerobic reflecting the thickness and permeability of the material. At the margins of the fill, some aeration and oxidation would be expected, but this is reflected in the initial source term and concentrations of sulphate in any drainage would be expected to decline (depletion of the source) as modelled using LandSim.

The influence of lime treatment on sulphate is more difficult to predict, however the precipitation of sulphate hydrates within the alluvium is more likely to result in a more rapid decrease in concentrations in drainage.

For the other chemicals a much slower rate of decline has been modelled and based on values given in the LandSim model (v2.5.17).

Infiltration and Drainage

Infiltration and drainage through the backfill is likely to be controlled by the permeability of the clay (~10^{-9} m/s) and assuming a vertical gradient of 1 this will be equivalent to a drainage rate of about 30 mm/year. Whilst the peat is characterised by a higher permeability, the excavation and placement of the alluvium will result in disruption of any peat layers such that peat is likely to be present as disconnected pockets in the backfill. In the short term (1 to 2 years) compaction of the backfill (including the influence of placing of up to 3m of granular material over the fill to allow for settlement and to facilitate reprofiling) may result in squeezing out of water from the peat but this will be constrained by the mixed nature of the alluvium backfill and the addition of lime to increase the mechanical strength of the alluvium.

The progressive placement of alluvium within the borrow pits together with a final layer of up to 3 m of granular material will result in settlement of the fill. Peat (~38% of excavated material) is characterised by a high in-situ water filled porosity (57 to 88%, Table 5.3) with the potential that water within it would be squeezed out from the mass of the infill and impact on groundwater, albeit some of this water will be taken up by hydration of lime. Similarly the air filled porosity (4 to 29%) would also reduce as a result of settlement.

The addition of lime will:

- Decrease the hydraulic conductivity of the fill and hence drainage rates;
- Reduce the volume of drainage of pore water through hydration of lime and evaporative loss (increase in temperature);
- Increase the geotechnical strength of the fill and hence reduce settlement and squeezing out of pore water.

The amount of settlement and volume of water squeezed out is difficult to predict given the addition of lime to the alluvium. Estimates of volumes have been made based on a settlement of 0.5 and 1m over 5 years and that 90% (average water filled saturation of peat) of this settlement can be attributed to squeezing out of the water filled porosity and 10% due the squeezing out of the air filled porosity. An estimate of 20% take up (hydration) has been assumed to provide an estimate of drainage rates.

Table O4 Estimate of Drainage Rates as a result of Settlement

Total amount of settlement (m)	Time over which release occurs (years)	Equivalent rate of drainage mm/year (approximate)[1]	Comment
0.25m	5	36, reducing to 30 after 5 years	
0.25m	2	90, reducing to 30 after 2 years	
0.5 m	5	72, reducing to 30 after 5 years	
0.5 m	2	180, reducing to 30 after 2 years	This high rate of drainage is considered to be unlikely given the permeability of the alluvium after treatment

Figures rounded to nearest 5mm/year.

For the purposes of the risk assessment, drainage rates after the site has been restored are considered to be controlled by the permeability of the infill to give an average drainage rate of 30 mm/year (assuming a mass permeability of 10^{-9} m/s) and a range of 10 to 50 mm/year. A 50% reduction in permeability due to addition of lime could reduce average drainage rates to 15 mm/year.

Infiltration during the backfilling phase has been assumed conservatively to be a factor of 3 times higher (90 mm/year with a range of 30 to 150 mm/year) the average long term drainage rate (to account for settlement and higher infiltration over the backfill area) and these rates have been assumed to occur over a period of 2 years. This represents an increase in drainage rates from previous assessments, but has been adopted to provide a more conservative assessment and is investigated as part of the sensitivity analysis.

Aquifer Properties

The basis for key input parameters for the unsaturated and saturated zone is given below:

- Dimensions (length and width) and depth of the borrow pits. The width of groundwater flow for each area has been defined based on the width of each area perpendicular to the direction of groundwater flow. The length of the groundwater flow path below the pits has been calculated to ensure the area of the receiving aquifer is consistent with the area of the pits (length x width = area).
- Unsaturated zone thickness. A minimum thickness of the unsaturated zone of 2 m has been specified to provide a conservative assessment ranging up to 7.7 m depending on the proposed excavation depth and maximum groundwater levels (Table 4.3).
- Hydraulic gradient. A gradient based on observed groundwater level data for March 2015 (high groundwater levels) has been used.
- Hydraulic conductivity. Permeability testing of boreholes (Table 4.4) indicates values of hydraulic conductivity in the range 4 to >21 m/d. Pumping tests in the wider area indicate that values of hydraulic conductivity can exceed 50 m/d. For this reason a hydraulic conductivity of 5 to 30 (average 15 m/d) has been used. This is slightly higher than the range previously used (5 to 21m/d, Amec 2014a), but reflects evidence from recent testing and may still represent an underestimate of groundwater dilution.

- Aquifer mixing zone. The aquifer mixing zone thickness was set as the aquifer thickness of 35 m. The mixing thickness was also calculated using the Environment Agency remedial target spreadsheet, but for each Area this exceeded the actual aquifer thickness indicating that the values of hydraulic conductivity used are an underestimate and that dilution has been underestimated. This is also flagged as an output from the LandSim runs.
- Background groundwater quality. Groundwater quality data for November 2014 to June 2019 and boreholes within and near the potential borrow pit locations (BP6, BP7, BP9, BP12, BP27, BP28, C7, CPB11, CPB13, CPB14, SD3, SD6, SD7 and SD8) has been used to define background conditions for the LandSim model.

Details for other input parameters (matrix hydraulic conductivity, density, organic content, dispersivity and porosity) are given in **Table O1**.

Contaminant Attenuation Parameters

Contaminant attenuation may occur as drainage moves through the Crag unsaturated and saturated zones. Attenuation of chloride was not modelled as it is a conservative substance. Attenuation parameters for ammonium, sulphate, sodium and phenanthrene are discussed below.

