

7.1 INTRODUCTION

7.1.1 This chapter discusses the geology, ground conditions, potential for contaminated land and hydrogeology at the AMEP site and details the approach to assessing the impacts of AMEP. This chapter also considers risks to groundwater as a result of the works and the subsequent operation of the site.

7.1.2 The specific environmental impacts related to dredging are addressed in this and subsequent chapters as follows:

- This chapter reviews the site investigation information available within the Humber Estuary and the soil types likely to be dredged. The proposed dredge methodology is described and potential disposal sites are identified.
- *Chapter 8* assesses the extent and concentration of the sediment plume that is likely to arise as a result of the dredge methodology described in this chapter. *Chapter 8* also contains an assessment of future maintenance dredging at the AMEP site and the impact on maintenance dredging likely to arise at adjacent ports.
- *Chapter 9* reports on the impact on water and sediment quality within the estuary as a result of AMEP including those dredging works described in this chapter.
- *Chapter 10* reports on, inter alia, the impact of dredging works on the aquatic ecology.
- *Chapter 14* reports on, inter alia, the impact on shipping navigating the estuary both during the capital and maintenance dredging works.
- *Chapter 18* reports on, inter alia, the impact of dredging on marine archaeology.

General

7.2.1 Legislation and Guidance relevant to the geology, hydrogeology and ground conditions on the site and the proposed development are as follows:

- Part 2A of the Environmental Protection Act (Contaminated Land); 1990;
- Defra Circular 01/2006; Environmental Protection Act 1990: Part 2A Contaminated Land (2006);
- Groundwater Directive (2006/118/EC);
- Environmental Protection (Duty of Care) Regulations 1991;
- Environmental Permitting (England & Wales) Regulations 2010;
- Groundwater Regulations 1998;
- Environment Act 1995;
- The Control of Pollution (Oil Storage) Regulations 2001;
- Contaminated Land (England) Regulations 2006;
- Planning Policy Statement 9: Biodiversity and Geological Conservation (2005).
- Planning Policy Statement 23: Planning and Pollution Control – Annex 2: Development on Land Affected by Contamination (2004); and
- BS EN 1997 Eurocode7, Geotechnical Design.

7.2.2 The key issues are described in further detail below.

European Legislation

Groundwater Directive (2006/118/EC)

7.2.3 The Groundwater Directive was established to prevent and control groundwater pollution. The Directive sets out criteria for assessing chemical status and identifying potential trends of pollution within groundwater bodies. The Directive also seeks to prevent and limit indirect discharges (through soil/subsoil) of contaminants into the groundwater.

UK Legislation

Environmental Protection Act 1990 (EPA) Part 2A: Contaminated Land

7.2.4 Part 2A of the EPA introduced a statutory definition of “Contaminated Land” based on significant harm or the likelihood of significant harm (including risks to human health) or the pollution or likely pollution of controlled waters (all groundwater, inland waters and estuaries but excluding groundwater perched above the zone of saturation).

7.2.5 Part 2A is regulated by Local Authorities who have a duty to determine whether the land in their area is classified as contaminated. When contaminated land includes pollution of controlled waters the Local Authorities must co-ordinate with the Environment Agency.

Environmental Protection (Duty of Care) Regulations 1991

7.2.6 The regulations enforce the requirement for the use of waste transfer notes for waste being moved from site to site. The regulations also state that all waste transfer notes are to be retained for 2 years.

Environmental Permitting (England & Wales) Regulations 2010

7.2.7 The Environmental Permitting Regulations (England and Wales) 2010 replaced the 2007 Regulations. The regulations now govern Pollution Prevention and Control (PPC), Waste Management Licensing (WML), water discharge and groundwater activities, radioactive substances and provision for a number of Directives, including the Mining Waste Directive.

Groundwater Regulations 1998

7.2.8 The Groundwater Regulations 1998 enact the EC Groundwater Directive within the UK. The regulations predominately control the acceptability of discharge of certain chemical species into the groundwater from new activities.

Control of Pollution (Oil Storage) Regulations 2001

7.2.9 These regulations were put in place to restrict oil escaping into the environment. It requires anyone in England who stores more than 200 litres of oil, to provide secure containment facilities for tanks, drums, Intermediate Bulk Containers (IBCs) and mobile bowers.

Contaminated Land (England) Regulations 2006

- 7.2.10 The regulations impose liability on polluter of contaminated land. Contaminated land is determined through an overall risk based assessment of the land.

The Conservation of Habitats and Species Regulations 2010

- 7.2.11 The Regulations provide for the designation and protection of European sites (as defined in Part 1 Section 8 of the regulations), the protection of “European protected species”, and the adaptation of planning and other controls for the protection of European Sites.

Planning Policy Guidance/ Statements

PPS 9: Biodiversity and Geological Conservation (2005)

- 7.2.12 PPS9 sets out planning policies on protection of biodiversity and geological conservation through the planning system. In the context of this PPS, geological conservation relates to the sites that are designated for their geology and/or geomorphological importance.

- 7.2.13 There are no geological sites currently designated on or within the vicinity of the site.

PPS 23: Planning and Pollution Control – Annex 2: Development on Land Affected by Contamination (2004)

- 7.2.14 PPS23 was published in November 2004, replacing PPG23, to complement the new pollution control framework under the Pollution Prevention and Control Act 1999 and the Pollution Prevention and Control Regulations 2000. It sets out guidance and policy relating to pollution control, air quality, water quality and land contamination. It seeks:

‘...to ensure that in the case of potentially polluting developments:

- the relevant pollution control authority is satisfied that potential releases can be adequately regulated under the pollution control framework; and*
- the effects of existing sources of pollution in and around the site are not such that the cumulative effects of pollution when the proposed development is added would make that development unacceptable. LPAs may wish to set out principles and policies to deal with cumulative impacts when drawing up their LDDs. Decisions on individual cases must always be justified on the facts applying to those cases.’*

Local Plan Policy

North Lincolnshire Council Local Plan

- 7.2.15 Policy DS7: Contaminated Land states that if any land proposed for development or redevelopment is suspected to be contaminated will be required to demonstrate the remediation is a viable option before permission is granted.

'Permission will on be granted on contaminated sites where a detailed site survey has been submitted, and a suitable scheme of remedial measures has been agreed...'

- 7.2.16 Policy DS8: Methane Emissions outlines the council's position on development on former waste disposal sites and the use of gas protection measures.

