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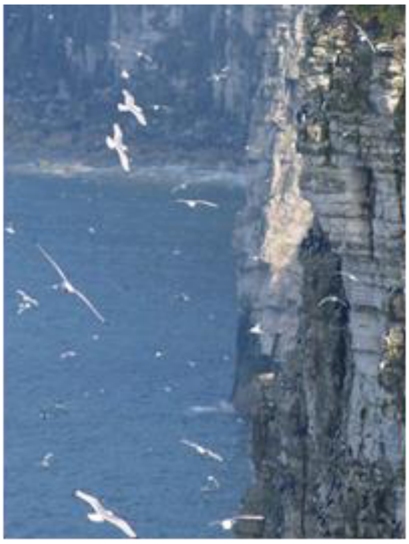
Able Marine Energy Park

Material Change 2

Dredge Disposal Benthic Invertebrate Scheme

(referenced in response to question 6.0.3)

Thomson environmental consultants



Able Marine Energy Park

Dredge Disposal Benthic Invertebrate Scheme

For

Able UK

Project No.: NABL115/002/001/002

September 2021

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Contents

1. Summary

1.1.1 The Able Marine Energy Park development requires a capital dredging operation, which will involve the disposal of dredged material at existing licensed disposal sites within the Humber Lower water body, which is a Special Area of Conservation, Special Protection Area, and Ramsar site. Site HU082 will be used for disposal of non-erodible material (up to 1 million tonnes) and site HU080 will be used for disposal of erodible material (up to 2.218 million tonnes).

1.1.2 The Benthic Invertebrate scheme for the dredge disposal aspect of the Able Marine Energy Park development is required to meet commitments and objectives detailed in the project's Marine Environmental Management and Monitoring Plan. Monitoring is required to assess changes in ecological potential of the Humber Lower water body (in terms of the Water Framework Directive status) and effects on the Conservation Objectives of the Humber Estuary European Marine Sites.

1.1.3 This Benthic Invertebrate scheme includes an assessment of previous monitoring data from the Humber Lower, the objectives of the monitoring scheme, the location of monitoring stations, the rationale behind monitoring locations and frequency of monitoring, quantitative benthic community targets, a timetable for conducting and reporting on monitoring activities, and a monitoring methodology.

1.1.4 The erodible material to be deposited at HU080 contains a fraction of gravel which is coarser in nature than the sediment present at HU080, which has not previously been used for the disposal of gravel. Previous monitoring conducted in 2015 assessed the areas that gravel was predicted to disperse over according to two numerical models. The Benthic Invertebrate scheme monitoring stations reflect the sampling design of the 2015 survey to enable the identification of temporal change.

1.1.5 The quantitative targets are for there to be no significant deleterious change in abundance, diversity, biotope composition, or Infaunal Quality Index score at the monitoring stations.

1.1.6 A total of 15 monitoring stations have been chosen to be representative of the range of biotopes, sediment types, and IQI scores present in the area. The monitoring stations cover the predicted extent of dredged sediment dispersal and control sites.

1.1.7 One monitoring survey will be undertaken 2 years after cessation of the dredge disposal activities. Results shall be reported within 10 weeks of completion of the survey.

1.1.8 Survey methodologies will be in line with standard monitoring protocols (Ware and Kenny, 2011; Davies et al., 2001; EA, 2013). Laboratory analysis of the samples will be undertaken by a laboratory that is a member of the National Marine Biological and Analytical Quality Control scheme (NMBAQC), following NMBAQC guidelines.

1.1.9 Standard univariate biological parameters, including Margalef's index of species richness, Shannon's diversity index and Pielou's evenness index, and multi-variate techniques (Bray-Curtis similarity coefficient and non-metric Multi-Dimensional Scaling (MDS) ordination) will be used to analyse the data and assign biotopes and an Ecological Quality Ratio (EQR) to the sampling stations.

1.1.10 Implementation of this BI scheme will identify any potential deleterious change to subtidal benthic invertebrate fauna in the Humber Lower, in terms of WFD status, as the monitoring stations reflect the sampling design of the 2015 survey, allowing identification of temporal change. Change will be detected via the quantitative targets for abundance, diversity, biotope composition and IQI class.

2. Introduction

2.1 Development Background

2.1.1 Able UK Ltd. has been granted a Development Consent Order (DCO) for the construction of the Able Marine Energy Park (AMEP). The AMEP will be an onshore facility for the construction of offshore wind turbines and other activities associated with sources of renewable marine energy.

2.1.2 Schedule 11, requirement 19, paragraph 2 of the AMEP DCO states:

"The authorised development must not commence until a marine environmental management and monitoring plan, reflecting the survey results and ecological mitigation and enhancement measures included in the environmental statement, has been submitted to and approved by the MMO (Marine Management Organisation) *after consultation with the Environment Agency, Natural England and the relevant planning authority."*

2.1.3 A Marine Environmental Management and Monitoring Plan (MEMMP) was produced to satisfy this condition, following consultation with stakeholders, which includes requirements for the monitoring of habitats and fauna in the vicinity of areas affected by the development.

2.2 The Brief and Objectives

2.2.1 The MEMMP includes the EA's proposed monitoring plans for the capital dredging and disposal activities for the AMEP development. For benthic invertebrates, this comprises:

"A scheme for the protection and enhancement of benthic invertebrates through the monitoring and management of disposal activities within, and immediately surrounding, the disposal sites."

2.2.2 Objective M6 of the MEMMP is to identify any deleterious change to the benthic invertebrate communities, specifically with regard to Water Framework Directive (WFD) status. This objective covers both the areas to be dredged and the disposal sites. For the disposal sites, subtidal benthic invertebrate surveys are proposed of the disposal sites themselves (HU080 and HU082) and the immediate vicinity.

Objective M6: To identify deleterious change to subtidal benthic invertebrate fauna due to dredging and dredge disposal	
Target	No impact on WFD status (status currently assessed as Moderate for Humber Lower).
Monitoring	Subtidal benthic invertebrate survey of maintenance dredge areas using a Day grab. Subtidal benthic invertebrate survey of areas within, and immediately surrounding, dredge disposal sites.

2.2.3 Able is therefore required to submit a Benthic Invertebrate (BI) scheme for approval by the MMO, after consultation with the Environment Agency, Natural England (NE), and the relevant planning authority. The BI Scheme must meet the existing commitments and objectives detailed within the MEMMP.

2.2.4 Able UK commissioned Thomson Environmental Consultants on 21.12.20 to produce the BI scheme for the monitoring of the two dredge disposal sites HU082 and HU080. The BI scheme is required to outline the approach for monitoring subtidal benthic invertebrate communities in the vicinity of the dredge disposal sites, which must be capable of identifying deleterious change in accordance with:

- The requirement to evaluate the contribution that the marine disposal activities make to the overall ecological potential of the Humber Lower water body (in terms of the WFD)
- The requirement to evaluate the dredge disposal activities in the context of the Conservation Objectives of the Humber Estuary European Marine Sites (EMS).

2.2.5 The brief for the document was to include:

- An assessment of data from previous monitoring conducted in the area to inform the BI scheme;
- The objectives of the monitoring scheme;
- The rationale behind monitoring locations and frequency;
- The definition of appropriate quantitative benthic community targets to allow potential impacts upon the WDF status of the Lower Humber to be identified;
- The location of monitoring stations;
- A timetable for conducting and reporting on monitoring activities;
- A detailed methodology for the monitoring including the surveys and subsequent laboratory analysis;

2.3 Geographical context

2.3.1 The AMEP development site is located in the Killingholme Marshes area, approximately 2 km east of North Killingholme and 3.3 km from Immingham to the south. The site lies on the southern bank of the Humber Estuary, between the Humber Sea Terminal (HST) and ABP Immingham Port (Figure 1).

2.3.2 The boundary of the site lies partially within the Humber Estuary, which is designated as a European Marine Site (EMS) as part of the Natura 2000 network. It is designated as both the Humber Estuary Special Area of Conservation (SAC) and the Special Protection Area (SPA) / Ramsar site.

2.3.3 The two planned disposal sites, HU080 (Middle Shoal) and HU082, are located east of the AMEP site toward the mouth of the Humber, close to the North bank (Figure 1). They lie either side of the Sunk Dredged Channel (SDC); the deep-water channel through the outer Humber that allows ships access to the ports. The SDC is maintained at a depth of 8.8m below Chart Datum, over a minimum width of 150m. Maintenance dredging of the SDC is carried out as often as necessary to maintain the advertised depth (Lonsdale et al., 2013).

2.4 Legislative context and background

2.4.1 The European Water Framework Directive (WFD) (2000/60/EC) introduced a comprehensive river basin management planning system to help protect and improve the ecological health of water bodies, using a catchment-based approach. In England, the Environment Agency (EA) is the competent authority for the WFD, which is implemented through river basin management plans (EA, 2015).

2.4.2 The overarching aim of the WFD is for water bodies to achieve Good Ecological Status (GES), by meeting both ecological and chemical criteria. Ecological status is defined by the condition of biological elements such as fish and invertebrate populations, the concentrations of supporting physico-chemical elements, and hydromorphology. The overall waterbody classification (high, good, moderate, poor, or bad) also includes an assessment of chemical status and is determined by the worst scoring quality element.

2.4.3 However, it is often not possible for artificial or heavily modified water bodies to achieve or be restored to GES within the timescales set out in the WFD. For these water bodies, the classification is carried out according to their ecological potential rather than status.

2.4.4 The development site lies within the Humber Lower water body (ID GB530402609201), which is a transitional water body and designated as a HMWB due to substantial modification for flood protection, navigation (i.e. dredging), and coastal protection. The WFD ecological target for the water body is therefore Good Ecological Potential (GEP). The Humber Lower water body has been classified by the EA as being at moderate ecological potential since it was first classified in 2009.

2.4.5 The WFD environmental objectives for HMWBs include:

- prevent deterioration of the status of each body of surface water;
- protect and enhance each artificial or heavily modified water body with the aim of achieving good ecological potential and good surface water chemical status, if not already achieved, by 22nd December 2021;
- aim progressively to reduce pollution from priority substances and aim to cease or phase out emissions, discharges and losses of priority hazardous substances.

2.4.6 The proposed monitoring and management measures for the AMEP development set out in detail in the MEMMP include specific objectives, targets and management actions which support the WFD objectives. Objective M6 of the MEMMP is to identify any deleterious change to the benthic invertebrate communities, with a target for of no impact on WFD status.

2.5 Dredge Disposal Background

2.5.1 The AMEP development will require a capital dredging operation which will remove material from the site to provide safe vessel access to the AMEP quay. The dredged material will subsequently be disposed of at existing licensed disposal sites within the Humber. The dredging and disposal strategy was submitted to the MMO as part of the AMEP DCO application (No. 2935) to construct the AMEP.

2.5.2 The capital dredge is expected to last between 4 and 5 months in total, with 350 deposits across two disposal sites.

2.5.3 The HU082 disposal site, located immediately to the north of the SDC (Figure 1), is believed to be unused for dredge disposal at present. The HU080 disposal site is located immediately to the south of the SDC. This site was licensed for the first time in the 1970s and has received nearly all of the maintenance dredge arisings from the SDC.

2.5.4 The dredged material to be disposed of at the two sites consists of erodible (soft clay, silt, sands, and gravels) and non-erodible (glacial till/stiff clay) material. Only the erodible material will be placed at the dispersive site HU080 while only non-erodible material will be placed at the capital site HU082. The DCO allows for up to 2.218 million tonnes of erodible material to be deposited at HU080 and up to 1 million tonnes of non-erodible material at HU082 (Table 1).