Ammonium. Attenuation of ammonium in the subsurface and aquifers is mainly by cation exchange processes and biological oxidation (nitrification) (EA, 2003b). Ammonium sorption coefficients K_d for the Crag were taken to be in the range 0.05 to 0.5 l/kg (EA, 2003b). Ammonium nitrification was assumed to have a half-life of 1 to 5 years. This is conservative as the heathland creation trials suggest that this process is rapid.

Sulphate. In most groundwater environments sulphate behaves as a conservative ion, however there is literature to indicate that sorption can occur in low pH conditions and in the presence of iron and aluminium oxides. For this assessment a partition coefficient in the range 0 to 0.25 l/kg was assumed.

Sodium. Attenuation of sodium is mainly by cation exchange processes. There is limited literature information on partition coefficients for sodium and therefore a conservative partition coefficient of 0 was assumed.

Iron. Published values for the partition coefficient for iron range from 1 to 10^4 l/kg (ConSim user manual). This wide range probably reflects precipitation of iron due to a change in geochemical conditions.

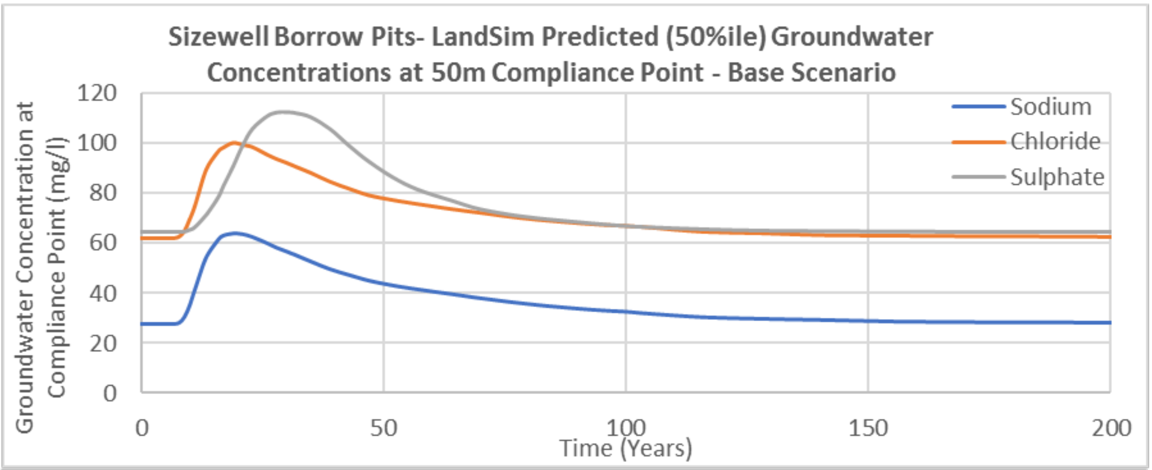
Phenanthrene (hazardous substance). Sorption and biodegradation are the primary attenuation mechanisms for PAHs in the subsurface. Sorption parameter K_d values for phenanthrene used in the risk assessment were calculated from:

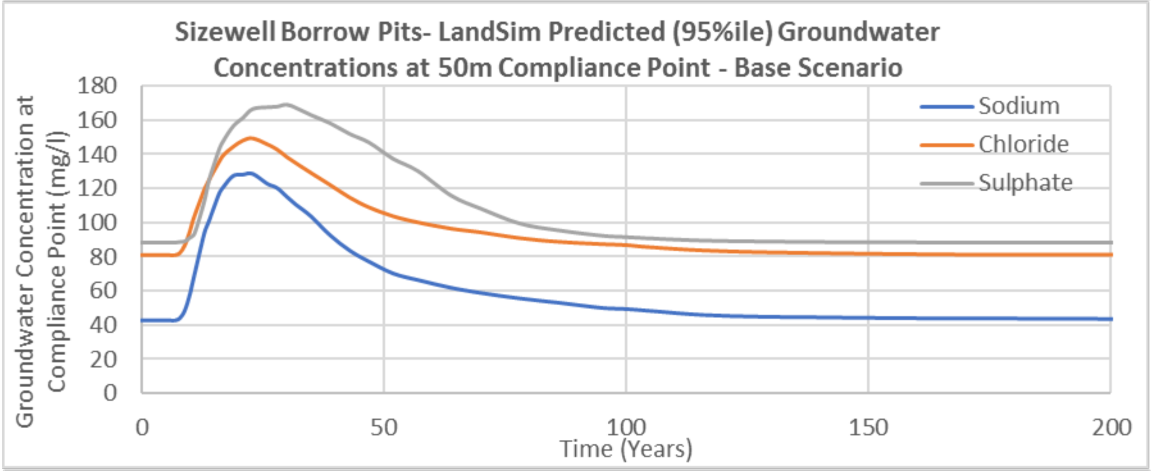
$$K_d = f_{oc} K_{oc}$$

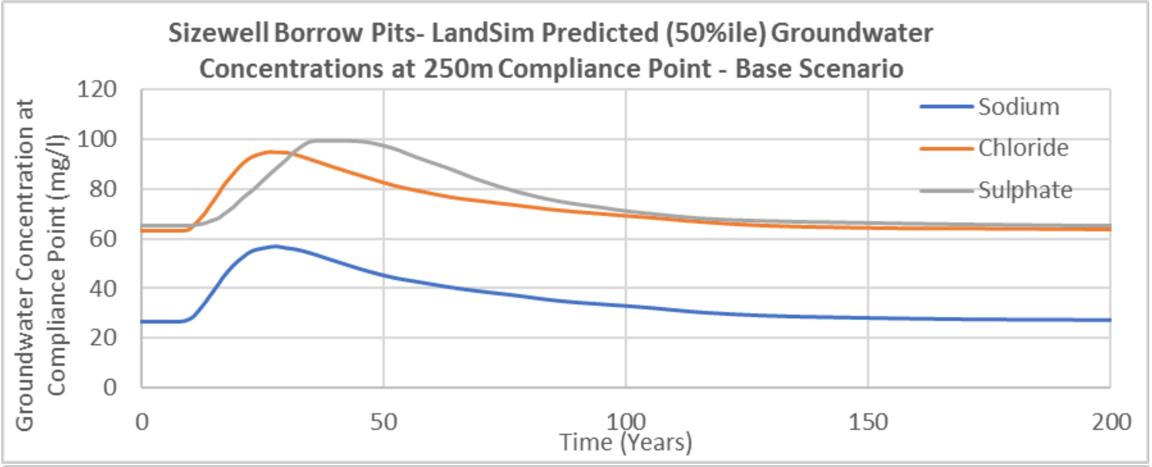
where K_d is the linear sorption coefficient (l/kg), f_{oc} is the soil organic carbon content; and K_{oc} is the organic carbon-water partition coefficient.