- 7.2.17 Policy DS15: Water Resources states that if the proposed development:

'adversely affect the quality and quantity of water resources or adversely affect nature conservation, fisheries and amenity by means of:
1. *Pollution from the development; or*
2. *Water abstraction unless adequate measures are undertaken to reduce the impact to an acceptable level'*

the permission will not be granted. Adequate mitigation measures must be submitted.

- 7.2.18 Policy M2: Secondary Aggregates and Recycled Materials outlines proposals for the use of secondary aggregates and recycled materials. It states that *'greater use of recycled materials and secondary aggregates could help to reduce the need for quarrying, and to a certain extent, landfilling.'*

Other

Defra Circular 01/2006

- 7.2.19 The circular outlines, inter alia, the Government's objective of identifying and removing unacceptable risks to human health and the environment; seeking to bring damaged land back into beneficial use and ensuring that the cost burdens faced by individuals, companies and society as a whole are proportionate, manageable and economically sustainable.

7.2.20 These objectives underlie the “suitable for use” approach to the assessment and remediation of contaminated land. The “suitable for use” approach consists of three elements:

- ensuring that land is suitable for its current use;
- ensuring that land is made suitable for any new use; and
- limiting requirements for remediation to the work necessary to prevent unacceptable risks to human health or the environment in relation to the current use or future use of the land.

Construction Code of Practice for the Sustainable Use of Soils on Construction Sites (Defra, 2009)

7.2.21 Defra developed the Code of Practice to provide protection and enhance the soil resources within the construction sector. The Code states:

‘Soil is a fundamental and ultimately finite resource that fulfils a number of functions and services for society which are central to sustainability. Some of the most significant impacts on this resource occur as a result of activities associated with construction activity, yet it appears that there is a general lack of awareness and understanding of this need within the construction industry.’

7.3 ASSESSMENT METHODOLOGY AND CRITERIA

Contaminated Land

Assessment Methodology

7.3.1 The adopted methodology for assessing risk associated with contaminated land comprises:

- hazard identification and assessment; and
- estimation and evaluation of any consequential effect.

7.3.2 Hazard identification and assessment establishes whether any potential contaminants are present and whether those contaminants can affect receptors through any potential pollutant linkages (PPL). Hazards are identified by undertaking a desk study; a review of historic land uses, sensitive land designations and site investigations. The sensitive receptors include construction workers, local residents, and users of public rights of way in the vicinity of AMEP. Sensitive receptors in relation to water quality include surface water (the Humber Estuary,

rivers, drains, standing water etc) and ground water. Other receptors to consider are flora and fauna which could be impacted as a result of contamination from the site.

- 7.3.3 Once contaminants have been identified and PPLs established then a Conceptual Site Model (CSM) is drawn up. A CSM has been prepared for both the construction and operational phases.
- 7.3.4 Risk estimation involves predicting, qualitatively or quantitatively the degree of harm or pollution that could occur as a consequence of the hazard. Risk estimation considers whether pollution is short or long term and the magnitude of harm created depending upon the sensitivity of the receptor.
- 7.3.5 Evaluation of the risk is the process of determining whether a residual risk is acceptable.
- 7.3.6 Results of the desk study and assessment of the CSM determine whether further intrusive site investigation is required. Testing of samples of on site soils and drift deposits and analysing the results against the EA's new soil guideline values will determine the extent, if any, of potential contamination.

Significance Criteria

- 7.3.7 In determining whether a risk is sufficiently significant that it could be harmful to a receptor requires reference to recommended limit values. Significance criteria for contaminated land require a chemical analysis of the soils on the site in question. Chemical results are assessed against Soil Guideline Values (SGV); these are generic assessment criteria (GAC) recently reissued by the EA. *Table 7.1* outlines the current SGVs.
- 7.3.8 Assessment criteria for organic contaminants such as Total Petroleum Hydrocarbons (TPH) (oils and diesels), and associated Polycyclic Aromatic Hydrocarbons (PAH) are established using a modelling system such as the CLEA system also produced by the EA.

Table 7.1 Soil Guideline Values (SGV)

Contaminant	Assessment Criteria SGV for Industrial Land (mg/kg)	Comments
Arsenic (As)	640	SGV
Cadmium (Cd)	1 400	SGV
Chromium (Cr)	5 000	SGV
Copper (Cu)	80, 135 or 200	MAFF(pH variable)
Lead (Pb)	750	SGV
Mercury (Hg)	410	SGV
Nickel (Ni)	1 800	SGV
Selenium (Se)	8 000	SGV
Zinc (Zn)	200 or 300	MAFF (pH variable)
Benzene	95	SGV
Toluene	4 400	SGV
Ethylbenzene	2 800	SGV
Xylenes	o-xylene	-
	m-xylene	SGV
	p-xylene	SGV
Phenol	3 200	SGV

Sources: EA, 2010 & Soil Code (MAFF, 1998a)

Hydrogeology

Assessment Methodology

- 7.3.9 Hydrogeology is the distribution and movement of groundwater in the soil and rocks of the Earth's crust, especially within aquifers.
- 7.3.10 The methodology used for assessing impact on the hydrogeology of a site is the same as that described for contaminated land above. Hazards are identified and PPLs established which are added to the CSM. An assessment has been undertaken for both construction and operational phases.
- 7.3.11 Groundwater sensitivity maps produced by the EA identify known principal and secondary aquifers in both drift and bedrock. The maps also show areas designated as groundwater Source Protection Zones (SPZs).
- 7.3.12 Where the CSM show that the identified hazards, for example dredging or piling, are a risk to a sensitive receptor, then a hydrogeological risk assessment is undertaken to establish the extent of the risk and the mitigation if required.

Significance Criteria

- 7.3.13 Criteria used for determining the risk to hydrogeology of the site are set out in Environmental Quality Standards (EQS) produced by the EA. The EQS are derived for both freshwater and marine/estuarine waters. However, due to the presence of a principal aquifer (chalk bedrock) below AMEP, freshwater EQS is deemed most appropriate for assessing the quality of groundwater.

Dredging

Assessment Methodology

- 7.3.14 The Marine Management Organisation (MMO) is responsible for the licensing of all dredging works below mean high water spring (MHWS). A works licence is also required from the Harbour Master.
- 7.3.15 To establish whether dredging and deposition of dredged material will give rise to any risk to the River Humber, a site investigation has been undertaken. Samples collected during the investigation were sent to CEFAS laboratory for analysis and to for specialist analysis.