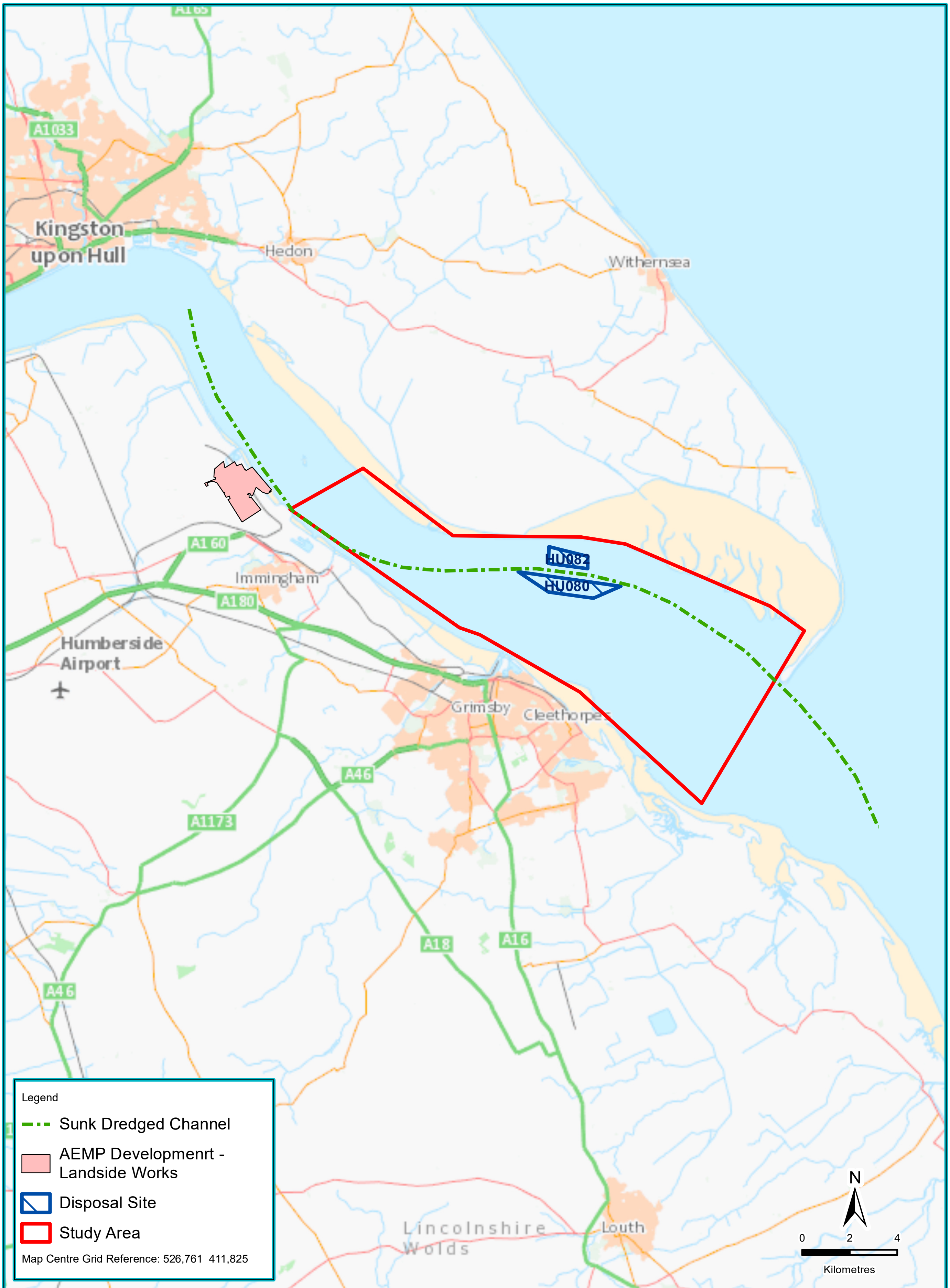
Table 1 Disposal sites

Disposal site	Type of material	Amount of material
HU080	Erodible - gravel, sand, silt, and soft clay	2.218 million tonnes
HU082	Non-erodible – stiff clay	1 million tonnes

2.5.5 Records of the amount of material deposited at HU080 between 1986 and 2019 (ABP, 2014) give an annual average disposal at HU080 of 3 million wet tonnes. There is high variability in the amount deposited each year, from nothing up to nearly 9 million tonnes. ABP are currently licensed to dispose of up to 7.8 million tonnes at HU080 annually. Therefore, the maximum amount that could be deposited by Able at this site for the capital dredge operation (2.2 million tonnes) will be significantly less than the average and substantially less than the amount that could potentially be deposited by ABP. As maintenance dredging of the SDC is carried out as necessary, the amount for disposal around the same time as the capital dredge disposal is not known.

2.5.6 The erodible material to be deposited at HU080 contains a fraction (130,000m^3) of gravel (grain size of 2-60mm) which is coarser in nature than that present at HU080. As HU080 has not previously been used for the disposal of gravel, numerical modelling was carried out (JBA, 2012; HR Wallingford, 2016) that indicated gravel deposited at HU080 would disperse outside of the disposal site boundary into the wider Humber Estuary. Due to the Humber's designated status as a SAC and SPA / Ramsar site, the MMO requested an assessment of the effects of gravel disposal on the surrounding benthic environment. Two assessments (GoBe Consultants, 2012 and HR Wallingford, 2016) concluded that the deposition of gravel would not cause substantially more extreme disturbance than routine maintenance dredge disposals, despite the difference in grain size (see Section 4.2 for more detail).

2.5.7 Schedule 8 of the DCO, the marine license for the AMEP development, relates to capital dredge disposal and details further monitoring and management measures that Able will undertake. These include ensuring that material is deposited into depressions at HU082, and that material is distributed evenly at each site.



Client	Able UK	Drawing Ref	NABL115/32239/1	
Figure Number	1	Scale at A4	1:218,980	
Figure Title	AEMP Development Site, Location of Disposal Site HU080 and HU082, and Study Area Boundary	Drawn: LF	Checked: EA	
		Date: 28/04/2021	Date: 28/04/2021	

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3. Methodology

3.1.1 A desk study was undertaken to collate existing data and information to inform the extent of the study area for the BI scheme, the monitoring locations, and the approach to setting quantitative benthic community targets. Consultation with the EA, MMO and NE was undertaken to discuss and agree on the scope of the BI scheme.

3.1.2 Records of designated sites, important species, and baseline conditions were then sought for the study area. Sources of information were as follows:

- The Multi-Agency Geographical Information for the Countryside (MAGIC);
- Cefas Open Science;
- Joint Nature Conservation Committee (JNCC) Open Data EUNIS (European Nature Information System) level 3 biotope maps;
- EA WFD routine monitoring data;
- NE SAC routine condition monitoring data.

3.1.3 The assessment of baseline conditions and potential impacts was also informed by existing documentation relating to the development including:

- Able Marine Energy Park Marine Environmental Management and Monitoring Plan, October 2020 (DS.AMEP.D16/38/Rev I).
- Able UK Ltd, ERM & Black & Veatch (2011). Environmental Statement Chapter 10: Aquatic Ecology
- ERM (2011). Able Marine Energy Park Habitat Regulations Assessment Report (TR030001/APP/15).
- ERM (2012). EX 10.4: Impact of Dredging and Dredged Material Disposal on 1) Subtidal and Intertidal Features and 2) Aquatic Ecology (TR030001/APP/14b).
- GoBe Consultants (2012). EX10.8: Able Marine Energy Park characteristation of disposal site and impact assessment of gravel disposal (TR030001/APP/).
- HR Wallingford (2012). Able Marine Energy Park and Habitat Compensation Scheme Water Framework Directive Assessment (TN DHM6835-02 R5).
- HR Wallingford (2016). Assessment of gravel disposal at H080 (DLM7473-RT002-R02-00)
- JBA Consulting (2012). Note to file: Assessment of impacts of disposal of AMEP capital dredge gravel fraction – additional assessment.
- Precision Marine (2016). Able Marine Energy Park: Assessment of gravel disposal at site HU080 – Benthic Survey 2015 (P016-01-0076\MEPB15 rev3).

3.1.4 The 2015 survey undertaken by Precision Marine involved the collection of samples from 26 stations in the Humber Lower, distributed to cover the predicted extent of deposited gravel dispersion and the vicinity (Precision, 2016). The resulting data from this survey were used to assign biotopes to each sampling station.

3.1.5 Further data were gathered from Defra and associated bodies/agencies including the EA and NE; the Humber Lower has been surveyed by the EA as part of WFD monitoring and by NE as part of SAC condition monitoring, for which benthic macrofaunal samples were collected using a Day Grab.

3.1.6 Data were obtained as either species abundance data, biotope data, or IQI (Infaunal Quality Index) data, and compared where possible to assess baseline conditions. The IQI is a multimetric tool used to assess the ecological status of the macrobenthic invertebrate infaunal assemblages to determine WFD status. It incorporates taxonomic diversity and evenness and proportions of sensitive and opportunistic taxa within macrobenthic invertebrate samples to derive an Ecological Quality Ratio.

3.1.7 A comparison was undertaken of the following datasets to asses temporal changes in habitat distribution:

- 2015 Precision marine survey data;
- EA WFD routine monitoring data from 2008, 2010, 2013 and 2016;
- NE SAC routine condition monitoring data from 1995, 2010 and 2016.

3.1.8 Biotope descriptions were taken from the classification system of Connor et al. (2004).

4. Baseline conditions

4.1 Study area

4.1.1 The Humber Lower is a large water body, covering an area of 247 km^2. The Humber is a macro-tidal estuary with high levels of suspended sediment, largely of marine origin, with up to 1.26 million tonnes of sediment estimated to be in the water column on a given tide (Townend and Whitehead, 2003). Chapter 10 of the environmental statement for the AMEP scheme notes that there is ‘accretion and erosion of intertidal and sub-tidal habitats’ throughout the estuary (Able UK et al., 2011).

4.1.2 The subtidal environment covers 46% (168 km^2) of the total area of the estuary and contains a variety of habitats, predominantly mobile sands and muds with patches of gravel and glacial till (Able UK et al., 2011). It is highly variable and dynamic, both spatially and temporally, in terms of physical parameters such as salinity, sediment type, hydrodynamic regime, sediment load, turbidity, and dissolved oxygen (GoBe Consultants, 2012).

4.1.3 A study area for the BI scheme was defined as an area that encompassed the two dredge disposal sites and the extent of predicted gravel dispersal. To allow a buffer for potential error in dispersal modelling and cover the potential Zone of Influence for the disposal activities, the study area encompassed the majority of the subtidal Humber Lower water body, from Immingham to Spurn Point (Figure 1). The study area encompasses all the sampling stations from the 2015 Precision Marine survey, to provide continuity of data.

4.1.4 Two modelling studies both concluded that the disposed gravel should not disperse to intertidal areas of the Humber Estuary (JBA, 2012; HR Wallingford, 2016). Although dispersal of fine sediment has not been modelled, there is not expected to be a significant amount deposited in the intertidal region. Therefore, only the subtidal environment is considered further.