The value of K_{oc} was taken from the ConSim user manual (K_{oc} = 23,000 l/kg) and the foc set as 0.0006 based on the results of the site investigation. Phenanthrene can potentially degrade in aerobic environments and a conservative degradation rate with a half-life of 3,650 days (10 years) (the ConSim user manual gives a range of 1,606 to 2,081 days) was assumed for the risk assessment in the unsaturated zone and aquifer.

Appendix O
LandSim Results


Sizewell Borrow Pits- LandSim Predicted (50%ile) Groundwater Concentrations at 50m Compliance Point - Base Scenario
Groundwater Concentration at Compliance Point (mg/l)
0
20
40
60
80
100
120
Time (Years)
0
50
100
150
200
Sodium
Chloride
Sulphate


Sizewell Borrow Pits- LandSim Predicted (95%ile) Groundwater Concentrations at 50m Compliance Point - Base Scenario
Groundwater Concentration at Compliance Point (mg/l)
0
20
40
60
80
100
120
140
160
180
Time (Years)
0
50
100
150
200
Sodium
Chloride
Sulphate


Sizewell Borrow Pits- LandSim Predicted (50%ile) Groundwater Concentrations at 250m Compliance Point - Base Scenario
Groundwater Concentration at Compliance Point (mg/l)
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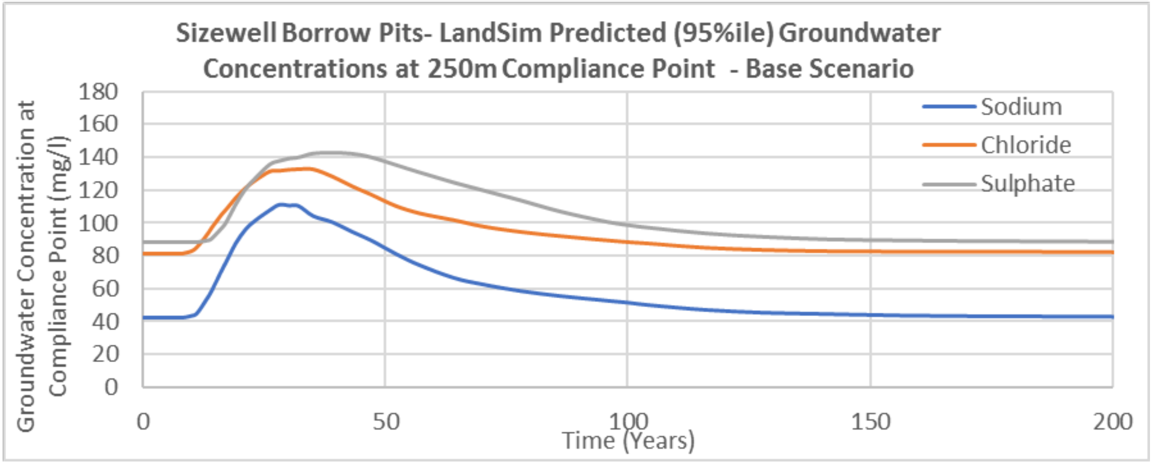
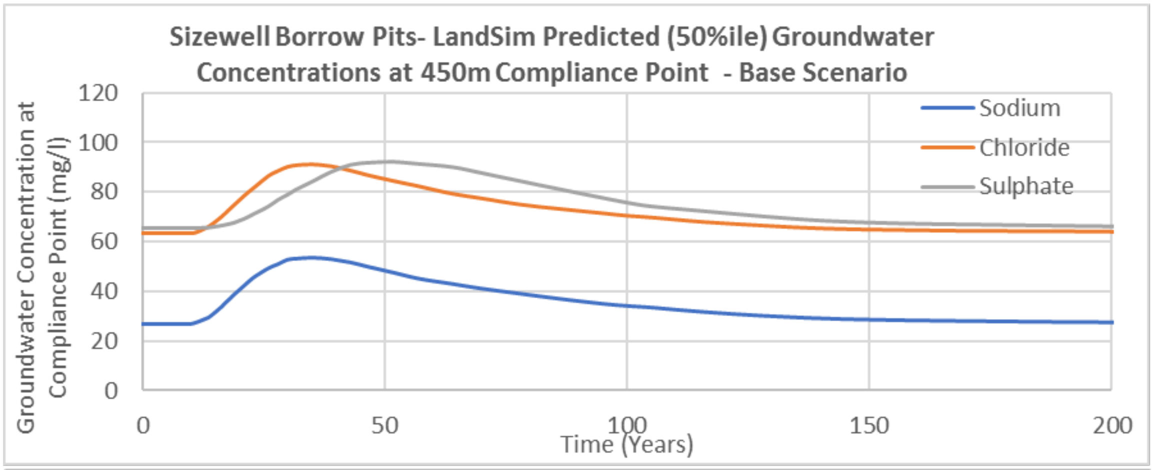
40
60
80
100
120
Time (Years)
0
50
100
150
200
Sodium
Chloride
Sulphate


Sizewell Borrow Pits- LandSim Predicted (95%ile) Groundwater Concentrations at 250m Compliance Point - Base Scenario
Groundwater Concentration at Compliance Point (mg/l)
0
20
40
60
80
100
120
140
160
180
Time (Years)
0
50
100
150
200
Sodium
Chloride
Sulphate