Significance Criteria

- 7.3.16 As with contaminated land, samples have been collected from locations within the proposed dredge area. The samples were analysed by a laboratory and the results compared against generic assessment criteria (action levels) produced by the Centre for Environment, Fisheries & Aquaculture Science (CEFAS) who act as the MMO's scientific advisor.
- 7.3.17 The criteria produced by CEFAS comprise two action levels, as shown in *Table 7.2*. Any contaminant below Action Level 1 threshold is classified as not a risk and any over the Action Level 2 threshold is considered a risk. Any contaminant that falls between the two thresholds is considered a potential risk. Professional judgement is required to determine whether any further actions are required.

Table 7.2 Generic Assessment Criteria for River Sediments (CEFAS)

	Unit	Action Level 1	Action Level 2
Arsenic	mg/kg	20	100
Cadmium	mg/kg	0.4	5
Chromium	mg/kg	40	400
Copper	mg/kg	40	400
Lead	mg/kg	50	500
Mercury	mg/kg	0.3	3
Nickel	mg/kg	20	200
Zinc	mg/kg	130	800
Dibutyl Tin	ug/kg	100	1000
Tributyl Tin	ug/kg	100	1000
Acenaphthene	ug/kg	100	1000
Acenaphthylene	ug/kg	100	1000
Anthracene	ug/kg	100	1000
Benzo(a)anthracene	ug/kg	100	1000
Benzo(b)fluoranthene	ug/kg	100	1000
Benzo(a)pyrene	ug/kg	100	1000
Benzo(g,h,i)perylene	ug/kg	100	1000
Benzo(k)fluoranthene	ug/kg	100	1000
Chrysene	ug/kg	100	1000
Dibenzo(a,h)anthracene	ug/kg	10	100
Fluoranthene	ug/kg	100	1000
Fluorene	ug/kg	100	1000
Indeno(1,2,3-cd)pyrene	ug/kg	100	1000
Naphthalene	ug/kg	100	1000
Phenanthrene	ug/kg	100	1000
Pyrene	ug/kg	100	1000
Sum of PAH's analysed	ug/kg	1710	15100
Sum of 7 PCB's	ug/kg	10	180
TPH	mg/kg	100	1000

Source: CEFAS (1994)

Gas

Assessment Methodology

- 7.3.18 A gas risk assessment desk study was the adopted assessment methodology in determining whether a risk was present on land at AMEP. The desk study involved identifying any landfills, former or current, that lie within 250 m of the site and a review of site investigations to identify potential sources of gas, for example peat and significant depths of made ground. It was also considered appropriate to identify whether the site is affected by radon gas by consulting a radon risk map (Miles. J C H et al 2007 Map 16).

Significance Criteria

- 7.3.19 Where a desk study indicates that proposed buildings lie within 250 m of a known landfill or over an area of thick made ground or peat, ground gas monitoring installations are installed and monitored as outlined in CIRIA C665 Assessing Risks Posed by Hazardous Ground Gases to Buildings (2007). Results from regular monitoring of the gas installations will deem whether there will be a risk from migration of hazardous gas. The risk is determined by comparing results against Table 7.5 in C665 (reproduced in *Table 7.3* of this document).

Table 7.3 *Determination of Risk from Hazardous Gas*

Situation	Risk Classification	Gas Screening Value (GSV) (CH ₄ or CO ₂) Threshold	Additional Factors	Typical Source of Generation
1	Very Low Risk	<0.07 l/hr	Typically CH ₄ <1% and/or CO ₂ <5%. Otherwise consider increase to situation 2.	Natural soils with low organic content. "Typical" made ground.
2	Low Risk	<0.7 l/hr	Borehole air flow rate not to exceed 70l/hr. Otherwise consider increase to characteristic situation 3.	Natural soil, high peat/organic content. "Typical" made ground.
3	Moderate Risk	<3.5 l/hr		Old landfill, inert waste, mine working flooded.
4	Moderate to High Risk	<15 l/hr	Quantitative risk assessment required to evaluate scope of protective measures.	Mine working – susceptible to flooding, completed landfill (WMP 26B criteria).
5	High Risk	<70 l/hr		Mine working unflooded inactive with shallow workings near surface.
6	Very High Risk	>70 l/hr		Recent landfill site.

Source: Table 7.5 from CIRIA C665

7.4 CONSULTATION

Overview

- 7.4.1 Responses from consultation, relating to this chapter, are summarised in *Annex 2.2*.

7.5 BASELINE

- 7.5.1 The topography of the site is typical of the area; flat low-lying land that is protected by flood banks beyond which are gently sloping mudflats and the River Humber. The boundaries of the AMEP site are defined in *Chapter 4*.
- 7.5.2 Historical plans show the site to be solely farmland/open fields until 1931 when the Goxhill & Immingham Railway is shown running north-south through the centre of the site. By 2003 part of the site had been developed for port related storage.
- 7.5.3 In the early 1970s, the land surrounding the AMEP site was developed for the oil and gas industry; an oil refinery in the west and gas works to the north.
- 7.5.4 Further detail on the historical land use of the application site and surrounding land is presented in Geo-environmental Assessment presented in *Annex 7.1*. The current site conditions are shown in *Figure 7.1*.

Previous Terrestrial Site Investigations

- 7.5.5 Several site investigations have been undertaken on the application site, both terrestrial and marine. *Table 7.4* outlines the site investigations, both the extent and findings. Further detail is presented in Section 4 of *Annex 7.1 AMEP: Phase 1 Geoenvironmental Assessment*.
- 7.5.6 Ground conditions encountered in the investigations all show consistency with cohesive alluvial deposits covering the eastern areas of the site, overlying cohesive glacial deposits underlain by chalk bedrock.

