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Dredged Material Disposal Site Monitoring Around the Coast of England: Results of Sampling (2013)

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Executive Summary

- This report presents the scientific findings and monitoring implications resulting from dredged material disposal site monitoring conducted under SLAB5 around the coast of England during 2013.
- The main aims of this report are to aid the dissemination of the monitoring results; to assess whether observed changes are in line with those expected; to compare the results with those of previous years (where possible); and to facilitate our improved understanding of the impacts of dredged material disposal at both a site-specific and a national (i.e. non site-specific) level.
- Targeted monitoring was conducted at six disposal sites during 2013, these were: North Tyne; Inner Tees; Outer Tees; South Falls; Site Y; and Site Z.
- Parameters monitored varied between sites (governed by site-specific issues) but included multibeam bathymetry and backscatter acoustic techniques, sediment particle size, sediment organic carbon, macrofaunal community assemblages and the assessment of a range of sediment contaminants including tri-butyl tin (TBT), polycyclic aromatic hydrocarbons (PAHs), organohalogens (e.g., pesticides, flame retardants) and trace metals.
- Variations (both spatially and temporally) in the concentrations of the various contaminant types were somewhat site-specific.
- Acoustic (multibeam and/or sidescan) data acquired allowed the successful determination regarding the fate of large increases in the quantities of deposited material at two disposal sites (South Falls and Site Y).
- The implications of these findings for each site are discussed with respect to the need for subsequent monitoring under SLAB5. However, these data do not represent the sole basis of such final decisions regarding monitoring; in addition, up-to-date intelligence regarding potential changes to the disposal regime and/or concerns raised from stakeholders are all embraced within the selection process for disposal site monitoring under this project.

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1. INTRODUCTION

1.1 Regulation of disposal activity in England

Until recently, the deposit of substances and articles in the sea, principally the disposal of dredged material, was controlled by a system of licences issued under Part II of FEPA. However, the responsibility for the licensing function in England and Wales on 1st April 2009 transferred from the Marine and Fisheries Agency to the Marine Management Organisation (MMO) for England and to the Welsh Government for Wales. The marine licensing provisions of the Marine and Coastal Access Act 2009 that came into force on 1st April 2010 have thus taken over from Part II of FEPA for the licensing function in England and Wales.

In licensing the disposal of dredged material at sea, numerous conditions associated with the relevant national and international agreements (e.g., the London Convention 1972 (LC72) and London Protocol of 1996 (LP96), the OSPAR Convention, the Environmental Impact Assessment Directive (97/11/EEC), the Habitats and Species Directive (92/43/EEC), the Wild Birds Directive (79/409/EEC), and the Water Framework Directive (WFD, 2000/60/EC)), must be considered to determine whether likely impacts arising from the dredging and disposal are acceptable (MEMG, 2003). Criteria considered under the various conventions and directives include the presence and levels of contaminants in the materials to be disposed of, along with perceived impacts on any sites of conservation value in the vicinity of disposal. Additional potential beneficial usage of the materials must be considered prior to a disposal consent being issued (MEMG, 2003).

One of the roles of Cefas is to provide scientific advice to the MMO on the suitability of the material for sea disposal at the application stage and, once a licence is granted, to provide technical advice on any monitoring undertaken as a result of licence conditions. Advice on the licensing of dredged material disposal at sea is provided by Cefas' Regulatory Assessment Team (RAT), work conducted under SLAB5 helps underpin the scientific rationale for such advice (see Section 1.3).

1.2 Disposal sites around England

There are approximately 155 open sites designated for dredgings disposal around the coast of England, not all of which are used in any one year. While the majority of these are located on the coast of the mainland, generally within a few miles of a major port or estuary entrance, a significant number are positioned within estuaries (e.g., Humber) or on intertidal mudflats as part of beneficial use schemes (Bolam et al., 2006).

In total, approximately 40 Mt (wet weight) are annually disposed of to coastal sites around England, although this can vary from 28 to 57 Mt (wet weight) (data for the period between 1986 and 2010). Individual quantities licensed may range from a few hundred to several million tonnes, and the nature may vary from soft silts to boulders or even crushed rock according to origin, although the majority consists of finer material (Bolam et al., 2006).

1.3 Overview of Cefas / MMO MoU contract SLAB5 'Monitoring of dredged material disposal sites'

In England, SLAB5 is one of several contracts funded by the MMO under a non-R&D MoU. The project provides field evaluations ('baseline' monitoring and 'trouble-shooting' surveys) at dredged material disposal sites round the coast of England. A major component of the project is, therefore, the commissioning of sea-going surveys at targeted disposal sites. Such field evaluations under SLAB5 are designed to ensure that:

- environmental conditions at newly designated sites are suitable for the commencement of disposal activities;
- predictions for established sites concerning limitations of effects continue to be met; and,
- disposal operations conform with licence conditions.

The outcomes of such surveys contribute directly to the licensing/enforcement process by ensuring that any evidence of unacceptable changes or practices is rapidly communicated and acted upon. As such, there are inherently strong links and ongoing discussions between the approaches and findings of this project with the work carried out by Cefas' RAT. One of the key roles of the latter is to advise the licensing authority (i.e., the MMO) of the appropriateness of current licences and the suitability of any new licence applications. The scientific outcomes of work undertaken within SLAB5 are circulated to the Cefas RAT *via* a number of routes including peer-reviewed publications (including both activity-specific and site-specific findings), internal documents, direct discussions and internal and external presentations. The production of this report, within which a summary of the annual findings is presented (Section 2), forms an important element of such scientific communication. It is not the purpose of this report to present a detailed appraisal of the processes giving rise to impacts at a particular site (this is more the role of, for example, peer-review outcomes) but to encapsulate the essence of the impacts associated with this activity in its entirety round the coast of England (see Section 1.5).

1.4 Sites monitored

To aid with determining which disposal sites should be selected for sampling in any one year, Cefas has derived a tier-based approach that classifies a number of possible issues or environmental concerns that may be associated with dredged material disposal into a risk-based framework (Bolam et al., 2009; Birchenough et al., 2010). The issues that pertain to a particular disposal site, and where these lie within the tiering system (i.e., their perceived environmental risk) depict where that site lies within the tiered system. This ultimately determines whether that site is considered for sampling during a particular year. It is intended that this approach should increase the transparency of the decision-making process regarding disposal site selection for SLAB5 monitoring, i.e., it establishes a model for site-specific decisions regarding sampling.

A tiered survey design and site assessment system, therefore, facilitates the prioritisation of dredge material disposal sites in terms of the need for, and the scale of, monitoring required at each site. In practice, this method will provide a scientifically valid rationale for the assessment of risks associated with relinquished, current and proposed disposal sites to the surrounding environment and amenities.

The disposal sites targeted for Cefas monitoring during 2013 are listed in Table 1.1. These sites were identified following consultation between Cefas case officers within the RAT and scientists in a number of key disciplines (e.g., benthic ecology, sediment contaminants). Additionally, these sites have been selected based on information from dredged material licence applications, consultation with the MMO and through concerns identified by stakeholders including conservation agencies and the general public.

Table 1.1. Dredged material disposal sites targeted for monitoring under SLAB5 during 2013.

	Geographical location off English coast	**Code**	**Prioritisation assessment: Tier**
North Tyne	Northeast	TY070	1
Inner Tees	Northeast	TY160	2
Outer Tees	Northeast	TY150	2
South Falls	Southeast	TH070	1
Site Y	Northwest	IS150	1
Site Z	Northwest	IS140	2

1.5 Aims and structure of this report

This report does not aim to present a critique of the processes leading to observed changes at dredged material disposal sites around the coast of England. Such appraisals are conducted *via* other reporting routes, either *via* discussions with Cefas case officers, presentations and subsequent publications at national and international conferences, and *via* papers in peer-reviewed journals (e.g. Bolam and Whomersley, 2005; Bolam et al., 2006; Birchenough et al., 2006; Bolam, 2014; Bolam et al., 2014a). The aims of this report are:

- To present the results of sampling undertaken during 2013 under SLAB5, thereby aiding the dissemination of the findings under this project;
- To indicate whether the results obtained are in line with those expected for each disposal site, or whether subsequent investigations should be conducted;
- Where possible, to assess the 2013 results in line with those of previous years to provide a temporal assessment (see Bolam et al., 2009; 2011; 2012; 2014b, for reports of previous years' monitoring);
- To facilitate our improved understanding of the impacts of dredged material disposal at both a site-specific level and a national level; and,
- To promote the development of scientific (or other) outputs under SLAB5.

Within previous SLAB5 reports, an appraisal of the findings of each data component (e.g., acoustics, sediment granulometry, macrofauna, contaminants) for each site was presented followed by a summary of the implications of such information for subsequent monitoring under SLAB5. Due to the inherent length of the former, the key outcomes of the report were perhaps not sufficiently prominent to the reader. Thus, in accordance with the format first established for Bolam et al. (2011), and that used within subsequent reports (Bolam et al., 2012; 2014b), the conclusions for each site are contained within Section 2 (below). The presentation of the more detailed scientific data is deferred to Appendix 2. For background information and impact hypotheses regarding each disposal site monitored during 2013, the reader is directed towards this appendix. Appendix 1 contains, as per the previous reports, information regarding the analytical and numerical methods used during the assessments of sediment contaminants (the reader may need to consult these whilst appraising Section 2).

2. CONCLUSIONS AND IMPLICATIONS FOR FURTHER MONITORING

The main findings of the monitoring data for each site are presented within this section (see Appendix 2 for more detail), together with their implications regarding the need for subsequent monitoring under SLAB5. However, it should be noted that these data do not represent the sole basis of such final decisions regarding monitoring; up-to-date intelligence regarding potential changes to the disposal regime and/or concerns raised from any stakeholder are all embraced within the selection process for disposal site monitoring under this project. Thus, the recommendations for monitoring presented here for each site, although representing a major component of the decision-making process, may or may not be altered by other site-specific factors.

2.1 North Tyne (TY070)

Monitoring at the North Tyne dredged material disposal site has been conducted under SLAB5 for a number of consecutive years. As such, a good understanding of the spatial variation in the biology, sediments and contaminants following disposal activity at this site has been acquired.

The faunal assemblages of the stations sampled within the disposal site are notably altered relative to those of the other stations (except one station immediately to the south of the site). However, such changes do not impart any reduction in a number of univariate metrics of community structure (numbers of species or total abundance) or biomass, while the diversity of the assemblages within the disposal site is enhanced from those outside of the licensed boundary.