Sizewell Borrow Pits- LandSim Predicted (50%ile) Groundwater Concentrations at 450m Compliance Point - Base Scenario
Groundwater Concentration at Compliance Point (mg/l)
120
100
80
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40
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0
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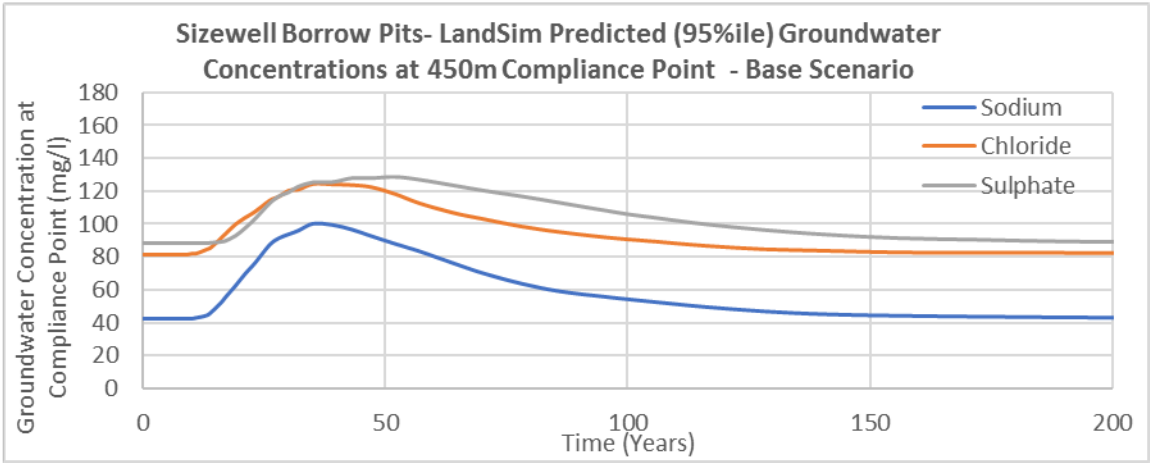
150
200
Time (Years)
Sodium
Chloride
Sulphate


Sizewell Borrow Pits- LandSim Predicted (95%ile) Groundwater Concentrations at 450m Compliance Point - Base Scenario
Groundwater Concentration at Compliance Point (mg/l)
180
160
140
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100
150
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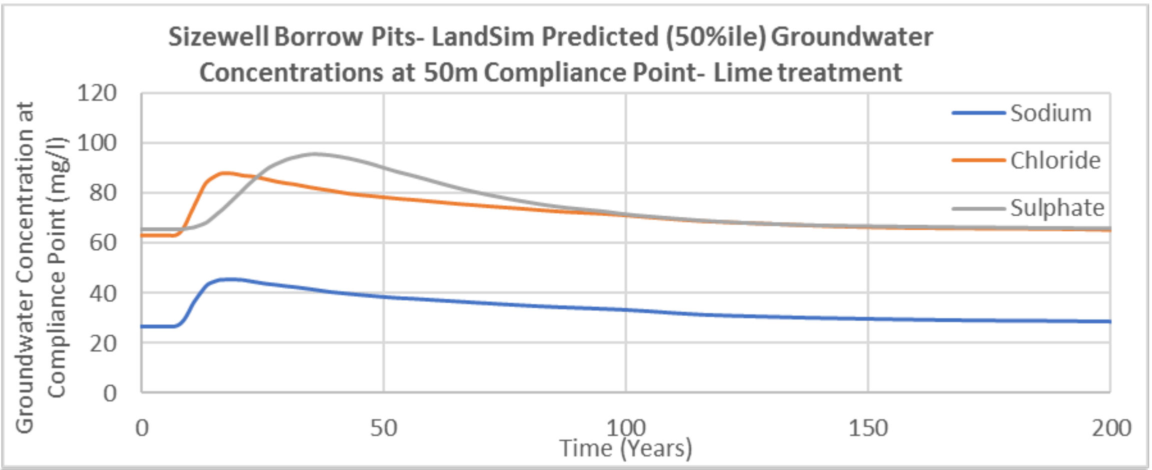
Time (Years)
Sodium
Chloride
Sulphate


Sizewell Borrow Pits- LandSim Predicted (50%ile) Groundwater Concentrations at 50m Compliance Point- Lime treatment
Groundwater Concentration at Compliance Point (mg/l)
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20
40
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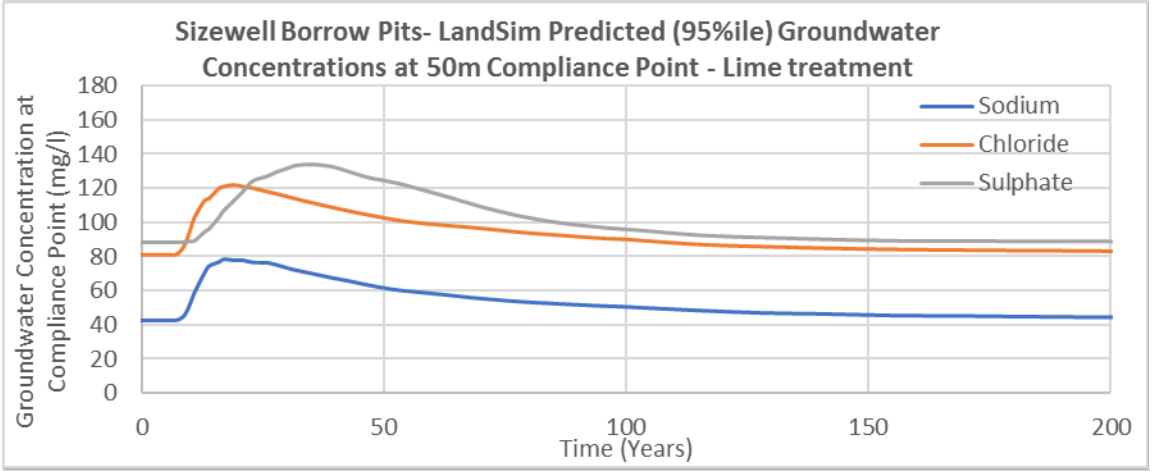
200
Time (Years)
Sodium
Chloride
Sulphate