4.2 Designated Sites

4.2.1 The EU Habitats Directive (92/43/EEC) requires the establishment of a network of important high quality conservation sites (Special Areas of Conservation (SAC)) that will make a significant contribution to conserving the habitat types and species identified in Annexes I and II of the Directive. The Estuary Annex I habitat type, a primary reason for the Humber Estuary SAC designation, includes as a sub-feature the ‘subtidal habitat’, as does ‘Sandbanks which are slightly covered by sea water all the time’. This includes subtidal coarse sediment (EUNIS biotope A5.1), sand (A5.2), mud (A5.3), and mixed sediment (A5.4) and the associated benthic communities (see Section 4.4 ‘Biotopes’). The conservation objectives for the SAC include maintaining the extent, distribution, structure, and function of qualifying habitats.

4.2.2 The Humber Estuary is also designated as a Special Protection Area (SPA) and a Ramsar site. SPAs, designated under the EU Birds Directive (79/409/EEC), provide for the protection of rare or vulnerable species listed in Annex 1 of the Directive (Article 4.1), for regularly occurring migratory species (Article 4.2) and for the protection of wetlands, especially wetlands of International importance. Under the 1971 Ramsar Convention on Wetlands of International Importance, signatory states are required to protect wetland sites of International importance, including those that are important waterfowl habitats.

4.2.3 Table 2 presents the relevant designated sites with an overview of the reasons for designation.

Table 2 International designated sites.

Site Designation	Grid Reference	Area (ha)	Description
Humber Estuary SAC	SE 83851 11031	36,657.15	Annex I habitats in the Humber that are a primary reason for site selection are 1130 'Estuaries' and 1140 'Mudflats and sandflats not covered by seawater at low tide'. Priority habitats include 'Coastal lagoons' and 'Grey dunes.' Other qualifying features that are not the primary reason for site selection include the Annex I habitats 'Sandbanks which are slightly covered by sea water all the time', '*Salicornia* and other annuals colonizing mud and sand', 'Atlantic salt meadows', 'Embryonic shifting dunes', 'White dunes', and 'Dunes with *Hippopha rhamnoides*.' Annex II species present as a qualifying feature, but not a primary reason for site selection, are Sea lamprey, River lamprey and the Grey seal.
Humber Estuary SPA	TA 36373 07864	37,630.24	The site supports populations of rare or vulnerable bird species listed in Annex 1 (Article 4.1) of the EU Birds Directive (79/409/EEC) and regularly occurring migratory species (Article 4.2). SPA qualifying sub-features include intertidal mudflats and sandflats, saltmarsh, tidal reedbeds, coastal lagoons and unvegetated sand and shingle. The SPA encompasses all or parts of the following Sites of Special Scientific Interest (SSSIs): Humber Estuary SSSI, North Killingholme Haven Pits SSSI, Saltfleetby-Theddlethorpe Dunes SSSI, and The Lagoons SSSI.
Humber Estuary Ramsar Site	TA 35915 07884	37,988	The site meets Ramsar Qualifying Criterion 1, containing a representative, rare, or unique example of wetland. The site meets Ramsar Qualifying Criterion 3, for populations of species important for biological diversity – Grey seals at Donna Nook and Natterjack toad at Saltfleetby-Theddlethorpe. Criterion 5 is met by the waterfowl assemblage of international importance. Criterion 6 is met by species/populations occurring at levels of international importance. Criterion 8 is met as the Humber Estuary acts as an important migration route for river and sea lamprey.

4.3 Fauna

4.3.1 The fauna inhabiting the Humber Lower water body are standard for high-energy estuarine environments, with communities typically associated with disturbed sediments that are resilient to regular physical restructuring by sediment movements resulting from the hydrodynamic conditions. These communities are composed of opportunistic and pioneering species that are quick to colonise, or tolerant of, rapidly changing benthic environments.

4.3.2 Impoverished macrobenthic communities with low diversity dominate, with areas of high abundance and biomass. Variability in diversity and abundance is strongly linked with substrate type, with highest diversity found in areas of coarser sediment and highest abundances found in areas of muddy sediment (Hemingway et al., 2008). The subtidal areas of the Humber used as dredge disposal sites are low in both abundance and diversity, as is typical for such routinely disturbed environments.

4.3.3 The fauna in the study area (Figure 1) are typical of high salinity estuarine environments. The species recorded from the samples from the 2015 survey (Precision, 2016) correspond well with those from the sampling undertaken by the EA and NE (EA WFD routine monitoring data from 2008, 2010, 2013, 2016 and NE SAC routine condition monitoring data from 1995, 2010 and 2016); across all these data the species assemblages and abundances were generally similar.

4.3.4 Characteristic taxa from Precision, EA and NE monitoring that were recorded in high abundances include cirratulid polychaetes (*Aphelochaeta marioni, Tharyx spp.*), oligochaetes (*Tubificoides spp.*) and the amphipods *Corophium volutator* and *Bathyporeia spp*. Other characteristic taxa include the polychaetes *Scoloplos (Scoloplos) armiger* and *Nephtys spp*., and crustacea such as *Eurydice pulchra* and *Gastrosaccus spinifer*.

4.3.5 Diversity in the area is generally low, with fewer than 10 taxa per $0.1m^2$. Sandy areas are generally the most impoverished, with the fewest taxa recorded. Higher diversity can be found in areas of mixed sediment. The abundance of invertebrates is highly variable and generally lowest in sandy areas, with fewer than 10 individuals per $0.1m^2$. Very high abundances can be found in muddy areas where polychaetes such as cirratulids and spionids dominate, although diversity in these areas is still low.

4.3.6 No records of species of conservation importance were found for the study area. During the 2015 survey, *Sabellaria spinulosa* and *S. alveolata* were recorded at two stations near the north bank of the Humber, toward the mouth of the estuary (Precision, 2016). These polychaetes can form biogenic reefs, which are an Annex 1 habitat under the EU Habitats Directive. Both taxa are commonly recorded off the mouth of the Humber, occasionally in reef form. However, in all data analysed for the study area, they were not commonly recorded and only ever occurred in low numbers. They are, therefore, not considered to represent an established community and do not indicate the presence of protected Annex 1 reef.

4.4 Biotopes

4.4.1 Following the definition of Connor et al. (2004), a biotope is a combination of the abiotic characteristics of a habitat (primarily sediment type) and its associated community of species. In the marine environment, there is a strong relationship between the abiotic characteristics of habitats and the biological composition of the communities which they support.

4.4.2 The following biotopes are present in the area according to the JNCC EUNIS level 3 biotope maps. These habitats are described below, and their distribution is given on Figure 2.

- A5.1. Sublittoral coarse sediment. Including coarse sand, gravel, pebbles, shingle, and cobbles, generally with low silt content. The sediment is unstable due to tidal currents and/or wave action. This habitat is characterised by a robust fauna including Venus clam bivalves.
- A5.2. Sublittoral sand. Clean sands or non-cohesive slightly muddy, often subject to wave action and/or tidal currents which restrict the silt and clay content. This habitat is characterised by a range of taxa including polychaetes, bivalves and amphipods.

- A5.3. Sublittoral mud. Predominantly found in more sheltered areas with reduced influence of wave action and/or tidal currents, allowing fine sediment to settle. This habitat is often by dominated by polychaetes and oligochaetes.
- A5.4. Sublittoral mixed sediments. Heterogeneous sediments that may support a wide range of infauna and epibiota including polychaetes, bivalves, echinoderms, anemones, hydroids and bryozoa.

4.4.3 The majority of the study area is classified as sublittoral sand and sublittoral mud. There is one area of sublittoral coarse sediment toward the south bank and the mouth of the Humber, and a few areas of mixed sediment. Disposal site HU082 is almost entirely sand, with a small area of mixed sediment. Disposal site HU080 is composed of sand and mud.

4.4.4 The 1995 NE condition monitoring data fit very well to the JNCC broad scale maps, with all stations classified as variants of the biotope complexes 'Sublittoral sand in variable salinity (estuaries)' (A5.22) or 'Sublittoral mud in variable salinity (estuaries)' (A5.32). The most common biotope was '*Nephtys cirrosa* and *Macoma balthica* in variable salinity infralittoral mobile sand' (A5.222). These habitats are described below, and their distribution is given on Figure 2. No samples were collected from areas classified as sublittoral coarse (A5.1) or mixed (A5.4) sediment during this survey.

- A5.221. Infralittoral mobile sand in variable salinity (estuaries). Found in areas of strong tidal currents meaning no stable community is able to develop. Characteristic fauna includes epifaunal crustaceans or relatively low numbers of robust species, such as the isopod *Eurydice pulchra*. The polychaete *Capitella capitata* may occur frequently in some areas.

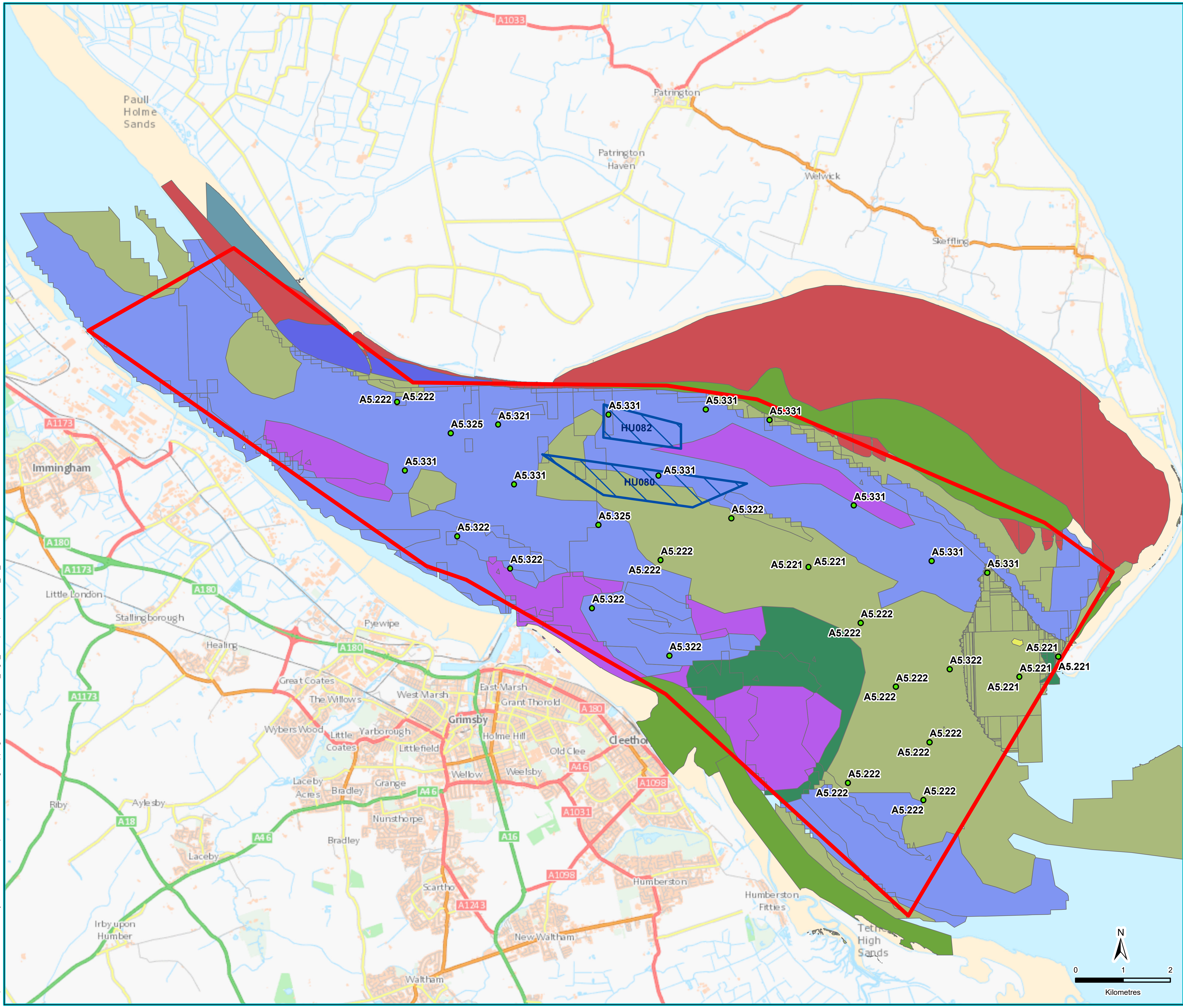
- A5.222. *Nephtys cirrosa* and *Macoma balthica* in variable salinity infralittoral mobile sand. Mobile sand in an unstable, shifting habitat due to tidal currents characterised by the polychaete *N. cirrosa* and the bivalve *M. balthica*. Additional characteristic species include the polychaete *Scoloplos armiger* and amphipods such as *Bathyporeia spp.*, although the biotope contains relatively few species, typically in low to moderate abundance.