The sediment monitoring data indicated that tri-butyl tin (TBT) concentrations remain low within and around this disposal site, while those of polycyclic aromatic hydrocarbons (PAHs) remain elevated and show a slight increase relative to previous years. All samples collected at North Tyne during 2013 exceeded the (effects range low) ERL for low molecular weight (LMW) PAHs (see Appendix 1.2), and those of three stations exceeded the effects range median (ERM) for the LMW PAHs and the ERL high molecular weight (HMW) PAHs. Regarding organohalogens (OHs), concentrations of chlorobiphenyls (CBs) at all stations were mostly below Cefas action level 1 (AL1). According to the OSPAR guidelines, most stations had 'good' environmental status for all ICES 7 CBs and 'good' status overall, although one station (within the disposal site boundary) had 'bad' environmental status for CB118 but 'good' status overall (see Appendix 1.3.6 for limit values). Enrichment relative to regional baseline concentrations (see Appendix 1.4) was observed for a number of trace metals, especially for Hg, Cd and Zn, although the highest enrichment was generally observed within the disposal site boundaries.

While intelligence regarding potential changes to the disposal regime must be utilised, monitoring data acquired during 2013 suggests that future monitoring at North Tyne should continue, focussing primarily on assessing concentrations of PAHs, OHs and trace metals.

2.2 Tees (Inner; TY150 and Outer; TY160)

Analogous to the situation for North Tyne, SLAB5 monitoring at the two Tees disposal sites has been conducted annually for a number of years and, as such, we have a good temporal dataset to draw upon when making contemporary assessments. Frequent monitoring here (and North Tyne) reflects the large amounts of material being disposed and the high contaminants concentrations of the material at source relative to those dredged for other parts of the English coast.

TBT levels remain low for the Tees disposal sites region (only detectable at two of the 17 sampling stations). Total PAH concentrations sampled at the Outer Tees site remains much lower than observed for the inner site, the latter showing highest concentrations within the limits of the disposal site boundary. Sediments from all Inner Tees sampling stations were found to exceed the ERL for LMW PAHs and the ERM for the LMW PAH was breached at all but one station. The ERL for the HMW PAH was breached at four of the 10 stations. Meanwhile, neither the ERL nor ERM for HMW PAHs were exceeded by the seven stations sampled for the Outer Tees.

Enrichment of trace metals concentrations relative to those of the regional baseline values was mainly observed for the Inner Tees site. The greatest enrichment for the Inner Tees was observed for As, Cd, Cr and Hg, although enrichment is far less for stations outside the limits of the disposal site boundary. The high trace metals concentrations naturally occurring for this region of the English coastline depicts that the regional baseline values are more appropriate than the OSPAR background assessment concentrations (BACs) for trace metals assessments of these disposal sites.

Subsequent monitoring should focus on assessments of contaminant concentrations at the Inner Tees site, unless disposal activity to the Outer Tees site increases.

2.3 South Falls (TH070)

The South Falls disposal site is a large disposal site off the north-eastern coast of Kent. This site has not been the focus of previous monitoring under the auspices of SLAB5 and thus little information regarding the biological or physical characteristics of its sediments was available. Monitoring at this site in 2013 was conducted specifically to ascertain the fate and biological impacts associated with a large deposition (6 Mt) of capital material from the London Gateway development project within the Thames.

The acoustic survey of the whole disposal site of South Falls revealed the site is composed of slightly gravelly sands, with large sand waves running across the area, interspersed with mega-ripples, which follow the predominant local sediment transport pathway. The backscatter data provided evidence of disposed material, appearing as regions of higher backscatter return, on the bed within the licensed boundary of the site. These materials were a mixture of silt/clay to the north and gravel to the south of the disposal site.

Although an appropriate assessment of biological impacts was hindered by an absence of baseline data, the spatial survey (of 14 stations for macrofaunal assemblage assessment) conducted under SLAB5 revealed that the taxonomic composition of the assemblages within the disposal site were within the variability of those of surrounding areas. Indeed, some of the highest biomass and diversity values observed were found within the disposal site boundary.

Subsequent monitoring of South Falls is advisable, especially as the current monitoring was conducted (November 2013) during the disposal campaign, with a predicted 2 Mt of material yet to be received.

Such monitoring should continue the acoustic approach taken in 2013, with biological monitoring being a secondary aim.

2.4 Site Y (IS150)

An acoustic survey of the whole of the Site Y disposal site was conducted during December 2013 aboard the RV *Prince Madog*. The aim of this survey was to acquire data to determine whether the disposal of unusually large quantities (for this site) of relatively non-dispersive, capital material from the Liverpool II development was conducted in accordance with a number of licence conditions. The data revealed the site to slope from 20.4 m deep to a maximum depth of 27.0 m (in the southwest), comprises beds of sand, and possesses large sand waves orientated in a north-south direction.

The non-dispersive material on the bed could be easily observed from the acoustic data, appearing as impact craters averaging 25 m in diameter and between 0.5 m and 1 m in depth. It was evident that these craters formed a grid pattern, indicating the material had been disposed evenly over the bed as per the licence condition, and were generally found in the southern part of the site where depths are greater (in accordance with a separate licence condition). Additionally, an average distance of 175 m between the disposal site boundary and the closest impacts crater to the boundary was observed, complying with a 100 m (minimum) distance under the licence condition. However, although the majority of the gas pipeline route is free of disposed material, there is evidence of a small number of deposits in the vicinity of the gas pipelines.

As disposal of further large quantities of material are planned for Site Y (generally more dispersive than that disposed during 2013), continued acoustic survey monitoring is advisable.

2.5 Site Z (IS140)

Site Z, situated slightly closer to the Mersey Estuary than the larger Site Y, has been the recipient of the majority of the maintenance dredged material that has been removed from Liverpool and neighbouring docks for many years – over 100 years in this general vicinity. This material is finer and more dispersive than the capital material disposed to Site Y in 2013, and is occasionally associated with slightly elevated with concentrations of certain contaminants.

A sediment survey was conducted at Site Z during 2013 to determine the contaminant concentrations of 14 stations within and surrounding the site, many of which had been previously assessed for contaminants under SLAB5. Concentrations of TBT and DBT for all stations were below the limit of detection, as has been the case during previous years. The highest total PAH concentrations were observed outside - to the south and west - of the disposal site boundary, and the concentration of the most southerly station, which had previously possessed the greatest concentration, showed a decrease from that in 2010. The ERL for LMW PAHs was breached at this most-southerly station and at one to the west of the disposal site, but the ERM for LMW PAHs was not exceeded at any station.

The highest concentrations of organohalogens were sampled at the same stations showing highest PAH levels (to the south and west of the site), values remain relatively low for those stations to the north and east of the site. Concentrations of CBs at all stations were below Cefas AL 1, and, according to the OSPAR guidelines, most stations had 'good' environmental status for all ICES 7 CBs and 'good' status overall. Five stations were classed as 'bad' environmental status for one CB but 'good' status overall, while the most southerly station had 'bad' environmental status for CB28 and CB118 and therefore 'bad' status overall.

Trace metals generally appear only slightly enriched according to the regional baseline values, with, unlike the spatial pattern observed for PAHs and OHs, more-or-less even levels of enrichment across the whole survey area.

Further monitoring of the contaminants concentrations at Site Z would be advisable, based on the results from 2013, if disposal in subsequent years continue in a similar manner (with respect to tonnages and physical and chemical characteristics) to that of recent.

3. Acknowledgements

A large number of Cefas staff has helped contribute to the work which has been conducted to produce this report. Such staff have been involved in all aspects of the work from an early stage, e.g., during discussions of the specific issues regarding dredged material disposal sites around the England coast (e.g. Cefas' RATs), through to the field sampling and the laboratory processing of the various components. In particular, staff within Cefas' Chemistry Function i.e., Pauline Learmonth, Joanna Uzyczak and Boby Thomas (organohalogens); Kerry Potter, Malgorzata Wilczynska and Phil Mellor (PAHs); and Lee Warford, Boby Thomas and David James (metals), and the Sedimentology Function, i.e. Briony Silburn and Caroline Limpenny, are gratefully thanked for processing the large numbers of samples that are required under SLAB5 and form the core of this report. Thanks go to the University of Bangor for their role in the acquisition and processing of the acoustic data for the Site Y disposal site. The structure and content of this report have been significantly improved following comments provided by Dr. Chris Vivian (and others) at various stages.

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APPENDICES

Appendix 1. Assessment methods for sediment contaminants

1.1 TBT

1.1.1 Methodology

The sediment samples were collected in hexane-rinsed glass jars and were frozen immediately after collection. The samples were collected for organics analyses, mainly organotins (TBT and DBT), organohalogens and hydrocarbons analyses. The whole (wet) sediment sample is homogenised then sub-sampled for the determination of the total solid content and for organotins analysis.

Sample extraction is initially carried out by alkaline saponification, the organotins compounds are then converted into their hydrides forms with the addition of sodium borohydride. The organotins hydrides are finally extracted back in hexane by liquid-liquid extraction. Analysis is undertaken using a Gas Chromatography-Flame Photometric Detector (GC-FPD) and quantification is done using external calibration. A certified reference material is run within each sample batch for quality control. Results are reported in mg kg^{-1} (ppm) dw.

1.1.2 Method used for assessment

In this report, since the method is similar to that used for the dredged materials analysis, direct comparison can be made and therefore we assess the organotins data against the actions levels used by the Regulatory Assessment Team (Table A1.1.1). In general, contaminant levels in dredged material below Action Level 1 are of no concern and are unlikely to influence the licensing decision. However, dredged material with contaminant levels above Action Level 2 is generally considered unsuitable for sea disposal. The latter situation most often applies only to a part of a proposed dredging area and so that area can be excluded from disposal at sea and disposed of by other routes e.g. landfill. Dredged material with contaminant levels between Action Levels 1 and 2 requires further consideration and testing before a decision can be made.

Table A1.1.1. Actions levels for organotins compounds.

ACTION LEVELS	Action Level 1 (mg/kg)	Action Level 2 (mg/kg)
Organotins; TBT/ DBT/ MBT	0.1	1

1.2 PAHs

1.2.1 Methodology

Sediment samples, collected in glass jars, were frozen immediately after collection and not defrosted until required for analysis. Each homogenised wet sediment sample was extracted using alkaline saponification followed by liquid/liquid extraction. A sample of sediment was taken for a total solids determination as all results are reported on a dry weight (dw) basis. The sample extract was then passed through an alumina chromatography column in order to remove polar compounds, concentrated to 1 ml and sealed in a vial. A suite of alkylated and parent PAH were then determined using coupled gas chromatography/mass spectrometry (GC/MS). Quantification was by means of deuterated internal standards added prior to digestion, with analytical quality control samples being run within each sample batch. Full details can be found in Kelly *et al*. (2000).