Sediment Surveys

- 7.5.7 A survey of sediment quality and particle size was conducted across the intertidal and subtidal zone in 2010. The results are reported in *Annex 7.2*

Table 7.4 Previous Site Investigations (1970-2007)

Title	Commissioned	Extent
CEGB Proposed Power Station Desk Study	CEGB July 1970	Review of historical land uses and SI undertaken by George Wimpey 1965.
Allott Atkins Mouchel: CEGB Killingholme Station Pre-Application Studies; Preliminary Report	CEGB July 1987	Desk study and review of 4 No. intrusive borehole investigations from early 1970s.
Exploration Associates Ltd: Factual Report on Ground Investigation	CEGB April 1989	Intrusive investigation: 9 cable percussive boreholes to depths of between 15.2 m and 23.3 m and 1 No. rotary borehole to 26.5 m bgl.
Weeks Consulting Ltd: Report on Options for Soil Stabilisation at Able Humber Ports Facility	Able UK Ltd April 2003	69 No. trial pits over 400 ha (39 of which are within application boundary).
Structural Soils Ltd: Ground Investigation at Killingholme	Able UK Ltd July 2005	13 No. cable percussive boreholes (9 of which within application boundary) to a max depth of 15.45 m bgl. No bedrock encountered.
Langdale – Smith & Co. Ltd: Ground Investigation at Area C North Lincolnshire	Able UK Ltd February 2007	Ground investigation for warehouse foundations. Investigation comprised 3 No. cable percussive boreholes to 20 mbgl and several plate load tests.

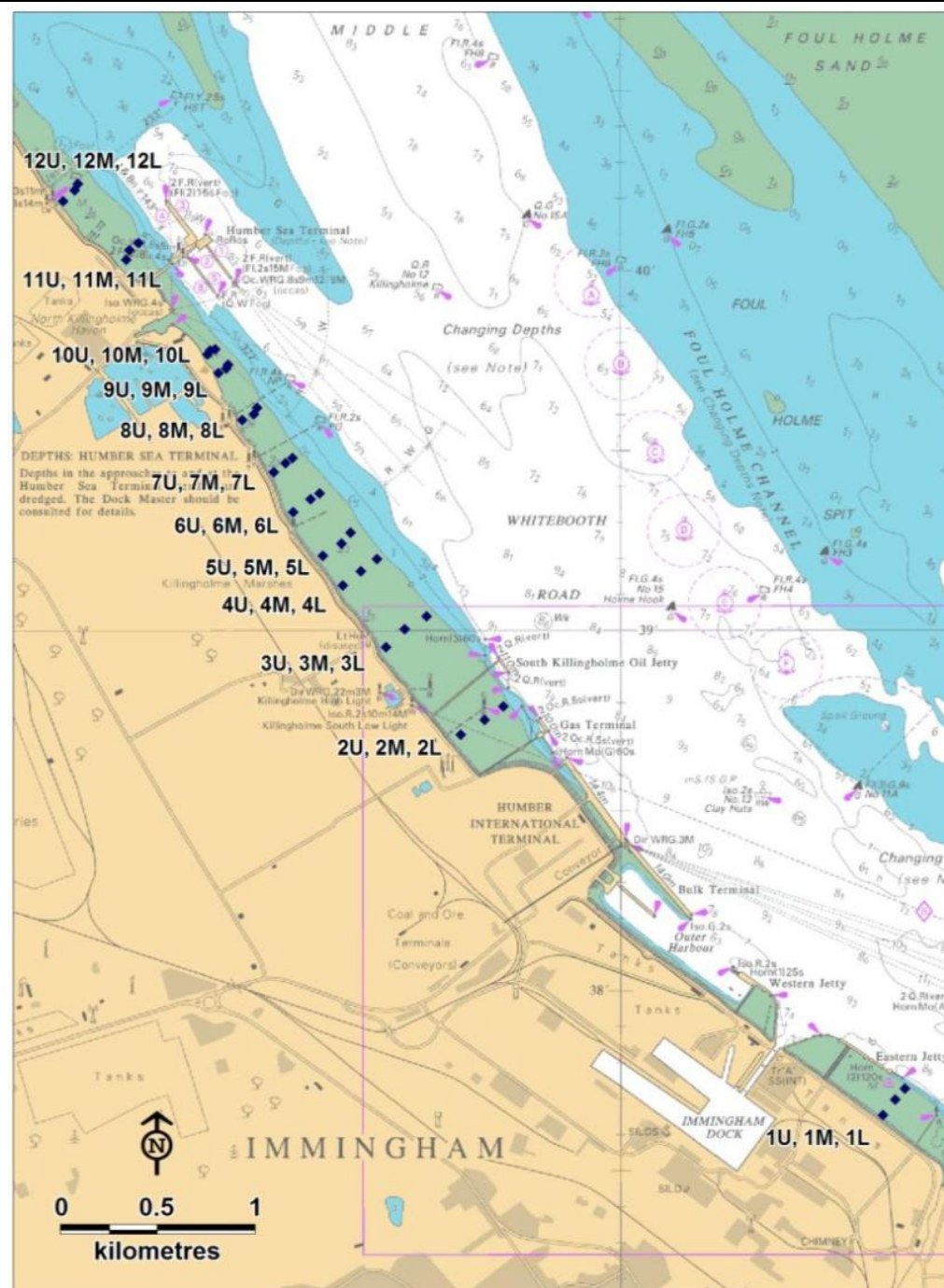
Source: Able UK Ltd Archive

CEGB: Central Electricity Generating Board

7.5.8 Sampling for the particle size analysis (PSA) and for contaminants was conducted using a 0.1 m² Hamon grab at 30 subtidal benthic stations and 36 intertidal stations (*Figure 7.2*).

7.5.9 The Folk Classification (Folk, 1954) system was used to determine the different sediment types as a ratio of sand to mud plus the percentage gravel content in each sample. The complete PSA dataset is included in *Annex 7.2*, with a summary of the intertidal and subtidal datasets shown in *Table 7.5* and *Table 7.6* respectively.

Figure 7.2 Sediment quality and PSA sampling across the intertidal and subtidal area



Source: IECS (2010)