- A5.321. *Polydora ciliata* and *Corophium volutator* in variable salinity infralittoral firm mud or clay. Characterised by a turf of the polychaete *P. ciliata* along with the amphipod *C. volutator*. Other important taxa include the polychaetes *Pygospio elegans*, *Hediste diversicolor*, and *Streblospio shrubsolii* and the oligochaete *Tubificoides benedii*.

- A5.322. *Aphelochaeta marioni* and *Tubificoides spp*. in variable salinity infralittoral mud. This biotope is common in stable muddy environments. In addition to the cirratulid polychaete *A. marioni,* and the oligochaetes *Tubificoides spp.*, other taxa that are common in this biotope include the polychaetes *Nephtys hombergii, Capitella capitata, Melinna palmata*, and other cirratulids.

- A5.325. *Capitella capitata* and *Tubificoides spp*. in reduced salinity infralittoral muddy sediment. This biotope has low species richness, dominated by the polychaete *C. capitata* and oligochaetes (*Tubificoides spp.*), generally found away from tidal channels in estuaries in areas with higher organic load.

- A5.331. *Nephtys hombergii* and *Macoma balthica* in infralittoral sandy mud. Characterised by the polychaete *N. hombergii* and the bivalve *M. balthica*. Other dominant species may include the bivalves *Abra alba* and *Nucula nitidosa*, and the polychaetes *Spiophanes bombyx* and *Lagis koreni*. The community is generally quite stable, and the substratum is typically rich in organic content.



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Legend

- Sampling Points

Biotopes

- A2.2
- A2.2 + A2.3
- A2.3
- A2.3 + A2.5
- A5
- A5.1
- A5.2
- A5.3
- A5.4
- Disposal Site
- Study Area

Map Centre Grid Reference: 529,661 413,958

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Drawing Ref	NABL115/32240/1
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Date: 28/04/2021	Date: 28/04/2021
Client	Able UK
Figure Number	2

Figure Title

JNCC level 3 EUNIS Biotope Map and 1995 NE Condition Monitoring Data

Filepath: S:\Marine Team\Projects\NABL115 - Disposal site monitoring\Mapping\Working\NABL115_Fig2_BiotopeMap1995Data_LF_280421.mxd

4.4.5 The data from the 2015 survey also fit to the JNCC EUNIS level 3 biotope mapping, with the exception of one station in an area defined as ‘Sublittoral mixed sediment’ according to the JNCC maps that was classified as the mud biotope ‘*Nephtys hombergii* and *Tubificoides spp*. in variable salinity infralittoral soft mud’ (A5.323). The majority of stations were again classified as variants of the biotope complexes ‘Sublittoral sand in variable salinity (estuaries)’ (A5.22) or ‘Sublittoral mud in variable salinity (estuaries)’ (A5.32). One station was classified as ‘Sublittoral mixed sediment’ (A5.4) during this survey, corresponding with the JNCC EUNIS level 3 biotope mapping. The distribution of these habitats is given on Figure 3. The additional biotopes not present in the 1995 data were:

- A5.323. *Nephtys hombergii* and *Tubificoides spp*. in variable salinity infralittoral soft mud. Characterised by the polychaete *N. hombergii* and oligochaetes (*Tubificoides spp*.). Other characterising species that may include the polychaetes *Streblospio shrubsolii* and *Aphelochaeta marioni*, and the cumacean *Diastylis rathkei typica*.
- A5.42. Sublittoral mixed sediment in variable salinity (estuaries). Coarse sediment, such as shells or stones, enable the development of diverse epifaunal communities, as well as infaunal communities. This biotope complex is therefore species rich, compared with purer sediments.

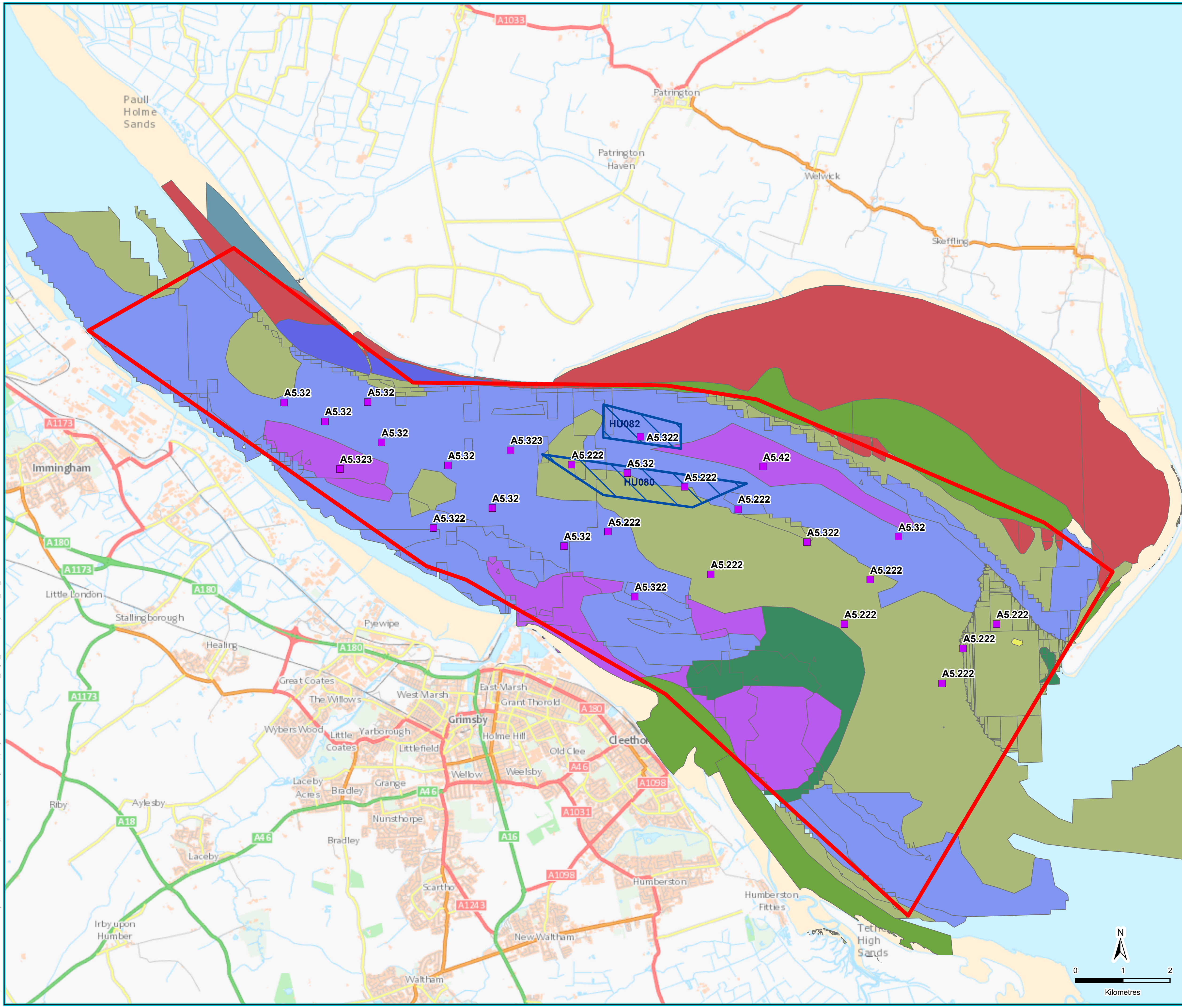
4.4.6 The 2016 NE condition monitoring data seem to indicate a spread of ‘Sublittoral sand’ (A5.2) since the 1995 NE condition monitoring, at the expense of ‘Sublittoral mud’ (A5.3) (Figure 4). The sublittoral mud biotopes A5.321, A5.322, and A5.331 were again recorded, with addition of two A5.23 biotopes: ‘Infralittoral mobile clean sand with sparse fauna’ (A5.231) and ‘Nephtys cirrosa and Bathyporeia spp. in infralittoral sand’ (A5.233). However, these two classifications are thought to be mistakes, as they are full salinity biotopes, rather than variable, which should be found in estuaries.

4.4.7 True variation in biotope composition between years appears to be limited and is likely to be due to the transitional nature of the biotope complex variants and related to changes in sediment type distribution due to the natural restructuring of the physical environment.

4.4.8 Two main types of biotopes dominate the study area; impoverished communities with low abundance and diversity in sandy areas, and ones with high abundances of a few taxa, but still low diversity in muddy sediment. Limited areas with higher diversity are linked to coarser mixed sediment, which provides surfaces for epifaunal species to colonise, such as encrusting bryozoans and hydroids, barnacles, and mussels.

4.4.9 In general, the biotopes in the area are characteristic of disturbed muddy and sandy environments. As the hydrodynamic conditions lead to large volumes of sand and mud being moved around the Humber and regular physical restructuring, the communities are routinely subject to disturbance and natural sediment deposition. Therefore, these communities are resilient to and tolerant of physical disturbance and smothering. They are characterised by robust, mobile species, generally able to move sufficiently to avoid adverse effects from this dynamic environment (HR Wallingford, 2016), and by opportunistic and pioneering species with high capacity for recruitment and recolonisation (Bellew and Drabble, 2004).

4.4.10 These biotopes are typical for dynamic mud, sand or mixed sediment subtidal sediments in lower estuaries and these findings are in line with those from other surveys (Allen & Proctor, 2014, Burdon et al., 2011, ABPmer & PMSL, 2010; PMSL, 2010; Allen, 2009; Allen, 2008; Allen, 2007 and Allen et al., 2003).