Sizewell Borrow Pits- LandSim Predicted (95%ile) Groundwater Concentrations at 50m Compliance Point - Lime treatment
Groundwater Concentration at Compliance Point (mg/l)
0
20
40
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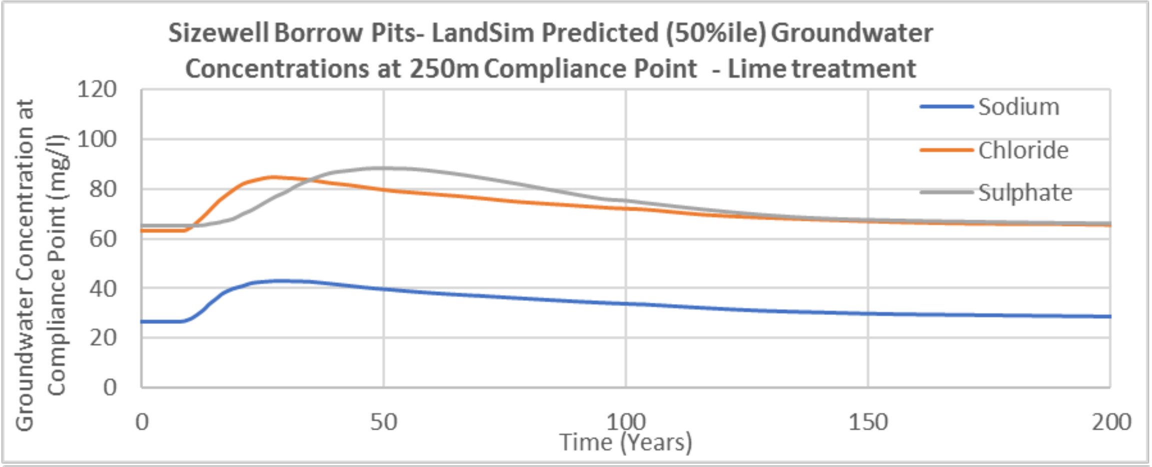
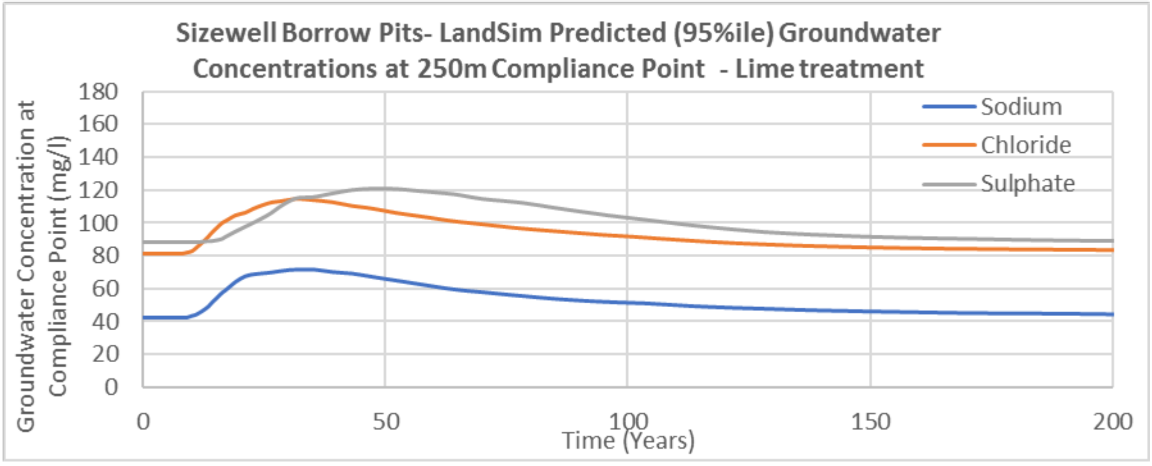
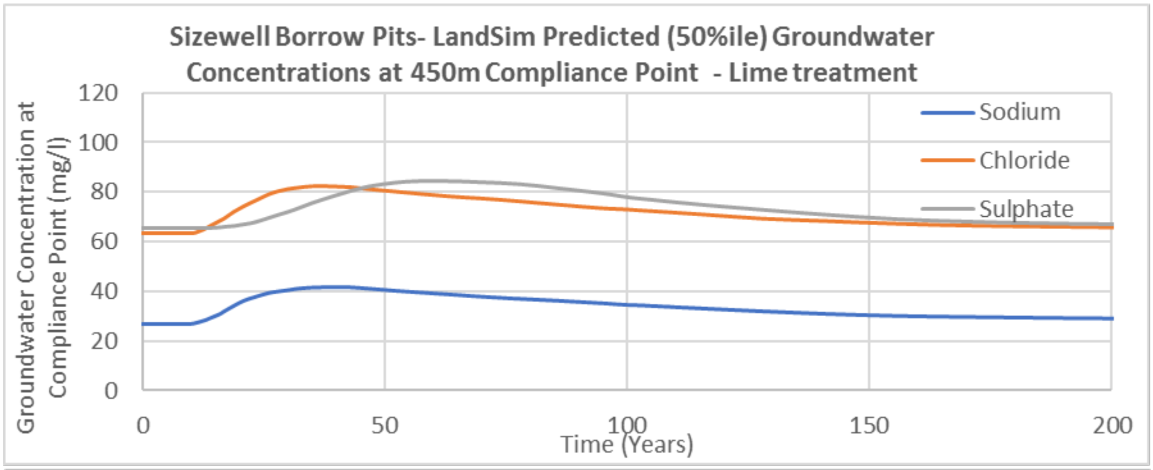
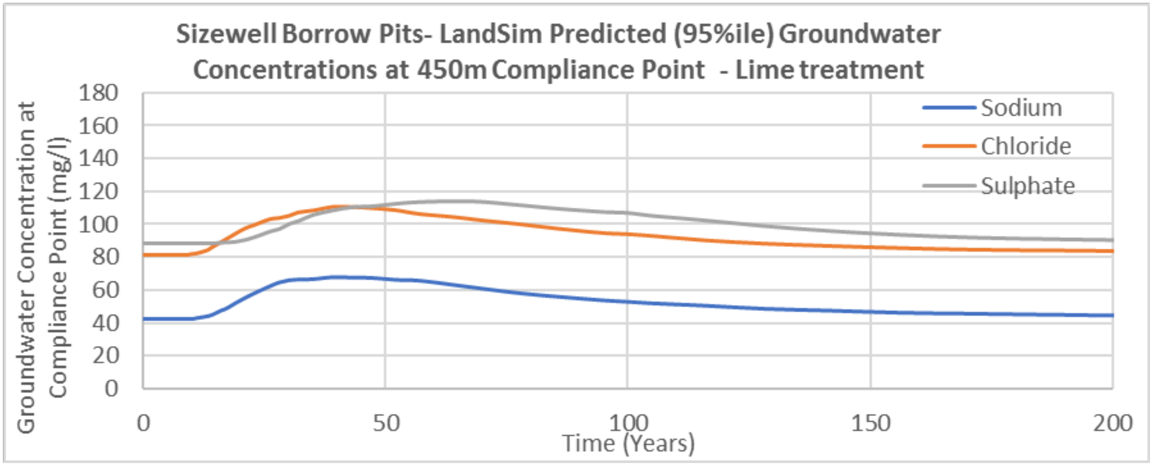
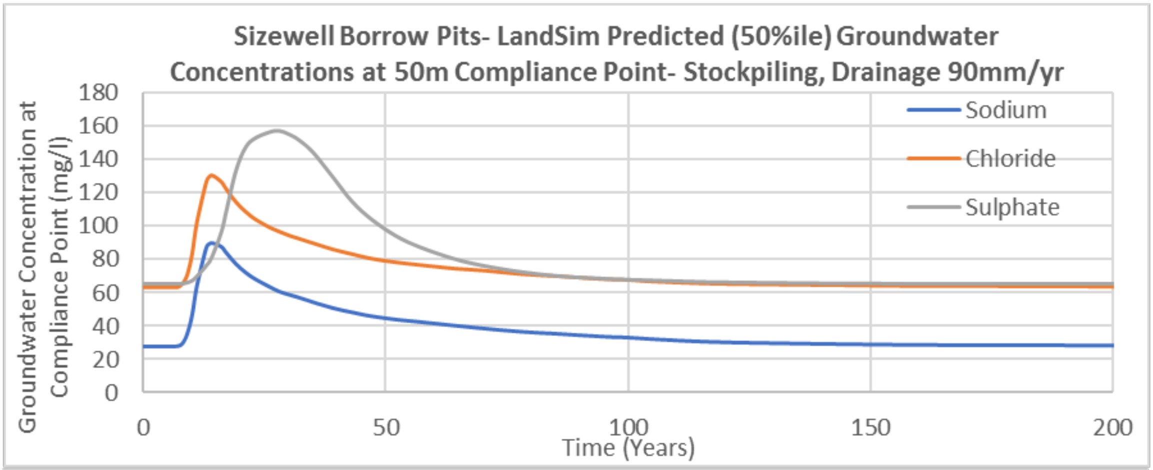
Time (Years)
Sodium
Chloride
Sulphate