1.2.2 Method used for assessment

Cefas currently has action level limits for contaminants such as trace elements and PCBs but none currently exist for PAHs. Reviews of what has been investigated in other countries has indicated that the most promising of the currently available co-occurrence methods is the Effects Range Low/Effects Range Median (ERL/ERM) methodology which is founded on a large database of sediment toxicity and benthic community information (Long *et al*., 1998).

The ERL/ERM methodology derives SQGs representing, respectively, the 10th and 50th percentiles of the effects dataset and can be derived for individual PAH compounds. In a regulatory context, where SQGs are to be used as informal (non-regulatory) benchmarks to aid in the interpretation of sediment chemistry (Long *et al*., 1998), this becomes complicated where a large number for individual PAH are determined, as is usually the case. This has led to separate ERL/ERM derived SQGs being set for “Low molecular weight PAHs” and “High molecular weight PAHs”. In this context;

LMW PAHs include 2- and 3-ring PAH compounds;

- Naphthalene
- monomethyl naphthalenes
- acenaphthene
- acenaphthylene
- fluorine
- phenanthrene
- anthracene

HMW PAHs include the 4- and 5-ring PAH compounds;

- fluoranthene
- pyrene
- benz[*a*]anthracene

- chrysene
- benzo[*a*]pyrene
- dibenz[*a,h*]anthracene

Although a wider suite of PAH is determined routinely for both licensing and monitoring purposes, these can be considered as toxicity markers for the PAH as a whole. The ERL and ERM concentrations applied are given in Table A1.2.1.

Table A1.2.1. ERL and ERM concentrations for LMW and HMW PAHs in sediments. The limits for LMW PAH are lower than those for HMW PAH as they carry a higher acute toxicity.

PAH compounds	**ERL** (µg kg^{-1} dw)	**ERM** (µg kg^{-1} dw)
LMW PAH	552	3,160
HMW PAH	1,700	9,600

1.3 Organohalogens

Full details of the analytical methodology are given in Allchin *et al*. (1989) and de Boer *et al*. (2001).

1.3.1 Sample extraction

Sediment samples were air dried and sieved (<2mm) in a controlled environment. 10 g of dried sediment were mixed with sodium sulphate, transferred to a glass Soxhlet thimble and topped with 1 cm of sodium sulphate. ^{13}C-labelled BDE209 was added as internal standard to all samples prior to the extraction step. Samples were extracted over a 6 h period using 50:50 hexane:acetone, with an average of 9 - 10 cycles h^{-1}. Sulphur residues were removed at this stage with copper filings.

1.3.2 Sample extract clean-up

An aliquot of the Soxhlet extract was cleaned up and fractionated using alumina (5% deactivated) and silica (3% deactivated) columns, respectively. The silica column fractionation results in two fractions, the first fraction containing polychlorinated biphenyls (PCBs) and BDE209 and the second fraction containing polybrominated diphenylethers (PBDEs).

1.3.3 Analysis of PCBs by GC-ECD

After addition of internal standard CB53, PCB concentrations were determined with an Agilent 6890 GC with µECD. The separation of analytes was performed on a 50.0 m × 200 µm, 0.33-µm-film-thickness DB-5 capillary column (J&W). The carrier and ECD make-up gas were hydrogen (32.2 psi constant pressure, initial velocity 50 cm/s) and argon/methane (95:5), respectively. The initial oven temperature was 90°C, held for 2.00min, then increased to 165°C at 15°C/min, to 285°C at 2°C/min, and finally held for 23 min. The injector temperature and detector temperature was 270°C and 300°C, respectively. A 1-µl extract was injected in splitless mode with a purge time of 2 min.

1.3.4 Analysis of PBDEs by GC-MS

After addition of internal standard CB200, PBDE concentrations were determined with an Agilent 6890 GC with 5973 MS in negative chemical ionisation (NCI) mode. The separation of analytes was performed on a 50.0 m × 250 µm, 0.25-µm-film-thickness DB-5 capillary column (J&W). The carrier gas was helium (30 psi constant pressure, average velocity 40 cm/s) and the reagent gas was methane (40 psi). The initial oven temperature was 90°C, held for 2.00min, then increased to 200°C at 30°C/min, to 295°C at 2.5°C/min, and finally held for 31.33 min. The injector temperature and detector temperature was 270°C and 200°C, respectively. A 2-µl extract was injected in splitless mode with a purge time of 2 min.

1.3.5 Analysis of BDE209 by GC-MS

BDE209 concentrations were determined with an Agilent 6890 GC with 5973 MS in NCI mode. The separation of analytes was performed on a 15.0 m x 250 µm, 0.1-µm-film-thickness DB-1 capillary column (J&W). The carrier gas was helium (1.3ml/min constant flow, average velocity 59 cm/s) and the reagent gas was methane (40 psi). The initial oven temperature was 90°C, held for 1.00min, then increased to 200°C at 25°C/min, to 295°C at 10°C/min, and finally held for 20 min. The injector temperature and detector temperature was 250°C and 200°C, respectively. A 2-µl extract was injected in pulsed splitless mode with a 20psi pulse until 1 min and a purge time of 2 min.

1.3.6 Quantitation methods

The identification of PCBs was based on the retention time of individual standards in the calibration mixtures. Quantitation was performed using internal standards and 7 calibration levels (range 0.5 – 100 ng/ml). The PCB standard solutions contained the following 27 compounds in iso-octane (IUPAC designations): Hexachlorobenzene; *p,p′*-DDE; CB101; CB105; CB110; CB118; CB128; CB138; CB141; CB149; CB151; CB153; CB156; CB158; CB170; CB18; CB180; CB183; CB187; CB194; CB28; CB31; CB44; CB47; CB49; CB52; CB66.

Quantitation for PBDEs was performed using internal standards and 8 calibration levels (range 0.1 – 50 ng/ml). The PBDE standard solutions contained the following 11 compounds (IUPAC designations) in iso-octane: BDE17; BDE28; BDE47; BDE66; BDE100; BDE99; BDE85; BDE154; BDE153; BDE138; BDE183; together with the internal standard CB200.

Quantitation of BDE209 was performed using an internal standard and 7 calibration levels (range 0.5 – 500 ng/ml). The BDE209 standard solutions contained IUPAC BDE209 in iso-octane, together with the internal standard $^{13}C_{12}$- labelled IUPAC BDE209.

1.3.7 Quality assurance / quality control procedures

AQC procedures included reagents purification, method blanks, and use of control charts created from repeated analysis of the SETOC 770 Certified Reference Material (CRM).

PCB concentrations were determined in the sediments and reported on a dry weight (dw) basis. The ∑ICES 7 CBs (CB28, CB52, CB118, CB153, CB138, CB 170, CB183), and the sum of all 25 measured CBs (∑CBs) were calculated. Where individual congener concentrations were below the limit of detection (LOD) of 0.2 µg/kg, a value of half the LOD was inserted for calculation of summed concentrations.

The Total Organic Carbon (TOC) content in the <2 mm fraction determined at a number of representative sampling stations was used to additionally calculate the contaminant concentration normalised to 2.5% TOC content. The TOC data from the representative stations was used to estimate the TOC content at adjacent stations for which this value was lacking.

Concentrations of PCBs in the sediment were compared with various action limits, to investigate whether any adverse effects in benthic biota were likely to be expected as a consequence of their presence. The current Cefas ALs for dredge disposal are: AL1 if ∑ICES7 CBs > 10 µg/kg, ∑CBs > 20 µg/kg, and AL2 if ∑CBs > 200 µg/kg. Concentrations are expressed on a dw basis. OSPAR have set criteria for Background Assessment Concentrations (BAC) and Environmental Assessment Concentrations (EAC) for the ICES7 CBs in sediments (see Table A1.3.1). Concentrations are expressed in µg/kg dw normalised to 2.5% organic carbon. Concentrations below BACs would be considered to have high environmental status. Concentrations significantly below EACs could be considered to have good environmental status and those above, bad environmental status. The station is deemed to have 'bad' environmental status if 'bad' status occurs for more than one ICES7 CB congener.

Table A1.3.1. OSPAR assessment criteria for CBs in sediment from CP2.

Sediment (µg/kg dw, normalised to 2.5% TOC)

Compound	**BAC**	**EAC**
CB28	0.22	1.7
CB52	0.12	2.7
CB101	0.14	3.0
CB118	0.17	0.6
CB138	0.15	7.9
CB153	0.19	40
CB180	0.10	12

1.4 Trace Metals

1.4.1 Methodology

The sediment samples were collected in plastic bags and were frozen immediately after collection. The samples were collected for PSA and metal analyses on the <63µm fraction. Details on obtaining the <63µm sediment fraction can be found in the Particle Size Analysis technical report.

The sample is digested in a mixture of hydrofluoric, hydrochloric and nitric acids using enclosed vessel microwave, the digest is made up in 1% nitric acid and further diluted prior to analysis by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) and Inductively Coupled Plasma-Mass Spectroscopy (ICP-AES). Quantification of Al, As, Cd, Cr, Cu, Fe, Li, Mn, Ni, Pb, Rb and Zn is done using external calibration with Indium as internal standard. A certified reference material is run within each sample batch for quality control. Results are reported in mg kg^{-1} (ppm).

Some samples contained insufficient silt/clay (<63µm) for trace metals determination. Values lower than the detection limits were omitted from the dataset. This is because several detection limits were higher than real values, causing spurious elevations.

1.4.2 Numerical assessments

1.4.2.1 Raw data

Two approaches were carried out on the raw data:

1. Data comparison between the stations located inside the disposal sites and those that are situated outside the disposal site. The average concentration is obtained over a number of years and sites to allow data comparison. This data is averaged and so might not reflect the true observed trend for individual stations.
2. Temporal trend is also assessed for stations within the disposal sites and outside the disposal site. The average concentration is calculated for each year to carry out temporal trend analysis.

1.4.2.2 Enrichment factors

In order to assess relative level of trace metal contamination for a sampled station, enrichment to a baseline is required. This report presents two assessment methods; (i) comparisons with OSPAR Background Assessment Concentrations (BACs) as in previous reports, and (ii) comparisons with regional baseline concentrations.

Enrichment ratio is defined as: $\dfrac{\text{Metal raw value}}{}$

OSPAR BAC or proposed baseline value

Enrichment is arbitrary defined in 4 levels:

0-1: no enrichment

1-2: slight enrichment

2-5: moderate enrichment

>5: high enrichment

The two assessment methods are detailed below (but refer to Cefas (2011) for a fuller explanation).

1.4.2.2.1 OSPAR BACs

OSPAR (BACs) are defined for Clean Seas Environment Monitoring Programme (CSEMP) assessment to determine temporal trends in concentrations (OSPAR, 2008). They are derived from Background Concentrations (BCs) which are based on concentrations recorded in 'pristine' areas.