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Legend

Precision 2015 Data

Biotopes

- A2.2
- A2.2 + A2.3
- A2.3
- A2.3 + A2.5
- A5
- A5.1
- A5.2
- A5.3
- A5.4
- Disposal Site
- Study Area

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Able UK	
Figure Number	
3	
Figure Title	
JNCC level 3 EUNIS Biotope Map and 2015 Precision Data	

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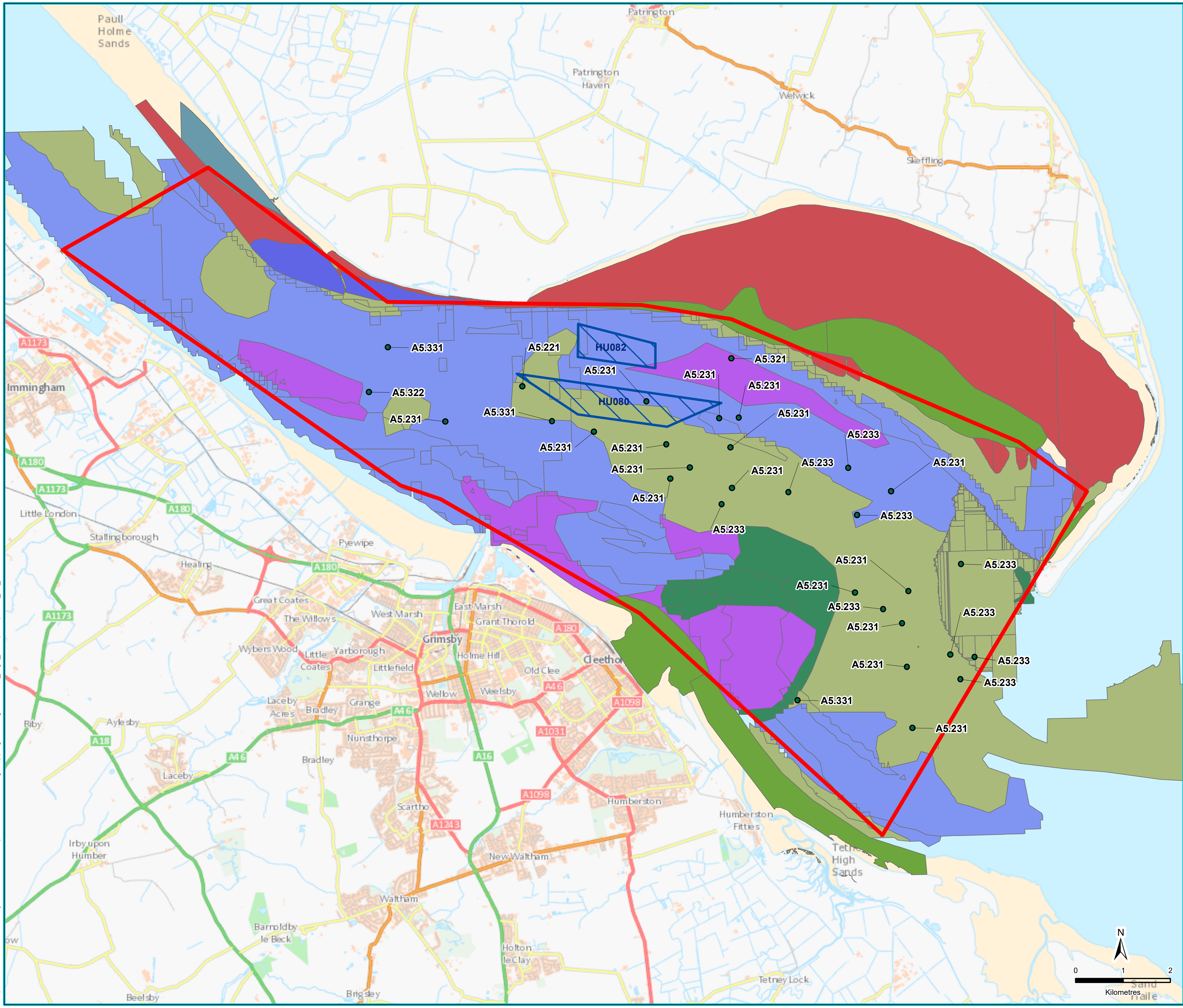

Filepath: S:\Marine Team\Projects\NABL115 - Disposal site monitoring\Mapping\Working\NABL115_Fig4_BiotopeMap2016_LF_280421.mxd

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Legend

- T2016 Sampling Points

Biotopes

- A2.2
- A2.2 + A2.3
- A2.3
- A2.3 + A2.5
- A5
- A5.1
- A5.2
- A5.3
- A5.4
- Disposal Site
- Study Area

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Client	Able UK
Figure Number	4
Figure Title	JNCC level 3 EUNIS Biotope Map and 2016 NE Condition Monitoring Data

4.5 Infaunal Quality Index Scores

4.5.1 EA IQI data from 2008 and 2010 for the Lower Humber show variability from ‘Poor’ to ‘High’ (Figure 5). The majority of stations were classified as ‘Moderate’ status, with only one station classified as ‘Poor’. IQI scores calculated from the 2015 survey data show an increase in IQI status in general, with the majority of stations classified as ‘Good’. Data from both sources indicate a ‘High’ status in the area of mixed sediment to the east of HU082. In areas of sandy sediment, the IQI score is generally ‘Good’. Muddy areas are more variable, with IQI status ranging from ‘Bad’ to ‘High’, but the majority of stations classified as ‘Moderate’.

4.6 Comparison with 2020 PSA data

4.6.1 Samples were taken by the EA in 2020 for PSA, and the data can be compared with the older PSA data to determine if significant changes in the macrofaunal community are likely to have occurred. Benthic invertebrates are strongly influenced by their physical environment, with dominant particle size correlating strongly with the type of macrofaunal community.

4.6.2 Figure 7 shows the dominant sediment type (mud, sand, or gravel) from the 2015 survey (Precision, 2016) and from the 2020 EA survey, for all stations within the study area. There is good agreement between the two datasets in terms of distribution of sand and mud. In both years, sand is the dominant sediment type in the middle of the estuary and toward the mouth, and mud is more common further upstream and toward the banks of the estuary.

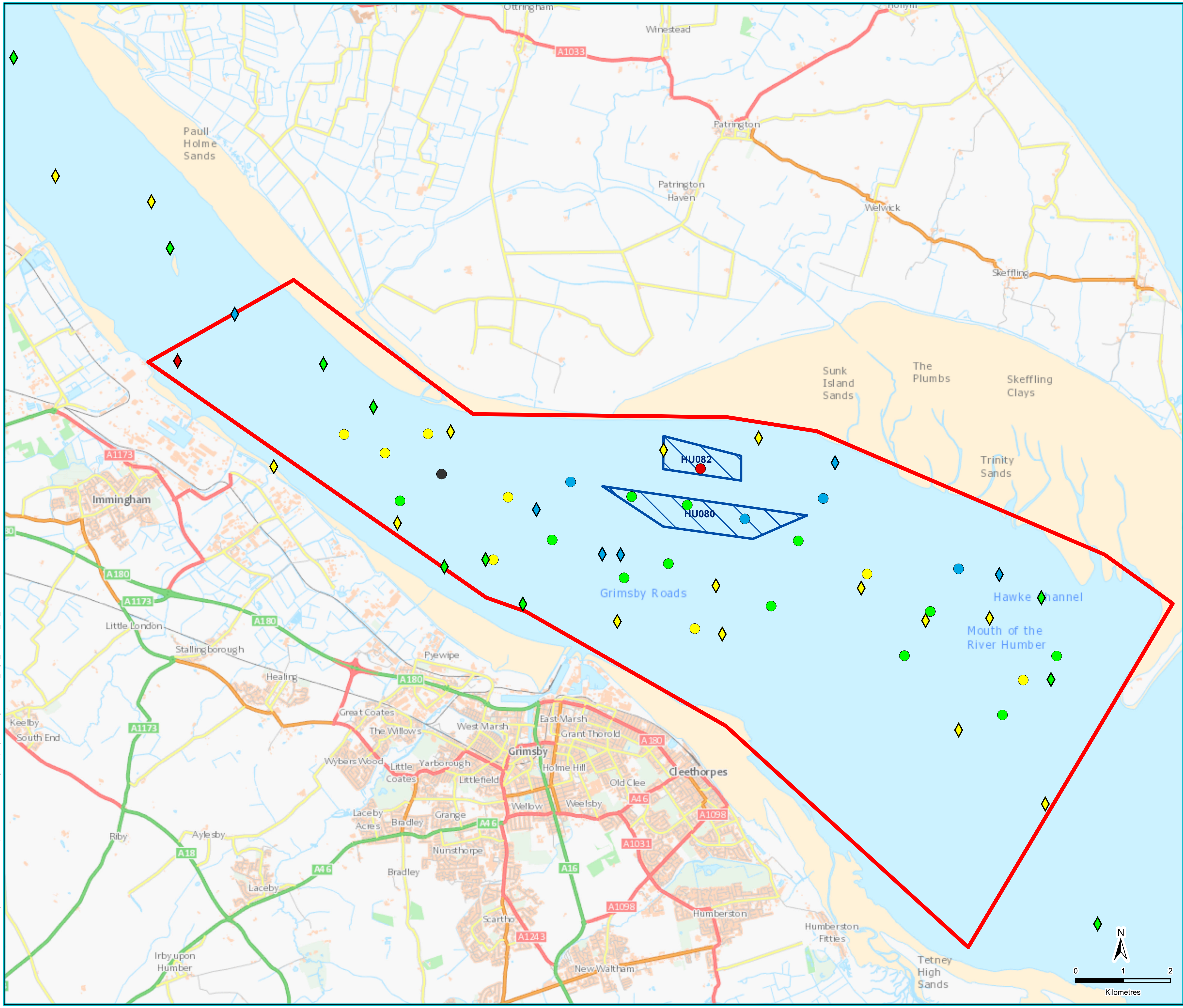
4.6.3 Gravel was recorded as the dominant sediment type at one station from the 2015 survey, located to the east of disposal site HU082 and classified as ‘Sublittoral mixed sediment in variable salinity (estuaries)’ (A5.42). One EA sampling station was also located to the east of HU082 and was also classified as gravel, indicating a continuation of this biotope. Gravel was recorded more in the 2020 dataset than in 2015, indicating a potential shift in sediment composition upstream from the disposal sites. However, this seems to be highly localised, as mud was recorded in the 2020 data at adjacent sites. Therefore, this may just be an artefact of the different sampling locations between the two years. The two 2020 sampling stations downstream of the disposal sites that were classified as gravel are not in the vicinity of any of the 2015 sampling stations,

4.6.4 The 2020 PSA data imply that little change in biotope composition has occurred between 2015 and 2020. Minimal changes in the physical environment (in terms of particle size) indicate that the macrofaunal communities are also likely to have remained largely the same.

4.7 WFD status

4.7.1 The Humber Lower water body is at moderate ecological potential overall. According to the EA Catchment Data Explorer, the water body is currently failing to meet its WFD objectives in respect of chemical status. The water body is at moderate potential in terms of invertebrates.

4.7.2 As disposal sites such as HU080 in the Humber Lower are used on a regular basis for very large quantities of dredged material it can be concluded that the benthic invertebrates in this area are accustomed to large amounts of sediment deposition. The site was in use during the water body classification period of 2006-2008 and disposal activities can therefore be considered to form part of the baseline (HR Wallingford, 2012).