Table 7.5 *Summary of PSA results from intertidal sediment samples*

Station No.	Shore position	Mean ϕ	Mean μm	% Gravel	% Sand	% Mud	Textural group (Folk)
1	Upper	5.88	16.98	0	14.5	85.5	Sandy mud
1	Middle	6.255	13.1	0	10.5	89.5	Sandy mud
1	Lower	5.772	18.31	0	19	81	Sandy mud
2	Upper	6.379	12.02	0	7.5	92.5	Mud
2	Middle	6.326	12.47	0	6.9	93.1	Mud
2	Lower	4.617	40.74	0	48.5	51.5	Sandy mud
3	Upper	6.774	9.139	0	4.5	95.5	Mud
3	Middle	5.461	22.7	0	20.6	79.4	Sandy mud
3	Lower	5.893	16.83	0	14.5	85.5	Sandy mud
4	Upper	6.616	10.2	0	5.5	94.5	Mud
4	Middle	5.864	17.17	0	15.5	84.5	Sandy mud
4	Lower	5.908	16.65	0	12.4	87.6	Sandy mud
5	Upper	6.416	11.71	0	7.5	92.5	Mud
5	Middle	5.847	17.38	0	16	84	Sandy mud
5	Lower	5.839	17.47	0	17.3	82.7	Sandy mud
6	Upper	6.654	9.93	0	5.2	94.8	Mud
6	Middle	6.608	20.51	0	20.3	79.7	Sandy mud
6	Lower	5.618	20.36	0	23.8	76.2	Sandy mud
7	Upper	6.122	14.36	0	8.4	91.6	Mud
7	Middle	4.828	35.22	0	42.4	57.6	Sandy mud
7	Lower	5.878	17.01	0	16.8	83.2	Sandy mud
8	Upper	6.459	11.37	0	6.9	93.1	Mud
8	Middle	5.605	20.54	0	19.9	80.1	Sandy mud
8	Lower	6.05	15.09	0	11.5	88.5	Sandy mud
9	Upper	6.249	13.15	0	8.7	91.3	Mud
9	Middle	5.764	18.41	0	17.3	82.7	Sandy mud
9	Lower	6.148	14.1	0	10.4	89.6	Sandy mud
10	Upper	6.12	14.37	0	13.3	86.7	Sandy mud
10	Middle	6.087	14.71	0	13.3	86.7	Sandy mud
10	Lower	5.133	28.49	0	29.3	70.7	Sandy mud
11	Upper	5.541	21.48	0	19.3	80.7	Sandy mud
11	Middle	5.158	28	0	29.8	70.2	Sandy mud
11	Lower	6.041	15.19	0	12.6	87.4	Sandy mud
12	Upper	6.687	9.708	0	6.7	93.3	Mud
12	Middle	5.397	23.73	0	23.2	76.8	Sandy mud
12	Lower	5.879	16.99	0	14.1	85.9	Sandy mud

Source: IECS 2010

Table 7.6 *Summary of PSA results from subtidal sediment samples*

Station No.	Mean ϕ	Mean μm	% Gravel	% Sand	% Mud	Sediment name	Textural group (Folk)
1	2.492	177.8	0	95.9	4.1	Moderately sorted fine sand	Sand
2	5.849	17.35	0	21.2	78.8	Very fine sandy medium silt	Sandy mud
3	4.907	33.34	0	43.5	56.5	Very fine sandy medium silt	Sandy mud
4	3.797	71.95	0	70.9	29.1	Very coarse silty fine sand	Muddy sand
5	6.236	13.26	0	14.4	85.6	Very fine sandy fine silt	Sandy mud
6	2.944	130	0	77.5	22.5	Fine silty medium sand	Muddy sand
7	4.274	51.68	0	60.4	39.6	Very coarse silty very fine sand	Muddy sand
8	5.91	16.64	0	18.8	81.2	Very fine sandy fine silt	Sandy mud
9	5.77	18.33	0	20.3	79.7	Very fine sandy fine silt	Sandy mud
10	5.014	30.96	0	41	59	Very fine sandy fine silt	Sandy mud
11	6.056	15.03	0	15	85	Very fine sandy fine silt	Sandy mud
12	1.879	271.8	1.6	83.8	14.6	Slightly very fine gravelly fine silty medium sand	Slightly gravelly muddy sand
13	3.305	101.2	0	70.5	29.5	Fine silty medium sand	Muddy sand
14	6.071	14.88	0	14.2	85.8	Slightly very fine gravelly fine silty medium sand	Sandy mud
15	3.181	110.3	0.2	71.1	28.7	Slightly very fine gravelly fine silty medium sand	Slightly gravelly muddy sand
16	3.366	97.02	2.2	60.5	37.3	Slightly very fine gravelly fine silty medium sand	Slightly gravelly muddy sand
17	4.474	44.99	0.7	44.5	54.9	Slightly very fine gravelly medium sandy medium silt	Slightly gravelly muddy sand
18	3.405	94.39	0	69.9	30.1	Fine silty medium sand	Muddy sand
19	2.909	133.2	3	69.6	27.3	Slightly very fine gravelly fine silty medium sand	Slightly gravelly muddy sand
20	3.296	101.8	0.9	68.2	30.9	Slightly very fine gravelly fine silty medium sand	Slightly gravelly muddy sand
21	3.734	75.15	0	59.8	40.2	Fine silty medium sand	Muddy sand
22	2.681	155.9	0.5	78.7	20.8	Slightly very fine gravelly fine silty medium sand	Slightly gravelly muddy sand
23	3.122	114.9	2.9	65	32	Slightly very fine gravelly very coarse silty medium sand	Slightly gravelly muddy sand
24	2.315	201	0	83.6	16.4	Fine silty medium sand	Muddy sand
25	4.969	31.92	0	43.2	56.8	Very fine sandy very coarse silt	Sandy mud
26	2.49	177.9	6.7	72.2	21.1	Very fine gravelly fine silty medium sand	Gravelly muddy sand
27	3.671	78.5	7.6	52.3	40.1	Medium gravelly fine silty medium sand	Gravelly muddy sand
28	4.338	49.45	0	47.5	52.5	Medium sandy very coarse silt	Sandy mud
29	0.22	858.5	46.7	31	22.3	Fine silty sandy coarse gravel	Gravelly muddy sand

Source: IECS (2010)

- 7.5.10 The sediment in the subtidal zone was more poorly sorted and had a coarser texture than the intertidal samples. Percentages of samples falling into each of the sediment types for the subtidal and intertidal samples are shown in *Figure 7.3*.