Normalisation of metal concentrations is required to account for differences caused by different sediment types present in the area surveyed. Normalisation of the metal concentrations to 5% aluminium using a pivot point is completed to derive the OSPAR BACs, using pivot point data defined in the assessment manual for contaminants in sediment and biota (OSPAR, 2008). Aluminium and lithium are both commonly used to normalise metal concentrations. Correlations between all trace metals, at each site, were completed to determine the best normaliser to use.

For most sites, there were no clear correlations between the trace metals and correlations values of aluminium and lithium indicate that the relationship between the normaliser and trace metals was not strong enough to endorse the use of Al or Li for normalisation.

As trace metal concentrations used for in this study were measured on the fine fraction of sediment (<63µm), normalisation to some extent has already been completed, therefore all enrichment calculation were based on the raw data.

1.4.2.2.2 Regional baselines

The above-mentioned Background Concentrations (BCs) are based on concentrations recorded in 'pristine' areas. There is only one set of values assigned by OSPAR for the whole North Atlantic (http://www.ospar.org). However, trace metal concentrations are known to show regional variation in the UK, largely related to the variable geology around the coast and historical industrial activity in the early 19th Century which has caused localised elevated levels (Ridgeway *et al*, 2003; Rowlatt and Lovell, 1994; Cefas, 2005). Therefore, for assessing enrichments at disposal sites, Cefas have developed regional baselines utilising various spatial datasets around England and Wales. Recently, an extensive study was carried out on 8 regions defined in the Clean Seas and Environment Programme (CSEMP) (Figure A1.4.1) and the proposed metals baselines concentration derived from this study have additionally been used in this report as a validation tool to i/ compare with OSPAR BACs values and ii/ to assess the credibility of using those proposed baselines values instead of the OSPAR BACs values when studying for metals enrichment. The proposed baselines for the areas are given in Table A1.4.1, along with the corresponding OSPAR BACs values for each metal (OSPAR, 2006).

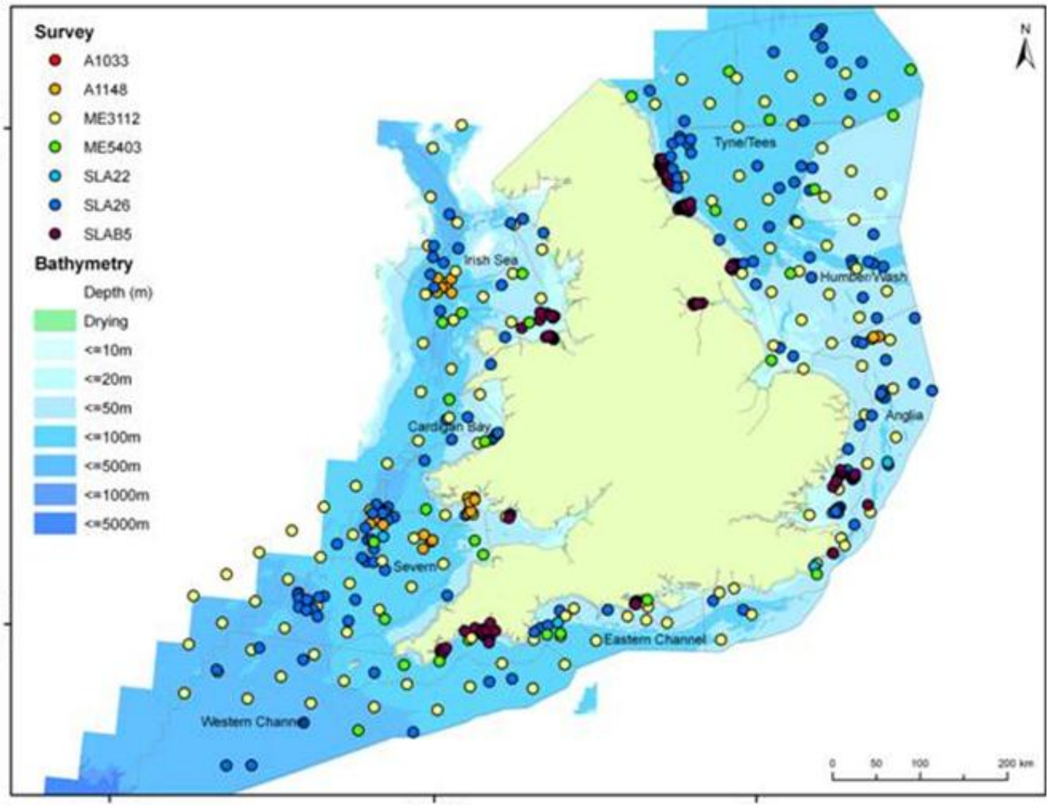


Figure A1.4.1. Location of stations sampled to provide metals data as part of the regional baseline approach.

Table A1.4.1. OSPAR BACs (in red) with proposed baselines for regions covered in disposal site assessment in 2010.

	As (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Cu (mg/kg)	Hg (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	Zn (mg/kg)
Anglia	33	0.2	115	40	0.16	56	46	130
Cardigan Bay	26	0.29	103	26	0.12	44	73	145
Eastern Channel	23	0.18	90	26	0.12	31	45	107
Humber Wash	30	0.17	109	31	0.21	44	67	129
Irish Sea	21	0.29	115	38	0.43	47	77	240
Severn	21	0.2	81	27	0.1	36	47	135
Tyne/Tees	27	0.31	135	29	0.35	55	131	171
West Channel	34	0.19	105	72	0.77	50	108	153
OSPAC BAC	25	0.31	81	27	0.07	36	38	122

Appendix 2. Results

2.1 North Tyne (TY070)

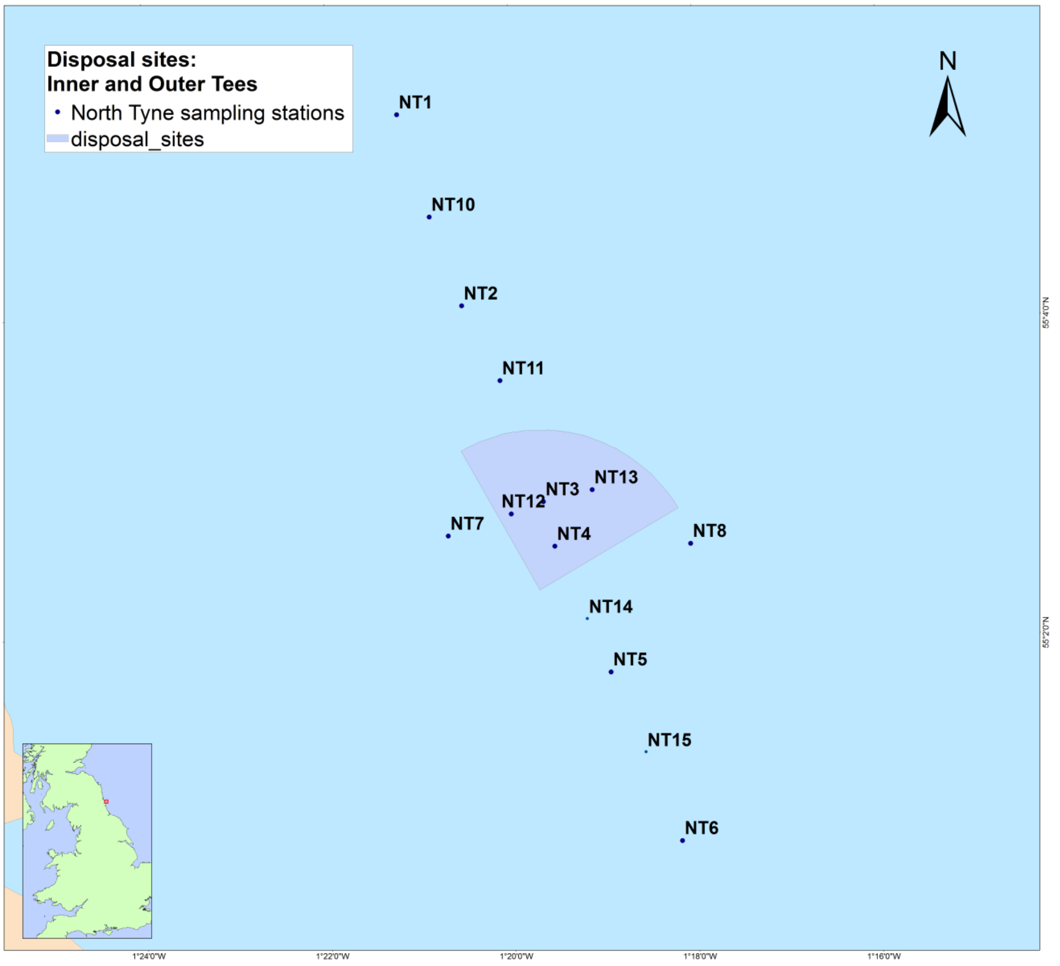


Figure A2.1.1. Locations of monitoring stations at North Tyne disposal site during 2013.

2.1.1 Background

Material disposed of to North Tyne is made up of predominantly silt and sand. In the past, the site received capital and maintenance dredgings, minestone mine-tailings and fly-ash from power stations. An application for the disposal of significant quantities of capital material (up to 1.3 million tonnes) from the Tyne navigational channel and deepening of berths was licensed with disposal activity undertaken during 2011. Some material under this application was excluded from sea disposal; some used for land reclamation while the portion accepted for sea disposal was used to top up the cap at

Souter Point (see Bolam et al., 2014b, for more information regarding Souter Point disposal site). The total licensed for sea disposal was approximately 1 Mt, apportioned to North Tyne and Souter Point.

The relatively contaminated nature of the dredged material potentially destined for the North Tyne site is a result of the region's industrial background. For example, the mining industry has resulted in elevated levels of heavy metals, and historical ship-building on the Tyne, together with large volumes of shipping traffic in and out of the wharves, have contributed to a legacy of TBT and hydrocarbon contamination.

RAT prioritisation assessment: Tier 1

- Where a significant increase in the quantity of material disposed of has occurred.
- Where there is the potential for the occurrence of elevated contaminant concentrations (between Cefas AL 1 and AL 2 in proposed dredged sediments) arising from historical or current activities at source (especially heavily urbanised/industrialised estuaries).

2.1.2 Parameters monitored

Sediment particle size distribution
Sediment organic carbon
Macrofaunal assemblages
Sediment contaminants (TBT, PAHs, organohalogens, trace metals).