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Historical Benthic IQI Score

- Good
- High
- Moderate
- Poor

Precision 2015 IQI Score

- Bad
- Good
- High
- Moderate
- Poor
- Disposal Site
- Study Area

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Figure Number: 5	
Figure Title: IQI Scores for 2008 and 2010 EA WFD Monitoring Stations and 2015 Precision Monitoring Stations	

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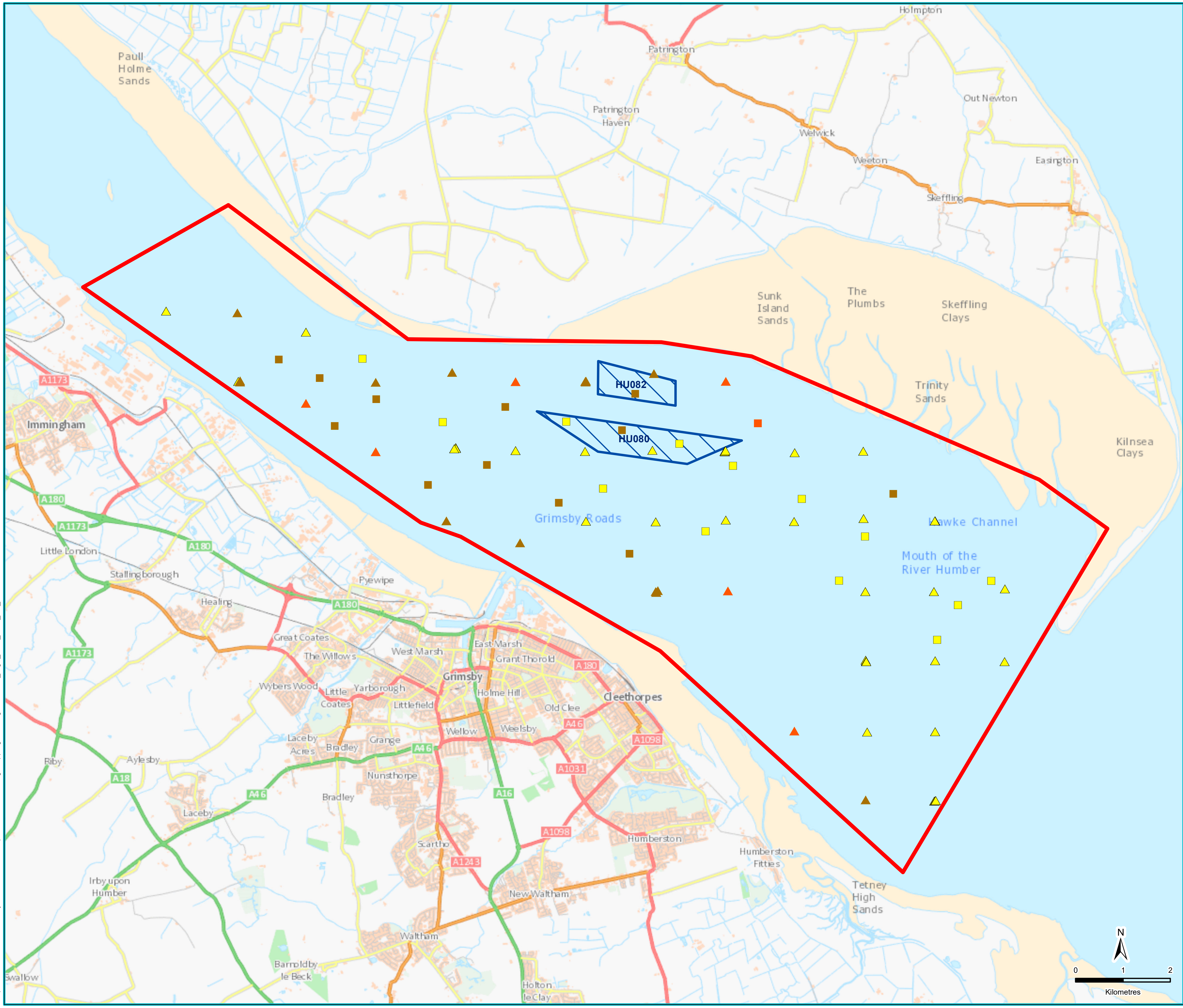

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Legend

Precision 2015
- Mud
- Sand
- Gravel

EA 2020
- Mud
- Sand
- Gravel
- Disposal Site
- Study Area

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Date	20/08/2021
Date	20/08/2021
Client	Able UK
Figure Number	6
Figure Title	EA 2020 and Precision 2015 PSA Data

5. Objectives of the monitoring

5.1.1 The BI scheme seeks to deliver the '*protection and enhancement of benthic invertebrate through monitoring and management of disposal activities'*. The monitoring programme therefore needs to identify changes in the benthic invertebrate communities which can be attributed to impacts arising from disposal activities. This requirement to identify '*deleterious change*' is specifically identified in MEMMP objective M6.

5.1.2 The AMEP ES identifies the following potential impacts on benthic invertebrates and habitats from dredge disposal the dredge disposal:

- Loss of subtidal habitat and benthic communities from dredge spoil disposal, for example through smothering;
- Disturbance of habitat and benthic communities from the sediment plume and/or dispersal of disposed material;
- Indirect changes to habitats from project-induced changes in hydrodynamic regime;
- Reduction of the overall Ecological Potential of the Humber Lower water body.

5.1.3 The target for limiting the extent of any deleterious change arising from these impacts is defined in objective M6 as there being '*No impact on WFD status (currently assessed as Moderate for Humber Lower)'.*

5.1.4 The Humber Lower is heavily used by a range of other users, including for dredging and disposal for other projects and routine maintenance. This use of the water body will be reflected in the baseline data. However, it is not possible to quantify the amount of dredging and disposal that will be carried out by other users concurrently with the AMEP project or subsequently. This monitoring scheme will identify potential changes in ecological potential in general compared to the baseline of usage of the Humber Lower, but results may be confounded if there are unusually large amounts of dredging and disposal in the area by other users compared to historical usage. Therefore, it may not be possible to attribute any deleterious change to the AMEP project specifically.

5.1.5 The BI scheme therefore aims to achieve objective M6 of the MEMMP of identifying potential deleterious change by selecting appropriate monitoring stations and specific, quantitative targets for the evaluation of the benthic invertebrate communities. The quantitative targets are described in Section 6.

6. Targets

6.1.1 The following quantitative targets have been defined to assess potential change in the benthic communities. The data from the 2015 survey (Precision, 2016) is to be used for comparison.

- Change in abundance and diversity across survey area to be within 20%;
- No significant alteration in biotope composition: no change in level 3 biotope composition;
- IQI Class to remain the same (or increase) for each station.

7. Monitoring stations: location and rationale

7.1.1 A total of 15 monitoring stations will be surveyed in the vicinity of the proposed dredging operations in the Lower Humber (Figure 7). The rationale for selecting the monitoring stations is described below. The monitoring stations reflect the sampling design of the 2015 survey to enable the identification of temporal change. Station codes have been maintained to facilitate ease of comparison between data from different years.

7.1.2 In order to meet the objectives of the monitoring programme to identify change with respect to subtidal habitats and biotopes (Section 5), the stations have been chosen to be representative of the study area, covering the range of biotopes, sediment types, and IQI scores present in the area. Monitoring stations have been chosen within and outside of predicted gravel dispersion areas, within the WFD assessment area for determining the ecological quality of benthic invertebrates.

7.1.3 Effects of disposal will be greatest in the areas subject to highest deposition rates i.e., within and in the immediate vicinity of the dredge disposal sites. The majority of the material (virtually all coarse material, such as sand and gravels) will be contained within a dynamic plume and settle on the bed of the estuary immediately around the disposal site, within a radius of approximately 100m (ERM, 2012). Therefore, no locations have been chosen within the boundaries of the dredge disposal sites, as agreed in consultation with the EA, as these are impacted areas that are likely to have depauperate fauna and are not considered to be representative of the rest of the Humber Lower water body in terms of WFD status. Additionally, as HU080 has previously received up to 8.9 million tonnes of material from dredge disposal per year, it is reasonable to assume that the material from the AMEP project is within the capacity of the site.

7.1.4 Monitoring stations have been chosen to focus on the effects of dispersion of erodible material from HU080, as the effects of disposal of non-erodible material at HU082 are expected to be minimal. Disposal of the non-erodible material at HU082 is unlikely to significantly affect benthic communities as the deposited material will be large lumps of stiff clay that will remain in situ, with gradual erosion occurring over a period of months to years (HR Wallingford, 2012). One of the aims of the HU082 site is to provide structure that aids in managing the maintenance dredging requirements within the adjacent SDC, therefore slow erosion is a feature of the material that is permitted for disposal here (HR Wallingford, 2012). Due to the strongly cohesive nature of the material, it is not expected to add significantly to background suspended sediment concentrations or disperse outside the disposal site in the form of a plume (ERM, 2012). There will, therefore, be a highly localised and temporary loss of benthic invertebrates where material is placed at the site, but no widespread or non-temporary effects.

7.1.5 A proportion of the finer deposited material will be entrained into a passive plume and will disperse away from the disposal site with the currents, which will add to background suspended sediment concentrations, may smother benthic species, and may cause a change in habitat by altering the sediment particle size distribution within the plume footprint as it settles out of the water column (ERM, 2012). In combination with the fact that the erodible material also contains a fraction of gravel which is coarser in nature than that found at HU080, which has not previously been used for gravel disposal, the disposal of erodible material at HU080 therefore has the main potential for transport and wider effects in the estuary. Monitoring stations have therefore been chosen to cover the extent of predicted gravel dispersal from HU080 (Figure 6) according to the two gravel dispersion models (JBA, 2012 and HR Wallingford, 2016),

7.1.6 The JBA and HR Wallingford numerical modelling studies of the dispersion of the gravel from disposal site HU080 (cited above) indicate that, subsequent to the disposal of the material within HU080, the gravels will disperse outside of the disposal site and the coarser gravelly material will slightly alter the sediment composition and thus habitats as it deposits.

7.1.7 However, due to the different hydrodynamic conditions used in the models, they predict significantly different dispersion areas. The JBA model was run over an 18-day spring-neap tidal cycle, using the fastest tide (water speeds of 2 m/s). the HR Wallingford model ran for a 30-day full spring-neap tidal cycle using two hydrodynamic conditions: a large spring flood tide and a large freshwater flow ebb tide (HR Wallingford, 2016),

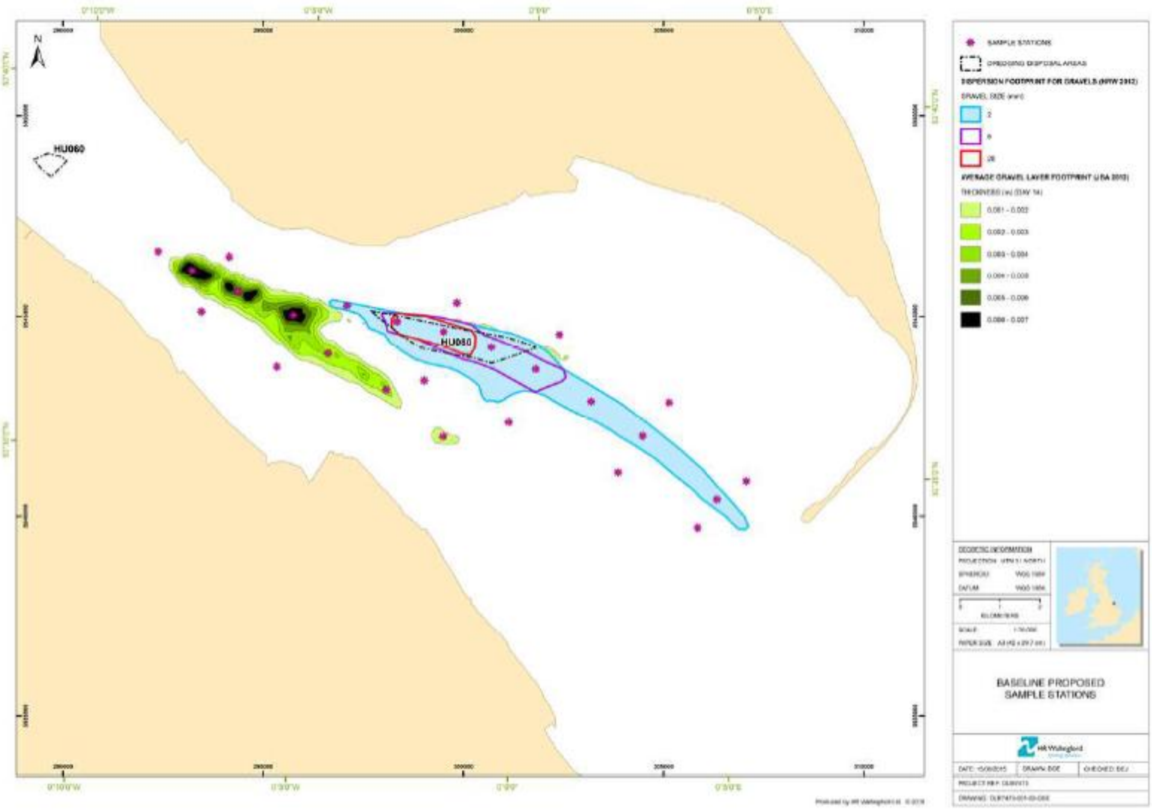


Figure 7*. Predicted gravel dispersal according to the JBA model (green) and the HR Wallingford model (blue). From HR Wallingford (2016).*