Estuarine Site Investigations

- 7.5.11 In June 2010, Yorkshire Forward commissioned a soils investigation of the mudflats and river bed between Humber Sea Terminal and ABP Immingham (the 2010 site investigation). The intrusive investigation was undertaken between 15 June and 15 July 2010 and comprised:

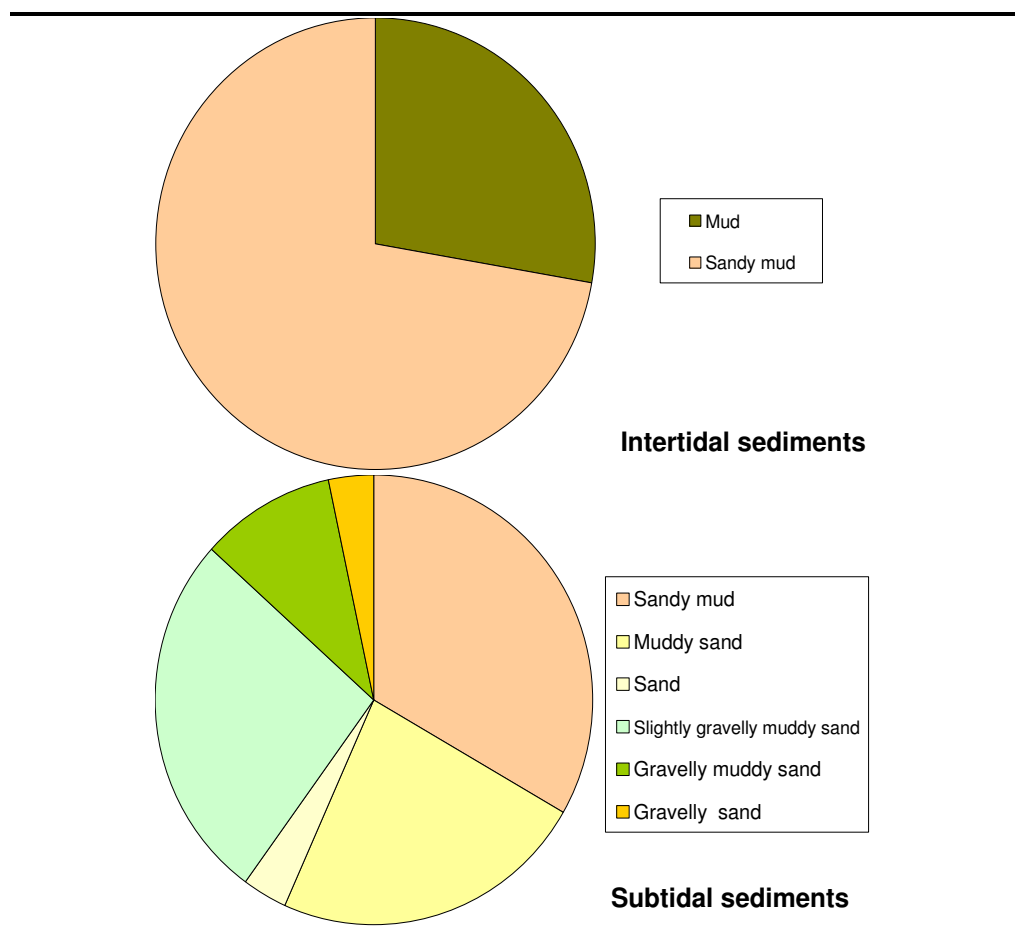
- 30 No. vibrocores boreholes (to max depth of 6 mbgl);
- Bathymetric Survey;
- Magnetometer Survey; and
- Unexploded Ordnance (UXO) desk study.

- 7.5.12 The results of the investigation are reported in the factual ground investigation report and reproduced in *Annex 7.3*. An interpretative report was prepared and is reproduced in *Annex 7.4*. Vibrocore locations are shown on *Figure 7.4*. A summary of the deposits and their general geotechnical characteristics encountered during the investigation is presented below.

Cohesive Alluvial Deposits

- 7.5.13 Cohesive alluvial deposits, comprising mainly clay and silt, were encountered at variable depths across the investigation area. Depths ranged between 0.3 m (VC 8) and 3.90 m (VC12). No cohesive alluvial deposits were encountered in vibrocores 11, 14, 18 and 23.
- 7.5.14 Geotechnical testing on samples obtained from the vibrocores indicate that plasticity ranges from low to high in both the clay and the silt. The grading curves show the particle size distribution to vary, and compositionally the material ranges from gravelly clay to silty clay with the clay fraction ranging from 11 percent to 35 percent.
- 7.5.15 The undrained shear strength of the alluvium is very low. The maximum shear strength recorded was 20 kN/m²; however, there is a significant proportion of the data which is less than 5 kN/m². Consolidation test data on a single sample of alluvium shows it to be highly compressible.

Figure 7.3 *Sediment types as percentages of samples*



Source: ERM

- 7.5.16 Peat layers were encountered within the alluvial clays at 6 vibrocore locations (VC 05, 07, 09, 12, 13 & 15). The peat is generally described as occurring in thin lenses, which range in thickness from <10 mm to <30 mm. At one location, VC13, two thicker, persistent bands of peat are recorded, each less than 100 mm thick.

Granular Deposits

- 7.5.17 There is some difficulty in differentiating whether the sand and gravels encountered are of alluvial or glacial origin. However, the presence of peat in VC 05, 06, 08 and 09, does indicate that the material may have an alluvial origin. In other cases, sand and gravel underlies cohesive glacial deposits, and therefore must be glacial in origin.
- 7.5.18 In general terms the grading test, results show the granular soils vary between silty sand and gravel, gravelly sand to silty fine sand. Typical thicknesses of the granular deposits vary between 0.3 m and 4.25 m.

Cohesive Glacial Deposits

- 7.5.19 The cohesive glacial deposits were encountered in the majority of the vibrocore locations but were not encountered in VC 07, 08, 09, 12 & 15.
- 7.5.20 The cohesive glacial deposits comprises soft to stiff, low to intermediate plasticity clay. The undrained strength data shows the strength range to lie generally between 30 kN/m² and 110 kN/m². The plasticity data shows the Atterberg Limits of the material lie in a tight range with the plasticity index (PI) varying between 7 percent and 25 percent.
- 7.5.21 The grading tests show the material to be well graded, with a size fraction ranging from fine to medium gravel to clay. The clay content ranges between 22 percent and 62 percent. The gravel fraction generally comprises sandstone, mudstone and chalk, however at certain locations, VC 05, 10, 13, 16 and 22 there is a very high proportion of chalk present. The data from previous investigations suggests that cohesive glacial deposits in this area are of the order of 10 m to 21 m thick.
- 7.5.22 Contamination testing from samples obtained from the vibrocores and near surface samples obtained on the intertidal and subtidal mudflats are summarised in *Annex 7.2*. Testing has identified potentially elevated levels of select contaminants however; discussions with CEFAS and MMO have established that the testing methods are too dissimilar for direct comparison with the CEFAS action levels.
- 7.5.23 In order to issue a preliminary dredging licence the MMO requested further sampling and testing to be undertaken via CEFAS methodology. Sampling was undertaken the week of 9 May 2011.