2.1.3 Results

2.1.3.1 Sediment particle size

The sediments of North Tyne are predominantly muddy sands, with some unimodal sands and some gravels and muds (Table A2.1.1). Sediment groups derived in 2013 are similar to those in 2012 (Bolam et al., 2014b) and any differences reflect changes caused by the sampling of additional stations during 2013 (Table A2.1.2).

Table A2.1.1 Average sediment descriptions and statistics for each sediment group at North Tyne.

Sediment group	Number of samples	Sample Type	Sediment description
NoT1	6	Bimodal, Poorly Sorted	Slightly Gravelly Sandy Mud
NoT2a	15	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand
NoT2b	20	Bimodal, Poorly Sorted	Slightly Gravelly Muddy Sand
NoT3	11	Polymodal, Very Poorly Sorted	Muddy Sandy Gravel
NoT4	6	Polymodal, Very Poorly Sorted	Gravelly Muddy Sand
NoT5	6	Unimodal, Moderately Sorted	Slightly Gravelly Sand

Sediment group	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
NoT1	0.82	40.74	58.44	0.79	1.42	5.37	13.19	19.97
NoT2a	3.76	76.44	19.80	2.74	4.66	10.84	29.47	28.73
NoT2b	3.69	78.43	17.89	1.97	4.04	23.24	33.68	15.50
NoT3	39.86	49.38	10.76	11.63	6.75	9.48	13.07	8.45
NoT4	22.85	55.64	21.51	8.53	9.20	12.64	11.09	14.19
NoT5	1.40	92.80	5.80	1.13	4.03	45.00	36.67	5.97

The temporal changes in sediment groups for sampling stations since 2006 are minimal except within the disposal site at NT3, NT4 and NT13 and to a lesser extent at NT13, as well as north at NT2, and south of the site at NT5 (Table A2.1.2). The greater temporal variation in sediment granulometry at stations within the disposal site may perhaps reflect changes in the nature of sediments being disposed, or variations caused by the differences in the proximity of samples to recent disposal events, as indicated in previous years.

Table A2.1.2 Sediment groups for each station sampled between 2006 and 2013 inclusive at North Tyne.

	Year							
Sample code	2006	2007	2008	2009	2010	2011	2012	2013
NT1	NoT2a	NoT2a	NoT2a	NoT2a	NoT2a	NoT2a	NoT2a	NoT2a
NT2	NoT2a	n	n	NoT4	NoT2a	NoT2a	NoT4	NoT1
NT3	NoT2b	NoT5	NoT5	NoT2b	NoT5	NoT2b	NoT2b	NoT1
NT4	NoT1	NoT5	NoT5	NoT2b	NoT1	NoT2b	NoT2b	NoT2b
NT5	NoT3	NoT2a	NoT2a	NoT2a	NoT2b	NoT2b	NoT1	NoT2b
NT6	NoT3	NoT4	NoT3	n	NoT3	n	n	NoT3
NT7	NoT3	NoT3	n	n	NoT3	n	NoT3	n
NT8	NoT2b	NoT2b	NoT2b	NoT2b	NoT2b	NoT2b	NoT4	NoT2b
NT10	n	n	n	n	n	n	NoT3	NoT4
NT11	n	n	n	n	n	n	NoT4	NoT2a
NT12	n	n	n	n	n	n	NoT2b	NoT5
NT13	n	n	n	n	n	n	NoT2b	NoT1
NT15	n	n	n	n	n	n	n	NoT3

The spatial variation in the proportional representation of gravel, sand and silt/clay for each sampling station in 2013 is shown in Figure A2.1.2 and the percentages of silt/clay content in Figure A2.1.3. NT13 and NT3 have the highest silt/clay content (>60%) within the disposal site, while the highest silt/clay content outside the disposal site was at NT2 (60%), to the north of the site. NT2 is located on the tidal axis from the disposal site, so high contents at that station may indicate recent dispersal of fines (silt/clay) from the disposal site. This notion could be further supported by concomitant contaminant concentrations. Silt/clay contents at all the other sampling stations range between 7% at NT12 to 31% at NT4 (Figure A2.1.2). No sample was collected at NT7 (immediately west of site – station abandoned) in 2013; gravel was present in notable proportions in previous years, and it is likely that the gravelly nature of the bed prevented successful sampling in 2013.

Silt/clay content in a subset of dredge sediments for licensing applications to dispose of at North Tyne was 61% +/-10. All the monitoring samples collected in 2013 contained less silt/clay than this except within the disposal site at NT3 and NT13 within the disposal site, as well as NT2 north of the site. These data indicate that the majority of the finer material disposed of to North Tyne is dispersed, predominantly in a north-northwest direction.

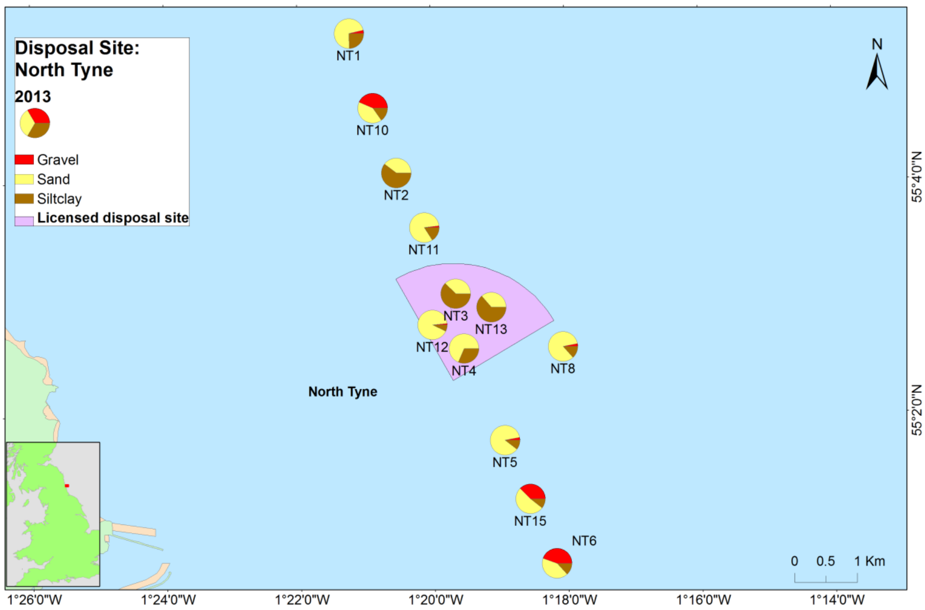


Figure A2.1.2 Pie charts of gravel, sand and silt/clay at North Tyne in 2013.

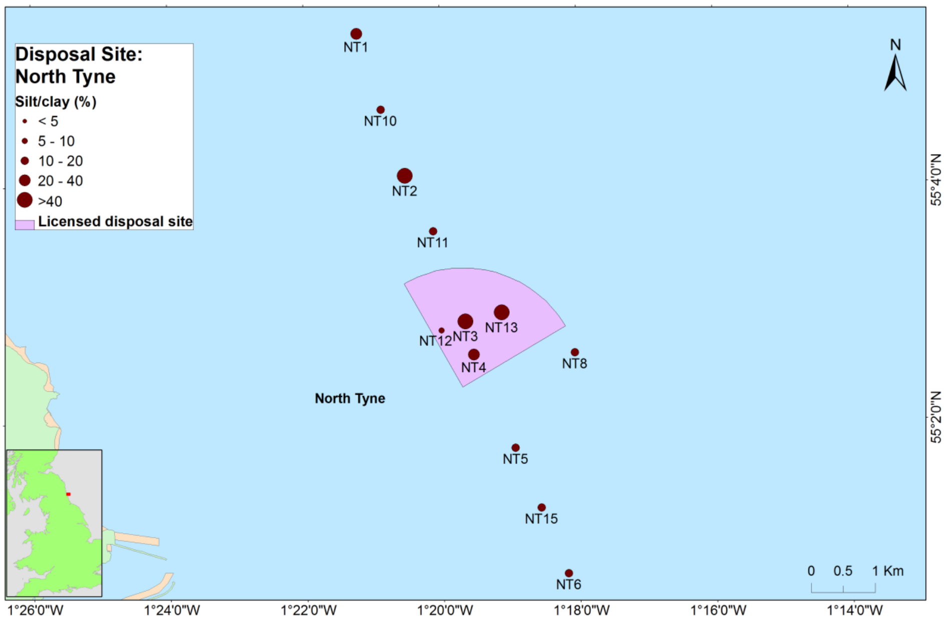


Figure A2.1.3 Silt/clay content (%) of sediments sampled at North Tyne in 2013.

2.1.3.2 Sediment organic carbon

Organic carbon values range from 0.9 to 6.2% in the <2 mm sediment fraction (Figure A2.1.4), and from 3.5 to 5.4% in the <63 µm fraction (Figure A2.1.5). These are similar to those observed between 2006 and 2012 for this site. Figure A2.1.5 indicates that the higher organic carbon contents in the <63 µm fraction were found at stations in the disposal site (i.e. at NT3, NT4, and NT12, NT13) as well as north of the site at NT2, and south of the site at NT5 (all >4.7 %).

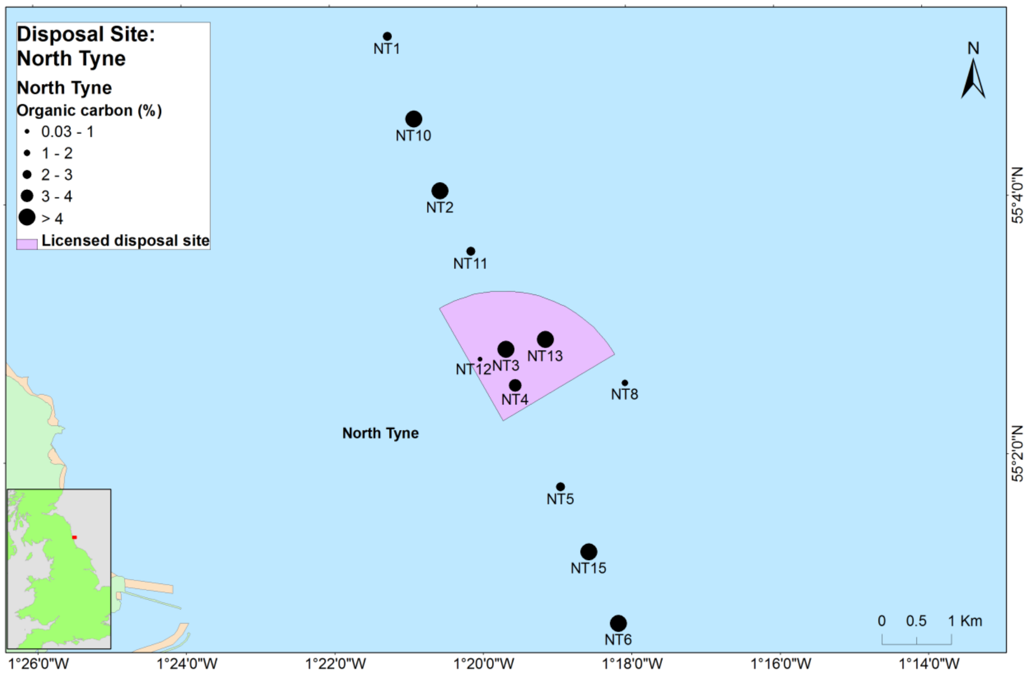


Figure A2.1.4. Organic carbon (%) in the <2 mm fraction at North Tyne in 2013.