7.1.8 The JBA model predicted that gravel (2-20mm grain size) would disperse to approximately 1km south of the Immingham Oil Terminal, as well as slightly downstream of HU080, in a layer of up to 8mm thick. This layer is predicted to reduce to 4mm four days post-disposal and to negligible thickness within a month of the end of the disposal campaign (JBA, 2012). The HR Wallingford model predicts a gravel layer of between 1-5mm thickness, which would disperse towards the mouth of the estuary rather than upstream towards the Immingham Oil Terminal (HR Wallingford, 2016).

7.1.9 The area of coarse sediment to the southwest of the study area has been avoided for monitoring because no previous sampling has been done here, so this would not form a useful basis for comparison. Additionally, coarse material is likely to cause difficulty with collecting valid samples (paragraph 9.1.4).

7.1.10 The location of the monitoring stations is shown in Figure 7 and detailed in Table 3, along with the abundance, diversity, biotope and IQI data from the 2015 survey results, as reference for the targets,

7.1.11 Monitoring stations have been selected as controls for different biotopes and sediment types. Sites 3, 7, 9, 11 and 26 are located outside of the predicted gravel dispersion area according to both models, so will act as controls across the range of biotopes and sediment types in the study area.

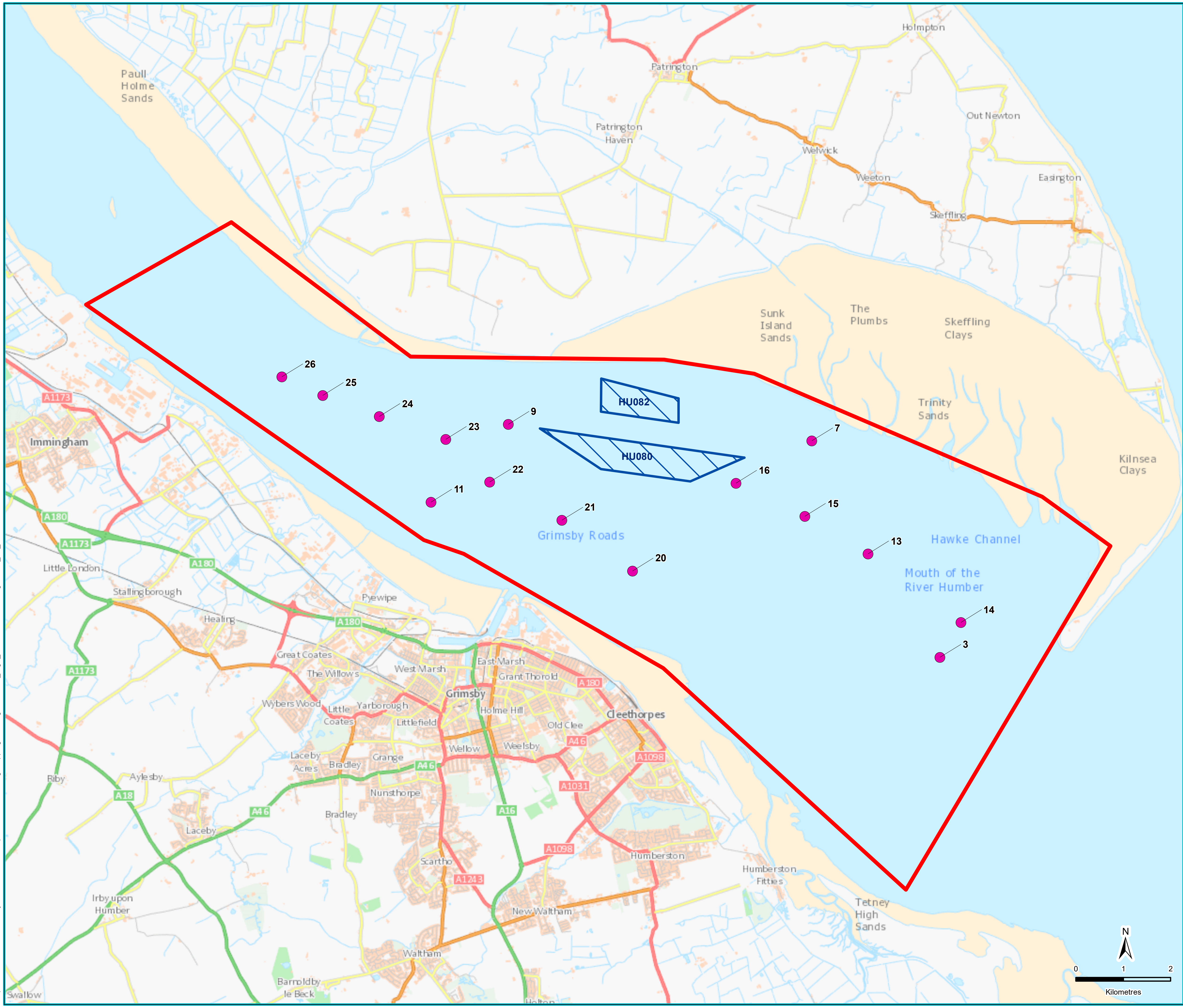
7.1.12 Site 7 is the only station from the 2015 survey that represents the 'Sublittoral mixed sediment' (A5.4)' biotope, being classified as 'Sublittoral mixed sediment in variable salinity' (A5.42). The sediments here were a more complex mixture of gravel, sand, and mud, than the other stations, where sands and muds were predominant. This site had the highest diversity of benthic invertebrate communities of any station across the study area across all data assessed and therefore is considered important for future monitoring.

7.1.13 Sites 13 to 16 are located within the predicted gravel dispersion area according to the HR Wallingford model, but outside of HU080 itself.

7.1.14 Sites 20 to 25 are located within the gravel dispersion area according to the JBA model.

Table 3 Monitoring stations.

Station	Latitude	Longitude	Abundance	Diversity	Biotope	IQI Class
3	53° 34' 13.0380" N	0° 04' 03.7440" E	5	7	A5.222	Good
7	53° 36' 44.3760" N	0° 00' 45.1860" E	38	256	A5.42	High
9	53° 37' 00.5040" N	0° 04' 04.4040" W	10	21	A5.323	High
11	53° 36' 08.7120" N	0° 05' 35.5440" W	11	3,017	A5.322	Moderate
13	53° 35' 25.0320" N	0° 02' 44.5140" E	4	32	A5.222	Good
14	53° 34' 36.3900" N	0° 04' 28.8300" E	3	3	A5.222	Moderate
15	53° 35' 51.9480" N	0° 01' 33.2220" E	4	4	A5.322	Moderate
16	53° 36' 15.9240" N	0° 00' 15.2220" E	5	46	A5.222	Good
20	53° 35' 17.9340" N	0° 01' 46.3020" W	17	501	A5.322	Moderate
21	53° 35' 53.9580" N	0° 03' 05.8320" W	17	100	A5.32	Good
22	53° 36' 21.2520" N	0° 04' 27.3240" W	15	29	A5.32	Good
23	53° 36' 51.2520" N	0° 05' 16.7100" W	6	23	A5.32	Moderate
24	53° 37' 08.1360" N	0° 06' 32.3400" W	1	2	A5.32	Bad
25	53° 37' 23.5860" N	0° 07' 36.6180" W	2	2	A5.32	Moderate
26	53° 37' 37.0320" N	0° 08' 22.9680" W	7	6	A5.32	Moderate



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Legend

- Proposed Monitoring Stations
- Study Area
- Disposal Site

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Figure Number: 8	
Figure Title: Location of Monitoring Stations	

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8. Timetable for monitoring

8.1.1 Although monitoring before marine disposal activities is specified in the MEMMP, it is considered that the above data provide a robust baseline. Therefore, additional monitoring immediately preceding the disposal activities is not necessary, as agreed with the EA provided an adequate baseline was in place.

8.1.2 Monitoring during dredge disposal activities is not proposed as necessary, contrary to the MEMMP. It is accepted that impacts will occur due to the disposal of dredged sediment, however these are likely to be short-term. Although monitoring during disposal may yield data on the extent of these short-term impacts, the data would not contribute significantly toward understanding any long-term impacts or effect on WFD status, and therefore should not be required.

8.1.3 One monitoring survey should be undertaken 2 years after cessation of the dredge disposal operation. Samples will be collected from the stations outlined in Section 7 according to the methodology outlined in Section 9.

8.1.4 This timescale will account for predicted recovery times from impacts, while limiting the amount of natural temporal change. Bellew & Drabble (2004) indicate that the recovery of mobile sand communities from aggregate dredging is generally rapid, ranging from a few months to two to four years for full recovery. According to Borja *et al.*, 2010 full recovery of macrobenthic invertebrates from dredging activities in soft subtidal habitats takes more than 1.5 years. In terms of the naturally high spatial variability and frequently low abundances that are prevalent in the study area, the assessment of the effects of gravel disposal by GoBe Consultants (2012) concluded that conditions after the disposal are likely to be indistinguishable from the baseline conditions after one year.

8.1.5 Monitoring results shall be reported within 10 weeks of completion of each survey. Within 10 weeks, all analysis will be completed, and a report produced (as per Section 9.3) and provided to Able UK and the EA.

9. Monitoring Methodology

9.1 Survey Methodology

9.1.1 This section describes the approach to be adopted for sample collection (Section 9.1), laboratory analysis (Section 9.2), statistical analysis (Section 9.3), and reporting (Section 9.4).

9.1.2 Four replicate samples will be collected at each site. One of these replicates will be used for subsequent Particle Size Analysis (PSA), as described in Section 9.3 below. One replicate will be processed for macrofaunal analysis, as described in Section 9.2 below. The remaining two replicates are to be preserved and stored in case additional macrofaunal analysis is required, until it is confirmed that this is not the case.

9.1.3 Survey methodologies will be in line with standard monitoring protocols, including:

- Guidelines for the Conduct of Benthic Studies at Marine Aggregate Extraction Sites (Ware and Kenny, 2011);

- The Marine Monitoring Handbook (Davies et al., 2001); and
- The Environment Agency's (EA) Operational Instructions for sampling and sample processing for macrobenthic invertebrates in TraC waters (EA, 2013) to ensure that methods and derived data are suitable for WFD assessment purposes.