Terrestrial Geology

- 7.5.24 The geological maps for the application site, Sheet 81 of the British Geological Survey (BGS) 1:50 000 map series (the Patrington sheet), indicates that the site is underlain by marine and estuarine alluvium in the east and glacial till in the west with a small outcrop of glacial sand and gravel in the south-east.
- 7.5.25 Historical borehole data indicates the estuarine alluvial deposits to be up to 4 m thick and are underlain by cohesive glacial deposits (till) up to 14 m thick. Borehole records show that the granular glacial deposits in the south of the site are up to 1 m thick at approximately 6 mbgl.
- 7.5.26 The Estuarine and Glacial deposits are overlain either by topsoil, in the areas still used as arable farmland or made ground in the developed areas in the north of the application site and along the railway line.

- 7.5.27 The application site is shown to be underlain by Burnham Chalk in the west and Flamborough Chalk in the east. Historical borehole logs indicate that the depth of the rockhead lies between 14.4 mbgl and 18 mbgl.

Estuarine Geology

- 7.5.28 The Patrington Solid and Drift map (Sheet 81) indicates that within the footprint of the proposed quay the mudflats are composed of Tidal Flat mud with outcrops of Tidal Flat sand and Gravel and Glacial Till. The channel bed comprises sands of Seabed & Tidal River Bed Deposits.

Hydrogeology

- 7.5.29 Using the EA's Groundwater Protection Policy revised aquifer classification (April 2010), three types of aquifer have been identified on site and details are presented in *Table 7.7*.

Table 7.7 *Aquifer Classification*

Aquifer Classification	Description	Onsite Geology
Principal	Layers of rock or drift deposits with high permeability can provide a high level of water storage and support water supply or river base flow on a strategic scale.	Burnham & Flamborough Chalk Formations. Present below entire site.
Secondary A	Permeable layers capable of supporting water supplies at a local scale. Formerly classified as minor aquifers.	Glacial Sand & Gravels (considered to be present in the south-east of site).
Secondary Undifferentiated	Deposit doesn't fit criteria for Secondary A or B. In previous classification deposits likely designated as both minor and non-aquifer in different locations due to the variable characteristics of the rock type.	Mudflats.

Source: EA (2010)

- 7.5.30 The remainder of the site is classified as unproductive strata, *'deposits with low permeability that have negligible significance for water supply or river base flow'*.

7.5.31 A detailed assessment of the hydrogeology of the site was undertaken and is presented in *Annex 7.5*. The risk assessment took into account the site investigation (*Annex 7.3*) and assessed the likelihood of whether dredging the river bed would expose the principal aquifer and, if so, if that would significantly increase saline ingress. The report also assessed the impact of piling for the quay construction.

7.6 *IMPACTS*

Agricultural Land

7.6.1 Construction of AMEP will mean the loss of Grade 3 land. The Agricultural Land Classification of England and Wales (MAFF, 1988) defines Grade 3 as good to moderate quality agricultural land which has

‘moderate limitations which affect the choice of crops, timing and type of cultivation, harvesting or the level of yield. Where more demanding crops are grown yields are generally lower or more variable than on land in Grades 1 and 2’.

7.6.2 This is assessed to be a minor adverse effect.

Contaminated Land

7.6.3 Contaminated land is not anticipated to present a significant source of potential impacts, since the majority of the site has historically been used as agricultural land, and the areas that have been industrially developed are either small and defined (in the case of the railway) or very recent and low risk (vehicle storage on hard standing). This recent change in land use and the presence of the railway in the centre of the site is likely to represent the greatest, albeit slight, potential for contamination.

7.6.4 The main potential pollutants are hydrocarbons. Where encountered they would pose a threat to the controlled waters of the Humber Estuary and to a lesser extent leaching into the major chalk aquifer which is considered to be unlikely due to the thickness of cohesive glacial deposits overlying the chalk.

7.6.5 Approximately 2 million m³ of imported fill will be required to raise levels on existing terrestrial areas. Only uncontaminated material will be used in the Project.

7.6.6 Approximately 3.6 million m³ of fill will be required to raise levels within the footprint of the quay. The majority of this material will be marine aggregate dredged from licensed abstraction sites probably off the Humber.

Hydrogeology

7.6.7 Impacts on the hydrogeology may arise from both the contaminated land and dredging. Intrusive investigations of the mudflats and channel bed within the footprint of the proposed site indicates that there is at least 2 m of alluvial (cohesive and granular) overlying a weathered residual soil of the Flamborough Chalk.

7.6.8 The findings of the Hydrogeological Risk Assessment indicate that dredging will have no significant effect on the saline intrusion currently affecting the principal aquifer.

Dredging

7.6.9 The vibrocore investigation reported in *Annexes 7.3 and 7.4* shows that the general subsoil sequence in the area of the investigation comprises the following:

- very soft to soft alluvial clays/clayey silts – occasional thin peat layers;
- silty and gravelly sands; and/or
- soft to firm becoming stiff glacial till with beds of glacial sands and gravels.

7.6.10 At the request of MMO, additional soil samples were obtained in May 2011 from the proposed dredging area and submitted to CEFAS for analysis. The results are presented in Appendix 3 of the Dredging Strategy (*Annex 7.6*). The MMO have confirmed that the dredge arisings will be suitable for deposition within the Humber.

7.6.11 The respective volumes of the different materials to be dredged have been estimated from the 2010 site investigation and are presented in *Table 7.8*.

Table 7.8 *Volumes of Material Types to be Dredged*

Area	Dredge (m ³)
Reclamation Area	250 000
Anchorage Trench	44 500
Berthing Pocket	827 000
Approach Channel	682 000
Turning Area	132 000
TOTAL	1 935 500

Dredging Methodology

7.6.12 Dredging works will be undertaken according to the Dredging Strategy and methodology presented in *Annex 7.6*. Dredging will be undertaken using a combination of the following plant:

- trailing suction hopper dredger (TSHD);
- backhoe dredger (BHD); and
- bucket ladder dredger (BLD).

7.6.13 The methodology sets out the time required for dredging, the probable number of vessel movements and the constraints during the excavation process. The character of the dredged material is important in determining the options for disposal and the potential for beneficial use.