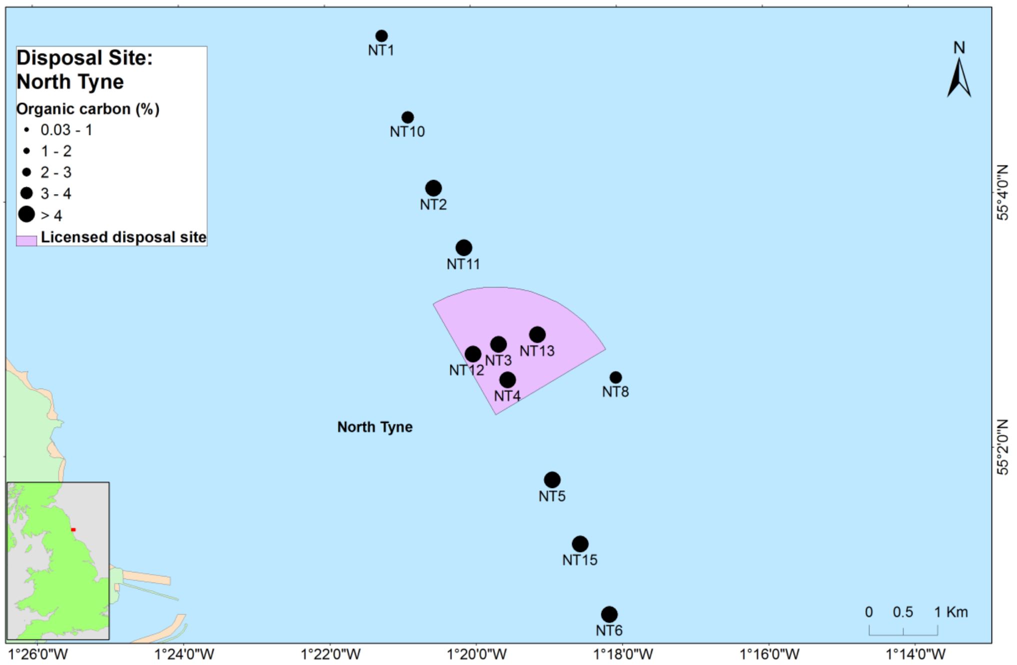


Figure A2.1.5. Organic carbon (%) in the <63 µm fraction at North Tyne in 2013.

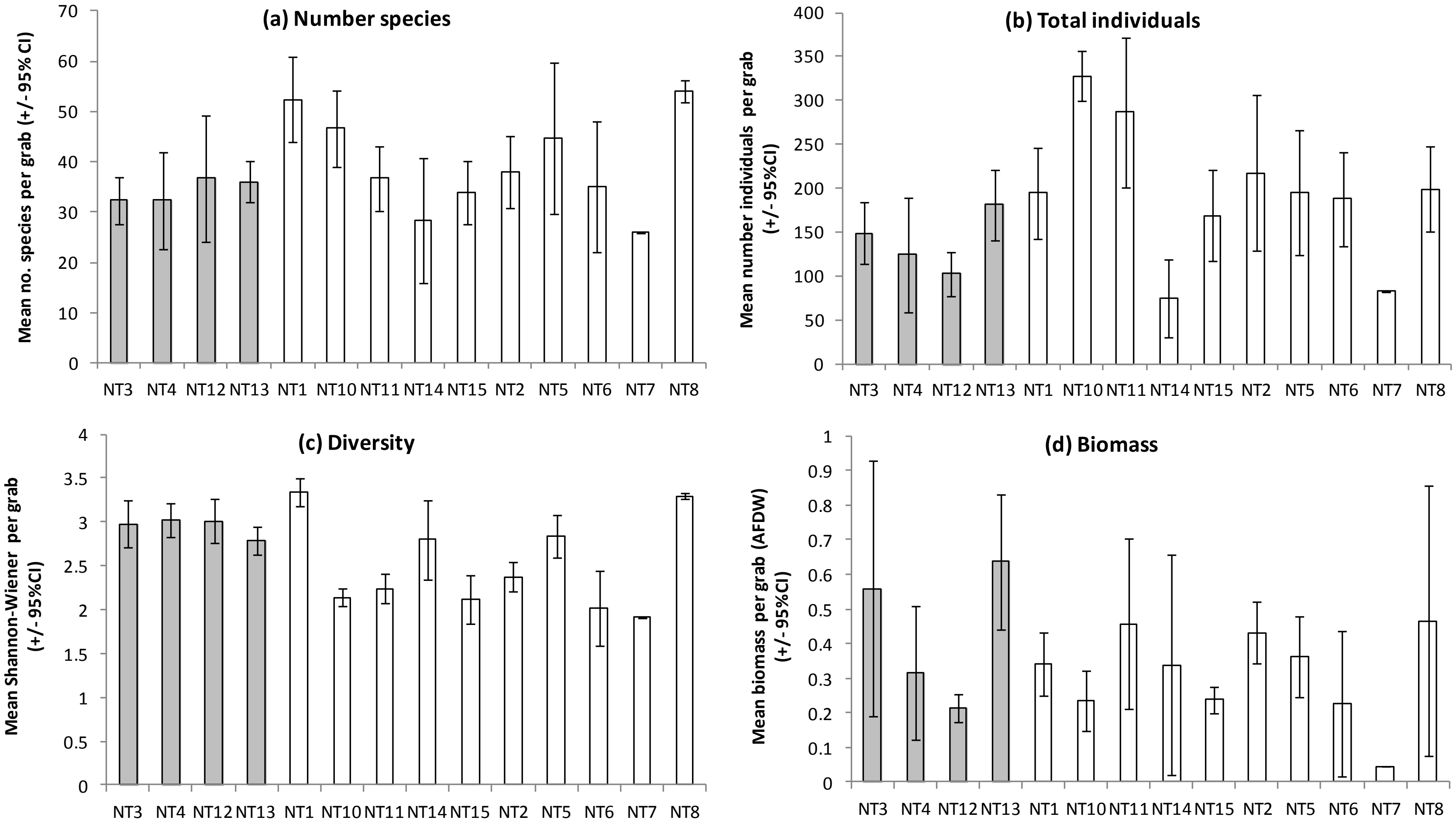
2.1.3.3 Macrofaunal assemblages

A total of 228 taxa (including colonials) were recorded from the 40 grab samples (triplicate grabs were taken at all stations stations except NT7 where only one grab was successfully deployed) taken at North Tyne, 2013. Of these, the worm *Lumbrineris cingulata* (sampled in all 40 grabs) was by far the most abundant across the stations, followed by *Amphiura filiformis* (35 grabs), *Kurtiella bidentata* (31 grabs) and *Peresiella clymenoides* (28 grabs).

The average values of the univariate metrics of community structure indicate that the assemblages of the four stations within the disposal site do not differ from those outside the disposal site. The mean values for number of species and total individuals per grab, diversity and wet biomass vary in accordance with those outside the site (Figure A2.1.6 (a-d)). There are some differences, such as the number of species at the most northerly station (NT1) is significantly higher than that of three of the stations inside the site, and its slightly more southerly neighbour (NT10) displays significantly higher total number of individuals. Notably, the diversity of the assemblages inside the disposal site is significantly higher than those at a number of stations located outside the disposal site boundary.

When the assemblages of the stations sampled are compared with respect to their numerical taxonomic composition (Figure A2.1.7) we see a slightly different picture. While the assemblages within the disposal site did not appear different from those outside based on derived univariate metrics (Figure

A2.1.6 (a-d)) we see that the assemblages inside the disposal site differ from those outside (they are all located to the left of the plot). This indicates that they have a different taxonomic composition, but these differences do not bring about different numbers of species, individuals, etc. One may postulate that the disposal activity has resulted in a decline (or absence) of a number of more physical-disturbance (sedimentation) sensitive taxa and other, less sensitive taxa having established within the site which are, otherwise, absent or at lower densities in areas away from the direct impacts of disposal. NT14, located outside but close to the southern boundary of the disposal site, has a community composition more comparable with those inside than those outside which indicates the assemblage here might be responding to disposal, either directly or due to subsequent erosion and deposition of material.



Figures A2.1.6(a-d). Univariate metrics (mean and 95% CI) of community structure for all stations sampled for macrofauna at North Tyne, 2013. Shaded stations represent those within disposal site boundary (for map, see Figure A2.1.1).

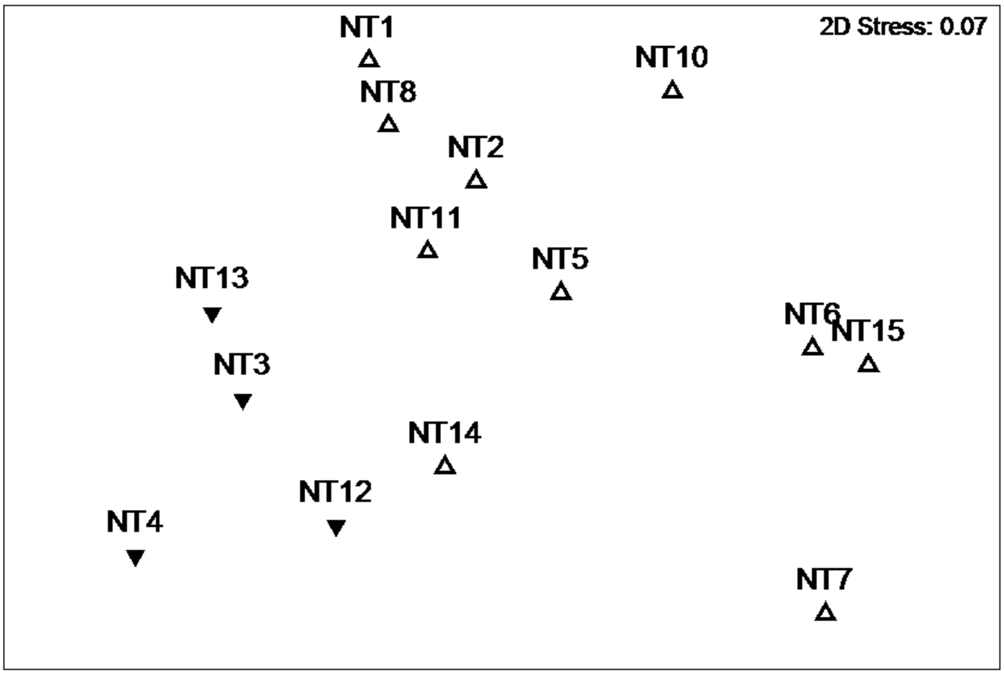


Figure A2.1.7. Non-metric multidimensional scaling ordination plot of macrofaunal community structure of the stations sampled at North Tyne, 2013. Stations presented in black are those within the licensed boundary of the disposal site. Based on a Bray-Curtis similarity matrix from square root-transformed abundance data (averaged across replicates).