Sizewell Borrow Pits- LandSim Predicted (50%ile) Groundwater Concentrations at 250m Compliance Point - Lime treatment
Groundwater Concentration at Compliance Point (mg/l)
0
20
40
60
80
100
120
0
50
100
150
200
Time (Years)
Sodium
Chloride
Sulphate

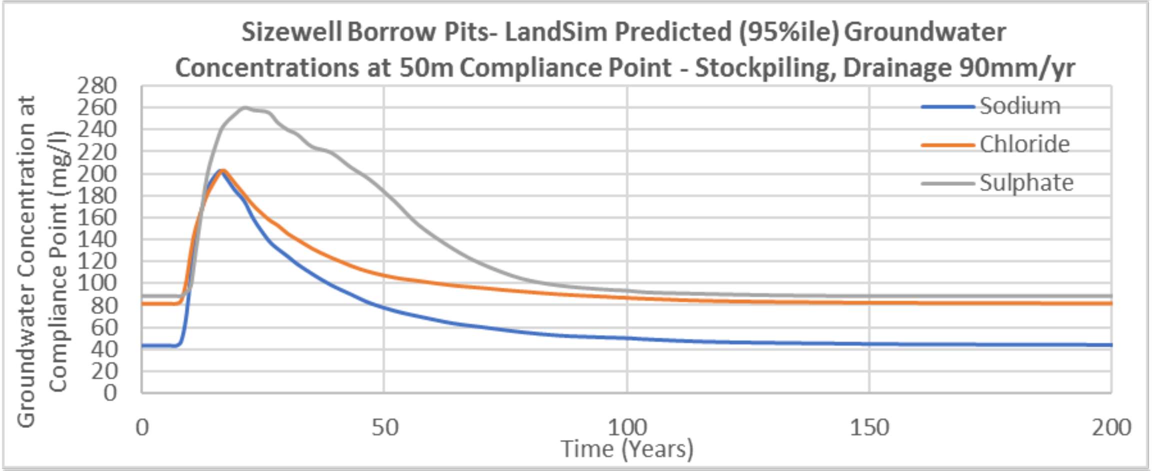

Sizewell Borrow Pits- LandSim Predicted (95%ile) Groundwater Concentrations at 250m Compliance Point - Lime treatment
Groundwater Concentration at Compliance Point (mg/l)
0
20
40
60
80
100
120
140
160
180
0
50
100
150
200
Time (Years)
Sodium
Chloride
Sulphate


Sizewell Borrow Pits- LandSim Predicted (50%ile) Groundwater Concentrations at 450m Compliance Point - Lime treatment
Groundwater Concentration at Compliance Point (mg/l)
120
100
80
60
40
20
0
0
50
100
150
200
Time (Years)
Sodium
Chloride
Sulphate