9.2 Sample Collection

9.2.1 The surveys will be carried out from a suitable vessel equipped with A-frame and winch for deployment of the grab. A 0.1m^2 Day grab will be used, as this is the standard technique employed for benthic survey by the Environment Agency in the Humber. A Hamon grab will also be available as contingency if sediment is too coarse for the successful collection of samples using the Day grab. On-board sample processing and preservation will be conducted by suitably experienced and qualified staff.

9.2.2 At each pre-determined station position, the 0.1m^2 Day grab will lowered vertically to the seabed at an even rate, with care taken to ensure the survey vessel remains in position. Lowering speed will be reduced to a maximum of 0,2 m/s as the grab nears the sea floor, to further reduce the bow-wave and water turbulence. Once the grab makes contact with the sea floor (observed by slack on the wire), the grab will be recovered to the deck.

9.2.3 Each sampling attempt will be recorded with station code, time of sampling, DGPS position, and water depth recorded on the survey log.

9.2.4 Adequate material must be retained for analysis; therefore, each grab sample will next be assessed for validity. The depth of sediment within the grab will be measured, with a minimum of 7cm depth required for muddy samples and 5cm for coarser samples. The grab will also be checked for material caught in the jaws. If sediment depth in the grab is sufficient and there is no evidence of material caught in the jaws, then the sample will be deemed valid, and processing will proceed.

9.2.5 If the sample is not valid, 3 further attempts should be made, with each attempt being stored on deck until a valid sample is obtained. If no valid sample is obtained, then sampling should be attempted again using a Hamon grab to obtain an adequate and representative sample. If low sample volumes are repeatedly collected, then expert judgement should be used to pick the largest and most representative samples, with the remainder being discarded.

9.2.6 Once deemed valid, each sample will be photographed with a visible label detailing:

- The survey code;
- The station code;
- The date of collection;
- Whether the sample is for macrofaunal analysis or PSA;
- The replicate letter/number (for macrofaunal samples).

9.2.7 A visual description of the physical characteristics of the sediment will then be recorded, along with any other relevant features, on the survey log.

PSA samples

9.2.8 Grab samples intended for PSA will be sub-sampled; a sub-sample (minimum 500ml) will be taken as a depth integrated ‘core’ to ensure the sub-sample is representative. This will be done by inserting a scoop vertically into the sediment as far as the grab base and rotating to create a core-like plug.

9.2.9 The sub-sample will then be placed into a clean container pre-labelled with the details outlined in 9.1.5 above.

9.2.10 PSA samples will be kept cool until they are taken ashore and frozen within 24 hours of collection.

Macrofaunal samples

9.2.11 Each sample will be emptied from the Day grab into a large container and the grab rinsed into container to ensure all fauna is collected. The sample will then be washed gently through a 0.5mm sieve using sea water.

9.2.12 Conspicuous fauna and any large stones or shells will be transferred directly to the sample container to avoid damaging small, fragile specimens. A nested sieving technique (0.5mm and 1mm) will be employed if required to further reduce the potential for fragile invertebrates to be damaged.

9.2.13 Once sieving is completed, the material retained on the sieve mesh will be photographed with a visible label.

9.2.14 The retained material will then be carefully washed to the edge of the sieve and backwashed into the sample container. The sieving equipment will be checked for fauna trapped in the mesh, which will be carefully removed with forceps and added to the rest of the sample.

9.2.15 The sample container will be pre-labelled with the details outlined in 9.1.5 above. Additionally, the label should show ‘Part 1 of 1’ if the whole sample is in one container, or ‘Part 1 of 2’ and ‘Part 2 of 2’ as appropriate if it is necessary to split a sample between multiple containers. The containers will be labelled both inside and out to ensure sample integrity, with internal labels of waterproof paper.

9.2.16 The sample will be preserved by adding 10% borax buffered formalin solution. This should be done following appropriate health and safety protocols and precautions to ensure it is not possible for any spillages into the water.

9.2.17 The sieving equipment will be thoroughly cleaned between each sample to ensure material is not transferred between samples.

9.3 Laboratory Analysis

9.3.1 Samples will be logged immediately upon receipt at the laboratory, and the log compared to the survey log.

Macrofaunal analysis

9.3.2 Analysis will be undertaken by a laboratory that is a member of the National Marine Biological and Analytical Quality Control scheme (NMBAQC). Samples will be analysed in accordance with the NMBAQC Processing Requirement Protocol (Worsfold et al., 2010) and the guidelines set out in ISO:16665 by suitably qualified and experienced staff.

9.3.3 A sample tracking procedure will be followed throughout analysis to ensure sample integrity and traceability. This should include assigning each sample a unique laboratory reference code and the use of a log to record details of each stage of sample processing including the date of completion and the initials of the analyst. All parts of a sample will be labelled at each stage of processing with a minimum of the survey code, sample code, and laboratory reference code.

9.3.4 Samples will be stored in fixative for a minimum of 48 hours before processing. The formalin will then be decanted, in a ventilated area or under a fume extractor, over a fine mesh sieve into an appropriate container and subsequently appropriately disposed of.

9.3.5 The residue on the sieve will then be washed back into the rest of the sample. Samples will be washed through with water to remove any remaining formalin, and fractionated over a nest of sieves, down to 0.5mm, for ease of sorting.

9.3.6 The residue from each sieve will be washed into separate white trays. Water will be added to the trays and the contents agitated. Immediately after agitation, the light fraction will be decanted to another tray to separate lighter fauna from the sediment. This procedure may be repeated up to 3 times,

9.3.7 All fractions will then be decanted into separate labelled containers for examination under a stereoscopic microscope, where all macrofauna will be extracted. Fauna will be sorted into taxonomic groups and placed into separate labelled vials with 70-80% alcohol.

9.3.8 Extraction of fauna will be checked by a second analyst, with any found fauna added to the original vials.

9.3.9 All macrofauna will then be identified, using standard taxonomic literature, with taxonomic nomenclature compliant with the World Register of Marine Species (WoRMS). Identification will be to the lowest possible taxonomic level, usually species, for most taxa. Higher taxonomic levels will be used for taxa such as Nemertea and Nemaotda, in line with national standards.

9.3.10 The macrofaunal specimens will also be enumerated to give abundance of each taxon per sample. Colonial taxa will be recorded as present.

9.3.11 A minimum of 10% of identifications will be checked by a senior taxonomist. All fauna will be retained for 2 years.

Particle Size Analysis

9.3.12 Analysis will be undertaken by a laboratory that is a member of the NMBAQC scheme and will follow the NMBAQC guidelines for PSA supporting biological analysis (Mason, 2016). PSA will be undertaken using a combination of laser diffraction and dry sieving.

9.3.13 Prior to processing each of the sediment samples, any conspicuous fauna thought to be alive at the time of sampling will be removed and recorded, along with a visual assessment of the sediment type. Each sample will then be mixed thoroughly to homogenise.

9.3.14 Initially, a representative portion of the sample will be wet sieved over a 1mm mesh sieve, to give sediment of <1mm sediment of approximately 100ml for laser diffraction. Each sample will have three sub-samples run through laser diffraction analysis, with each sub-sample measured three times by the instrument, to give a total of 9 measurements for each sample.

9.3.15 The remainder of the sample will then be wet sieved over a 1mm mesh sieve. The >1mm sediment will be transferred to a labelled tray and oven dried at 100°C. Once dry, this portion of each sample will be dry sieved using a sieve shaker with a nest of sieves at 0.5phi intervals. The residue retained on each sieve will then be weighed to a minimum of 2 decimal places.

9.3.16 The <1mm fraction will be left to settle for 24 hours and the clear water above the sediment siphoned off. The sediment will then be transferred to a labelled tray and oven dried at 100°C. Once dry, this portion of each sample will be weighed to a minimum of 2 decimal places.

9.3.17 Samples will be retained in labelled containers until appropriate internal Quality Assurance procedures have been completed.

9.4 Statistical Analysis

9.4.1 The PSA data will be analysed using the Excel based software package GRADISTAT (Blott & Pye, 2001) to give standard sedimentological statistical parameters including mean/median grain size, skewness, kurtosis, sorting coefficient and bulk sediment classes. Each sample will be assigned a description based on the Folk and Wentworth classification systems (Folk and Ward, 1957, Wentworth, 1922). As a quality control measure, these classifications will be checked against the original sample descriptions.

9.4.2 Data will be interrogated using the statistical analysis package Primer (Clarke & Warwick, 1994; Clarke & Gorley, 2015) to provide comparative information on the macrofaunal communities in the survey area. Standard univariate biological parameters for benthic analysis will be calculated including:

- The number of taxa at each station (S)
- The total number of individuals (abundance) at each station (N)
- Margalef’s index of species richness (d)
- Shannon’s diversity index (H') – a measure of diversity incorporating both the number of species and the distribution or equitability of individuals between species. High values of H’ indicate a more diverse community whilst low values indicate low diversity.
- Pielou’s evenness (J’) – a measure of evenness or equitability which describes the distribution of individuals between species. High values of J (approaching 1) indicate that

abundances are evenly spread between species, whilst low values of J (approaching 0) indicate that the majority of animals are comprised of a few species, a situation which often occurs in low diversity areas subject to disturbance or organic enrichment.

9.4.3 Multivariate analysis of the abundance data will be carried out to describe the main patterns and assemblages within the area. Classification (cluster analysis) of the data will be undertaken using the Bray-Curtis similarity coefficient to give a similarity matrix, represented diagrammatically as a dendrogram.

9.4.4 This will be followed by a non-metric MDS (Multi-Dimensional Scaling) ordination. This technique uses the same Bray-Curtis similarity matrix to place sample points onto a 2-dimensional plane in a configuration where the inter-sample similarities are most closely represented. Two samples with a high similarity index will appear close together while those less similar will appear further apart.

9.4.5 IQI scores will be calculated for each sampling station using the macrofaunal and PSA data.

9.5 Reporting

9.5.1 The macrofauna data will be tabulated and provided as a matrix of abundance of each taxon per sample/station in and Excel spreadsheet. Any rare, protected, or otherwise noteworthy species will be highlighted on the matrix. The taxonomic nomenclature will be compliant with WoRMS.

9.5.2 PSA data from laser diffraction and dry sieving will be merged and presented as percentage weight in each half-phi category in each sample to give a continuous grain size distribution for each sample.

9.5.3 The macrofaunal and PSA data of each station will be used to determine the habitat type through biotope classification. The characteristic fauna and sediment type of each cluster group will be used to interrogate comparative tables produced by Connor et al. (2004) to assign biotopes to the cluster groups.

9.5.4 A report will be produced for each survey detailing the methodologies and results, with appropriate mapping, and raw results provided as appendices. The results from the survey completed 2 years after cessation of dredge disposal will be compared to the targets set out in Section 6. Reports will be completed within the timeframe set out in Section 8.

10. Conclusion

10.1.1 Implementation of this BI scheme will identify any potential deleterious change to subtidal benthic invertebrate fauna in the Humber Lower, in terms of WFD status, as the monitoring stations reflect the sampling design of the 2015 survey, allowing identification of temporal change. Change will be detected via the quantitative targets for abundance, diversity, biotope composition and IQI class.

10.1.2 The monitoring stations are representative of the range of biotopes, sediment types, and IQI scores present in the area, allowing potential different effects in different habitats to be identified. In addition to monitoring stations located within the predicted area of impact, monitoring stations are also included outside of the predicted area of impact, to give control stations for the different biotopes and sediment types.

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