2.1.3.4 Sediment contaminants

2.1.3.4.1 TBT

Concentration of TBT was above Cefas AL1 (but remained below Cefas AL2) at NT13 (0.49 mg/kg). Stations NT3 and NT4 exhibited detectable levels of TBT (0.08 and 0.06 mg/kg, respectively), albeit below Cefas AL1. The remaining stations recorded TBT levels well below Cefas AL1 or <LOD. This observation is similar to the previous years' findings.

2.1.3.4.2 PAHs

The highest summed PAH concentration in 2013 was 61,600 µg kg^{-1} dry weight found at NT13 within the disposal site (Figure A2.1.8). This is a similar concentration to the highest concentration found in 2012 (at NT7). NT7 was not sampled in 2013, but was just off the western edge of the disposal site and which had a summed PAH concentration of 64,100 µg kg^{-1} dry weight. The second highest concentration (52,000 µg kg^{-1} dry weight) found during the 2013 survey was at NT6, sampled for the first time in 2013, at the southern limit of the survey (Figure A2.1.8).

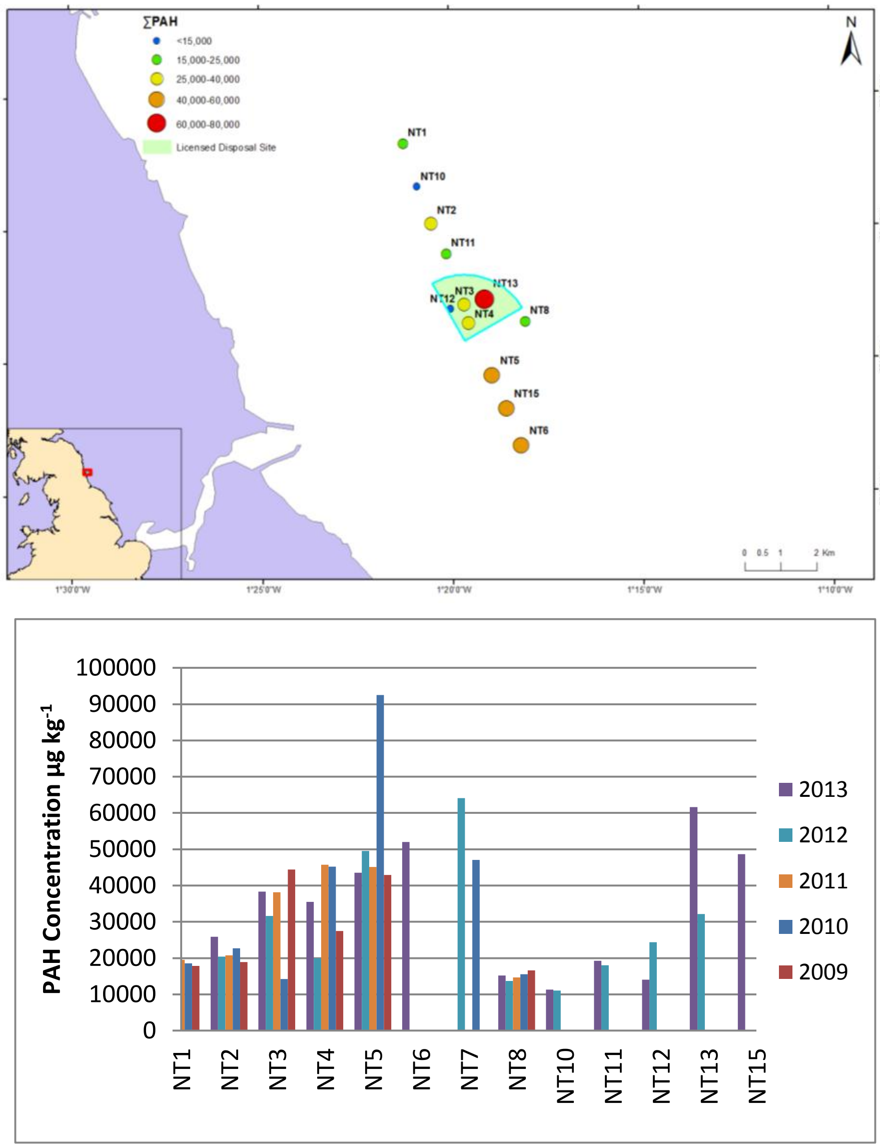


Figure A2.1.8. Summed PAH concentrations (µg kg^{-1} dry weight) for stations sampled at North Tyne, 2013 (top) and concentrations observed during 2009 to 2013 (bottom).

The lowest summed PAH concentration in 2013 was 11,300 µg kg^{-1} dry weight, at NT10, approximately 3 km north-northwest of the disposal site. This is comparable to the concentration sampled there during 2010 (11,000 µg kg^{-1} dry weight) (Figure A2.1.8). The generally lower total PAH concentrations observed north of the disposal site relative to those to the south is consistent with previous observations (Bolam et al., 2009; 2012).

Concentrations found at the other stations sampled in 2013 showed more elevated levels than observed in 2012 for NT2, NT3 and NT4, but these concentrations were within the ranges found over recent years for these stations. Stations NT10 - NT13 were sampled in 2013 for the second time and the data obtained allows us to improve our understanding of the spatial variability of PAH concentrations in this area.

All sediment samples collected at North Tyne during 2013 exceeded the ERL for low molecular weight (LMW) PAHs. Sediments from NT13, NT3 and NT2, exceeded the ERM for the LMW PAHs. Sediments from NT13, NT3 and NT2 exceeded the ERL for the high molecular weight (HMW) PAHs, but no stations exceeded the ERM for the HMW PAHs. Evaluation of the PAH data indicated that the source in all the sediment samples was predominantly petrogenic, generally with >90% of the PAH content arising from oil rather than combustion sources for NT6, NT15, NT12 and NT12, and, for the rest of the sampled stations, >74% of the PAH content arising from oil rather than combustion sources.

2.1.3.4.3 Organohalogens

At North Tyne, CBs were detected at all stations (∑ICES7 CBs range <0.7-11.0 µg/kg dw) (Figure A2.1.9). Concentrations of CBs were lowest at NT8 to the east of the disposal site, generally close to LODs, with low concentrations also at NT12 within the disposal site. The highest CB concentrations were found at NT11 just north of the disposal site (∑ICES7 CBs 11.0 µg/kg dw) and NT13 (∑ICES7 CBs 10.4 µg/kg dw), within the disposal site.

BDEs were detected at all stations (∑11 BDEs range 0.4-9.5 µg/kg dw) (Figure A2.1.10) and, like that for CBs, the lowest concentration was at NT12 within the disposal site, and NT8, to the east of the disposal site. The highest BDE concentrations of 9.5 and 6.8 µg/kg dw were found at NT13 and NT3, respectively, inside the disposal site (Figure A2.1.10). BDE47 and BDE99 are the dominant congeners present, indicative of the pentaBDE technical mixture, but BDE183 was also detected, suggesting that the octaBDE or decaBDE technical mixture was also in use. Penta and octa technical mixtures are no longer in use, having been banned in the EU since 2004.

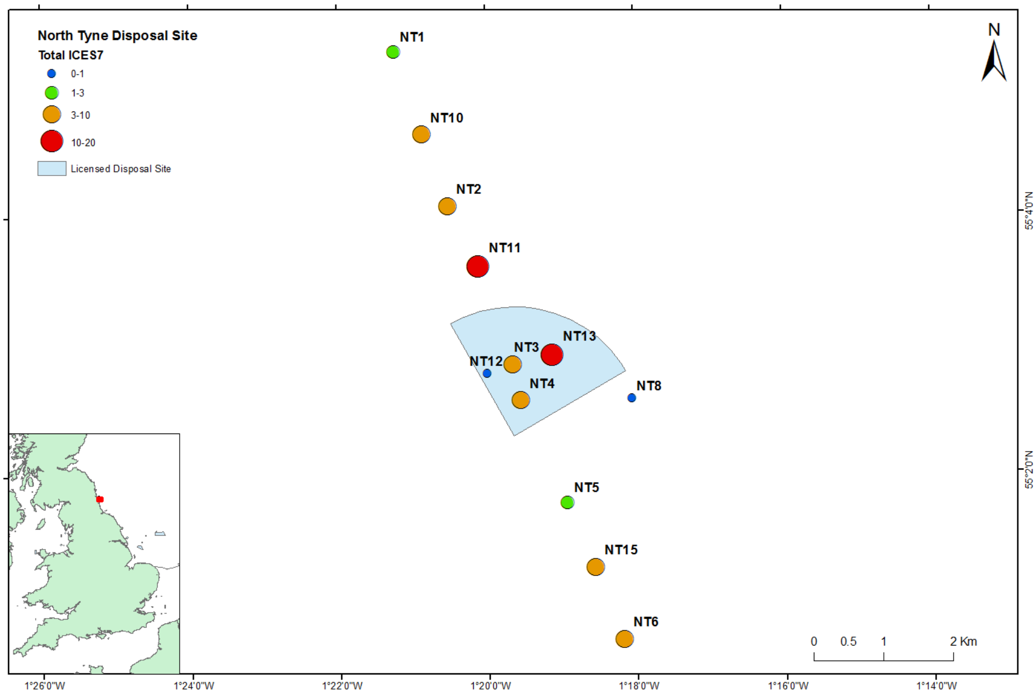


Figure A2.1.9. ∑ ICES7 CB concentrations at North Tyne, 2013.