Maintenance of Humber Estuary Sediment Supply

7.6.14 The potential for beneficial use of the dredged material as backfill to the quay is being investigated; however, at this stage it is considered unlikely that the material could be used without some form of treatment. Therefore, subject to discussions with the MMO, unsuitable erodible material is likely to be distributed in a sustainable manner between the existing licensed deposit grounds within the estuary or at another location to be agreed with the regulatory authorities. Deposition sites will, as far as possible:

- Match the character of material being deposited with the existing bed sediments or be similar to materials that are regularly deposited during maintenance dredging or have previously been deposited from capital dredging works elsewhere; and
- Locate the materials, particularly the softer alluvial sediments, where natural distribution away from the deposit location could add to

accretion rates on intertidal areas within the estuary and thereby assist reducing existing erosion rates.

- 7.6.15 Whilst the exact dredge methodology for the different material types is yet to be determined, the following disposal strategy is currently proposed based on the most likely dredge methodology.
- 7.6.16 The alluvial clays and silts should be suitable for dredging by TSHD and will have a character very similar to maintenance dredge material. The most suitable location for this material to be deposited would therefore be Middle Shoal, where the material would disperse estuary wide and this would be little different to a maintenance dredge activity.
- 7.6.17 Should a backhoe dredger be used for all or part of the alluvial clays and silts, the material might include clumps. Any soft backhoe dredged alluvium could potentially be deposited at the Middle Shoal deposit ground. The Middle Shoal Deposit Ground would also be a suitable location for the silty and gravelly sands.
- 7.6.18 At this stage it is understood that, for the glacial clay materials, a suitable deposit site lies to the north of the Sunk Dredged Channel.

Gas

- 7.6.19 A likely result of erection of buildings within an area affected by hazardous gas will be the required installation of gas measures into the foundation of the buildings. However, it is unlikely that any buildings will be constructed within the landfill buffer.

Construction Phase

- 7.6.20 Potential impacts during construction result from the change in contamination sources, receptors (construction workers, visitors and ecology) and pathways compared to the baseline. Construction of the proposed development could include the following activities which would influence contamination sources and pathways:
- vegetation clearance, excavation and removal of the ground which would potentially remove contaminants (if present) but could also release and mobilise contaminants (if present) during the clearance/excavation process;
 - redistribution of the ground and contaminants (if present), which could increase the potential for leaching of contaminants from the ground to the controlled waters receptors or introduce contaminants

into new areas of the development site and thus to additional receptors;

- stockpiling of excavated material prior to either re-use or removal which could release contaminants (if present) in the stockpile by entrainment in surface water run-off and increased leaching to groundwater;
- use of plant and equipment on the development site which could accidentally leak fuels and oils, and introduce contaminants into the ground;
- storage of fuel and oils on the development site which could leak/spill and introduce contaminants into the ground;
- importation and placement of fill which could include contaminants;
- placement of clean fill, foundations and hard standing which would potentially act as pathway barriers to human receptors and reduce the potential for infiltration of rainfall and reduce leaching to the controlled waters receptors;
- temporary dewatering of the excavations which could potentially alter the groundwater flow direction for a short time and draw groundwater and contaminants into the excavation; and
- installation of service trenches which can act as preferential pathways for migration of vapours and for contaminants into groundwater.

Operational Phase

7.6.21 Potential impacts during the operational phase of AMEP may result from the change in contamination sources, receptors and pathways compared to those identified in the baseline. These could include:

- changes to receptors which will now comprise site occupants/visitors;
- storage and handling of materials on the development site which could leak/spill and introduce contaminants into the ground;
- changes to contamination sources, which could include removal or volatilisation of contaminants (source removal) during construction; and
- installation of vapour membranes in infrastructure preventing accumulation of vapours and ground gas.

7.6.22 A summary of the potential impacts for all phases are shown in *Table 7.9, Figure 7.5 and Table 7.5* respectively.

Table 7.9 *Potential Impacts during Construction and Operational Phases*

Potential Impact	Sensitivity	Magnitude	Mitigation / Comment
Site clearance: Mobilisation of contaminants which could enter Estuary via run-off and creation of dust.	Moderate	Low	Ensure that site works on potentially contaminated land is controlled in order to minimise dust.
Construction of piled quay and reclaimed land: Creating new pathway for any contaminants present within mudflats into chalk aquifer.	Moderate	Moderate	Piling works to comply with EA guidance. Piling method statement must be focused on this guidance.
Construction of buildings near former landfill: Potential for migration of landfill gas.	Moderate	Moderate	Proposed buildings within 250 m of the landfill will undergo GRA prior to construction
Storage of fuel & oil: Spillages and leaks	Low	Moderate	<ul style="list-style-type: none"> • Best site management practices will be adopted; • Machinery regularly checked for leaks; • Fuel containers to be bunded to 100 percent capacity – bunds to be kept empty at all times.

See *Table 7.1* for significance.
Source: Able UK Ltd 2010

7.7 **MITIGATION**

7.7.1 General mitigation for the terrestrial geology and ground conditions is not likely to be necessary. However, during site clearance works the planned excavation of soils will be undertaken in accordance with DEFRA (2008) guidance so as to minimise damage to soil structure and thus allowing reuse of the material.

7.7.2 Piling works associated with the construction of the new quay have the potential to create a new pathway for contaminants present within the surficial deposits eg tidal mudflat deposits into the chalk aquifer. The

risk will be controlled by undertaking a risk assessment and developing a method statement for piling works based on guidance on piling produced by the EA – Piling and Penetrative Ground Improvement, Methods on Land Affected by contamination: Guidance on Pollution Prevention (2001).

7.7.3 Buildings will not be constructed within 250 m of the Lindsey Oil refinery in the south-west of the site. However, final building locations will be tenant dependant and will be determined after submission of application, therefore gas risk assessments may be required

7.7.4 There are no additional mitigation measures to prevent further saline ingress as there is presently little cover in any event, in terms of superficial deposits, for the primary aquifer.

7.7.5 A dredging strategy has been prepared in consultation with the statutory regulators. The principal objective is to deposit arisings within a licensed site that has similar soil characteristics to the material being deposited. The dredging strategy is presented in *Annex 7.6*.

7.8 *RESIDUAL IMPACTS*

Construction Phase

7.8.1 At present the proposed AMEP site is only partially developed as port related storage. The remainder of the site is under agricultural use as arable and /or pasture and is classified as Grade 3 - good to moderate quality agricultural land (MAFF 1988b). The construction of AMEP would lead to the loss of Grade 3 agricultural land.

Operational Phase

7.8.2 There are no further residual impacts on the geology, hydrogeology or ground conditions during the operational phase.

7.9 *CUMULATIVE IMPACTS*

7.9.1 There no cumulative impacts related to the geology, hydrogeology or ground conditions of the site.

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