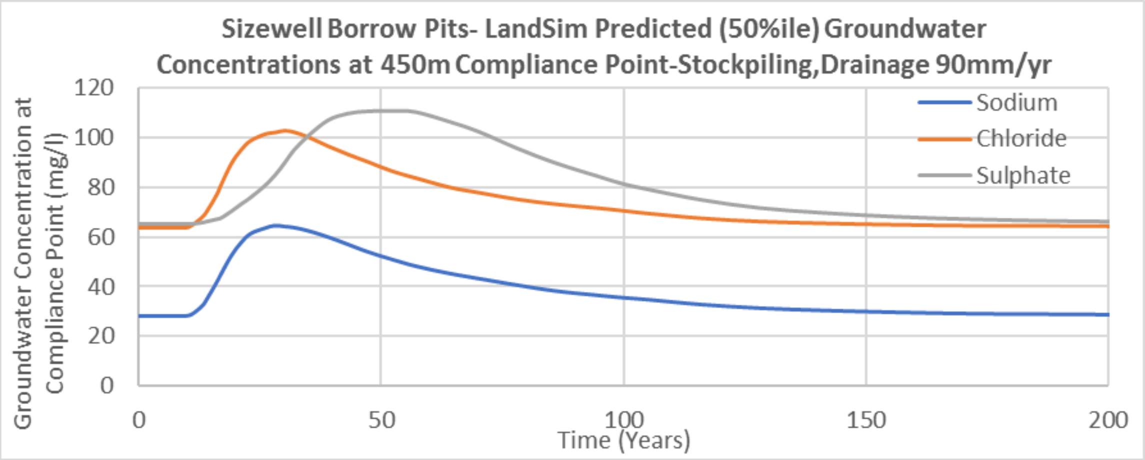

Sizewell Borrow Pits- LandSim Predicted (95%ile) Groundwater Concentrations at 450m Compliance Point - Lime treatment
Groundwater Concentration at Compliance Point (mg/l)
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
Time (Years)
Sodium
Chloride
Sulphate



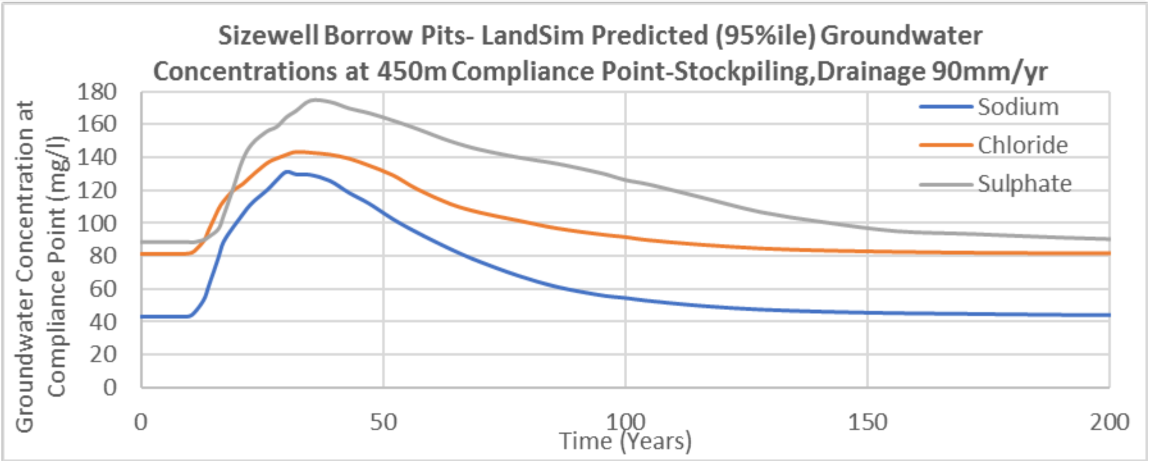
Sizewell Borrow Pits- LandSim Predicted (50%ile) Groundwater Concentrations at 50m Compliance Point- Stockpiling, Drainage 90mm/yr



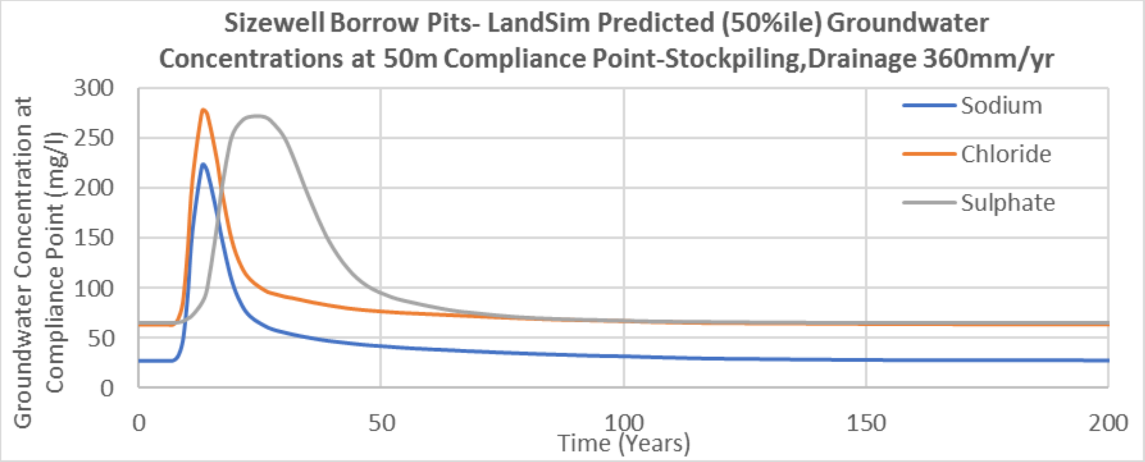
Sizewell Borrow Pits- LandSim Predicted (95%ile) Groundwater Concentrations at 50m Compliance Point - Stockpiling, Drainage 90mm/yr

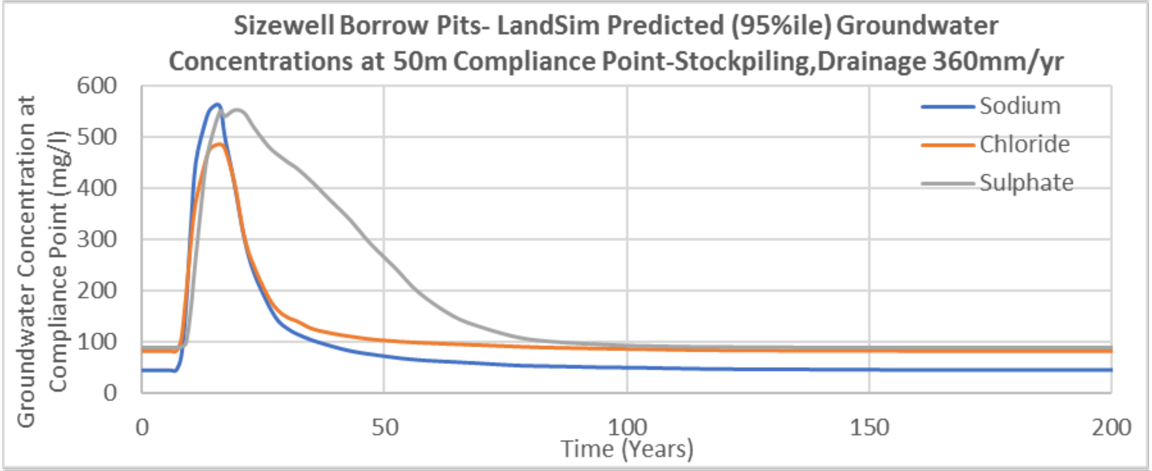


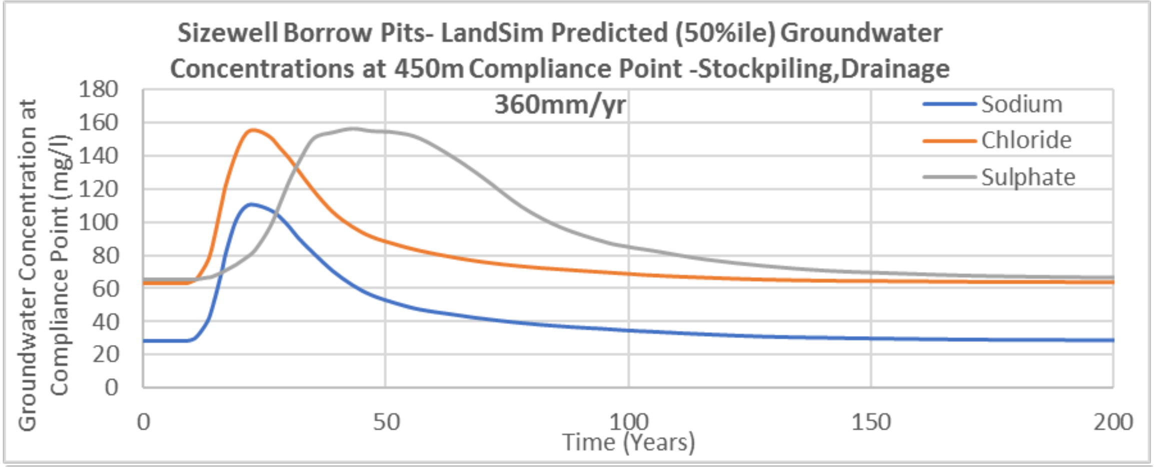
Sizewell Borrow Pits- LandSim Predicted (50%ile) Groundwater Concentrations at 450m Compliance Point-Stockpiling,Drainage 90mm/yr

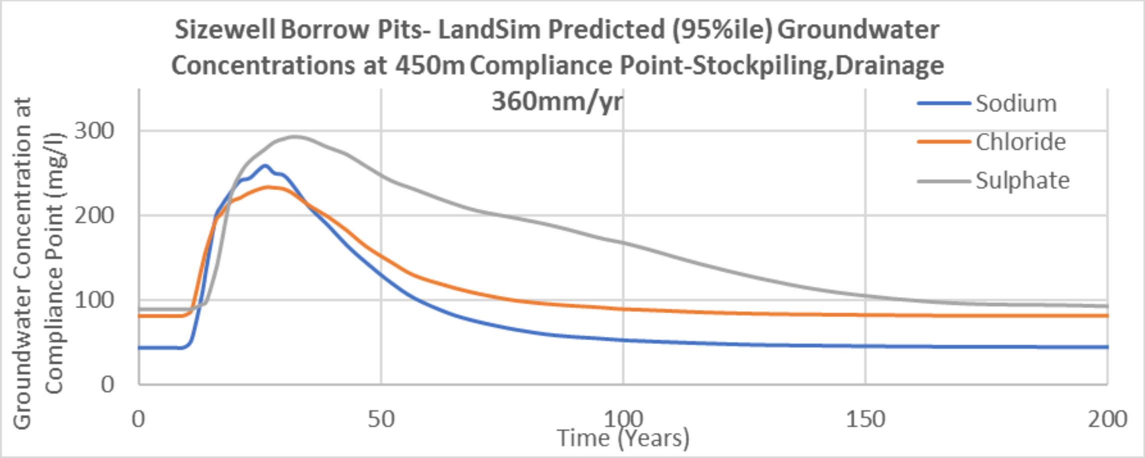


Sizewell Borrow Pits- LandSim Predicted (95%ile) Groundwater Concentrations at 450m Compliance Point-Stockpiling,Drainage 90mm/yr


Sizewell Borrow Pits- LandSim Predicted (50%ile) Groundwater Concentrations at 50m Compliance Point-Stockpiling,Drainage 360mm/yr


Sizewell Borrow Pits- LandSim Predicted (95%ile) Groundwater Concentrations at 50m Compliance Point-Stockpiling,Drainage 360mm/yr


Sizewell Borrow Pits- LandSim Predicted (50%ile) Groundwater Concentrations at 450m Compliance Point -Stockpiling,Drainage 360mm/yr


Sizewell Borrow Pits- LandSim Predicted (95%ile) Groundwater Concentrations at 450m Compliance Point-Stockpiling,Drainage 360mm/yr