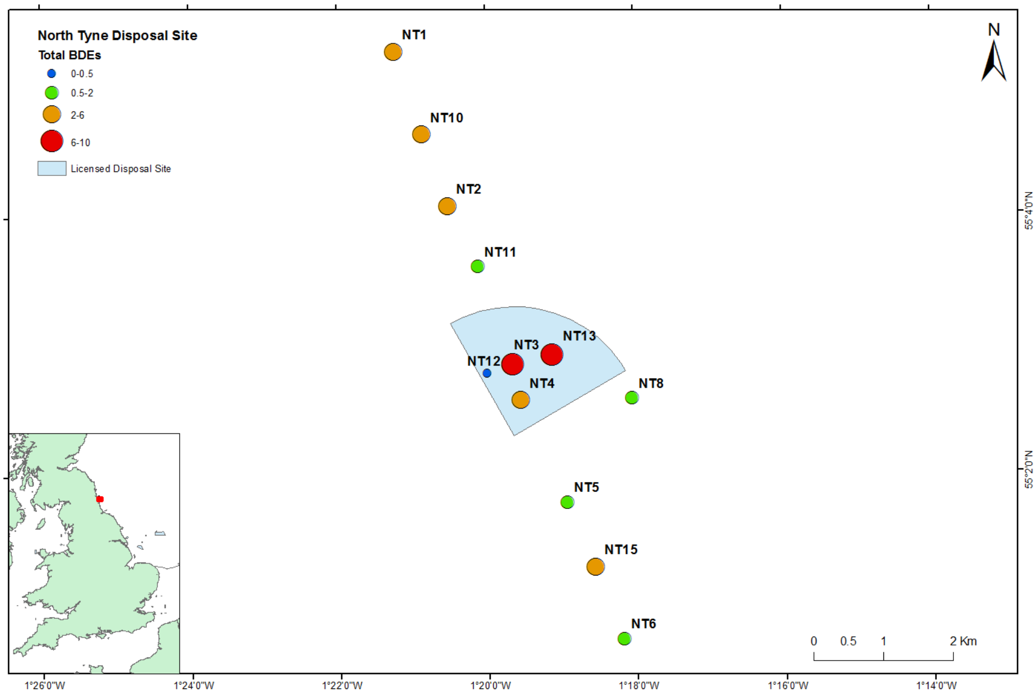


Figure A2.1.10. ∑ 11 BDEs concentrations at North Tyne, 2013.

BDE209 was detected at all stations (Figure A2.1.11) and was at higher concentrations than the other measured organohalogens (range 2.4-206 µg/kg dw). When included with the other BDEs, BDE209 made up >75% of the BDEs present (range 75-97%). BDE209 is indicative of the decaBDE technical mixture, which had been in use more recently than the other technical mixtures, although it's use has now been restricted in the EU since 2008. High concentrations of 206, 185 and 152 µg/kg dw were found at NT13, NT3 and NT4, respectively, which are all within the disposal site. The next highest concentration of 70 µg/kg dw was found to the north of the disposal site at NT2, with all other stations all <16 µg/kg dw.

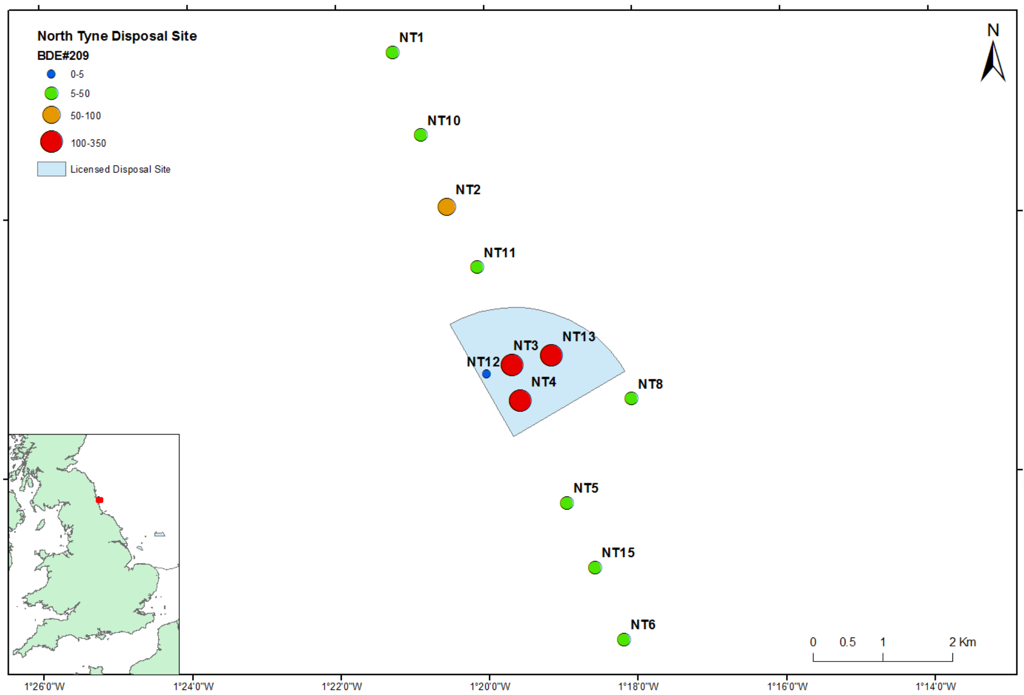


Figure A2.1.11. BDE209 concentrations for the North Tyne Stations, 2013.

Concentrations of CBs at all stations were mostly below Cefas AL 1. The exceptions were NT11 and NT13 which were just above Cefas AL 1 for CBs. No FEPA action levels exist for BDEs including BDE209. According to the OSPAR guidelines, a most stations had ‘good’ environmental status for all ICES 7 CBs and ‘good’ status overall. NT13 had ‘bad’ environmental status for CB118 but ‘good’ status overall. No stations had ‘bad’ status overall. No OSPAR guidelines exist for BDEs at present.

Tables A2.1.3 to A2.1.5 display the concentrations of organohalogens from 2006 to 2013 to allow an assessment of temporal changes for North Tyne. For CBs, the majority of stations show increases over time, although there are no clear trends overall. Levels of CBs at NT1, NT4, NT6 and NT8 are very similar to previous years. However, levels at NT10, NT2, NT11, NT13 and NT7 in 2013 are the highest they have been over this period. A similar, albeit slight, increase over time is seen for ∑11 BDEs. Like CBs, levels of ∑11 BDEs at NT1, NT4, NT6 and NT8 are very similar to previous years, and levels at NT10, NT2, NT3 NT13 and NT7 are the highest they have been over this period. Levels at NT11 and NT5 in 2013, however, were lower than in previous years. Similarly, BDE209 levels during 2013 at NT3, NT4, NT13 and NT6 were higher than previously recorded, while more-or-less stable at NT10, NT11 and NT8. Two of the stations within the disposal site in 2013, NT3 and NT13, displayed the highest concentrations ever recorded in 2013.

Table A2.1.3. Temporal trends (2006-2013) of ∑ICES 7 CBs concentration (in µg/kg dw) at North Tyne.

Station	**∑ICES 7 CBs concentration (in µg/kg dw)**							
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
NT1	1.54	0.97	2.11	0.93	0.98	1.13	1.37	1.34
NT10							2.63	6.62
NT2				1.69	1.63	2.66	2.67	4.72
NT11							2.89	11.0
NT12							17.0	*0.7*
NT3	1.48	2.03	1.79	4.12	1.63	11.9	3.39	7.8
NT4	7.21		*0.7*	4.58	11.0	5.84	2.63	4.63
NT13							1.61	10.4
NT8	5.21	2.03	0.81	*0.7*	1.12	1.10	1.13	*0.7*
NT5	2.7	7.59	6.05	3.24	11.9	2.72	3.88	1.37
NT15								5.47
NT6	2.44	2.54	3.88		2.09			3.36
NT7		1.55			1.76		2.24	

Note, concentrations in italic represent estimates of concentrations for samples where all ICES 7 congener concentrations were below LODs. Cell colours for 2013 reflect change in concentration compared to the previous observation for that station where green = decrease, and red = increase in concentration.

Table A2.1.4. Temporal trends (2006-2013) of ∑11 BDEs concentration (in µg/kg dw) at North Tyne in the stations sampled during 2013.

Station	**∑11 BDEs concentration (in µg/kg dw)**							
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
NT1	1.56	1.68	1.27	0.95	0.93	1.92	2.45	2.27
NT10							2.61	5.09
NT2	5.28			1.27	1.84	2.12	2.30	5.74
NT11							2.99	1.58
NT12							0.67	0.40
NT3	1.72	1.54	0.49	2.55	0.52	1.84	1.60	6.80
NT4	13.2		0.28	1.27	4.18	7.10	1.48	4.12
NT13							0.92	9.54
NT8	1.86	2.84	1.42	0.74	1.65	1.40	3.98	1.78
NT5	2.18	4.49	0.96	5.89	1.31	2.10	2.45	1.23
NT15								4.49
NT6	7.69	4.12	1.18		1.34			1.61
NT7		1.77			0.84		1.98	

Note, limits of detection for BDEs improved between 2007 and 2008 and therefore values assigned to congeners below LOD are lower from 2008 onwards, resulting in a step decrease in ∑11 BDEs concentration for samples with congeners below LODs. Cell colours for 2013 reflect change in concentration compared to the previous observation for that station where green = decrease, and red = increase in concentration.

Table A2.1.5. Temporal trends (2008-2013) of BDE209 concentration (in µg/kg dw) at North Tyne in the stations sampled during 2013.

Station	**BDE209 concentration (in µg/kg dw)**					
	2008	**2009**	**2010**	**2011**	**2012**	**2013**
NT1	104.2	11.46	3.93	7.33	5.56	12.8
NT10					16.5	15.7
NT2		12.23	12.2	42.9	11.9	69.5
NT11					12.5	12.5
NT12					7.7	2.43
NT3	2.72	48.54	7.91	21.6	35.4	185
NT4	0.78	36.11	95.5	108	38.1	152
NT13					45.3	206
NT8	8.03	8.95	20.1	7.21	4.91	14.4
NT5	6.21	11.94	6.64	10.6	273	6.28
NT15						12.6
NT6	6.15		8.69			12.8
NT7			17.5		8.46	

Cell colours for 2013 reflect change in concentration compared to the previous observation for that station where green = decrease, and red = increase in concentration.

2.1.3.4.4 Trace metals

During the 2013 survey, samples for trace metals concentration assessment were collected at 12 stations with NT3, NT4, NT12 and NT13 being located within the disposal site (Figure A2.1.1). Levels of enrichment for North Tyne stations using OSPAR BAC and regional baseline values are presented in Figure A2.1.12. Assessment of the metal enrichments shows that a slight enrichment for As is observed along the north-south transect, including all four stations located within the disposal site. No enrichment is recorded elsewhere. Both methods, the OSPAR BAC and baseline values, show similar observations. No clear temporal trend was observed from 2006 to 2013 for As for either stations within or outside the disposal site (Figure A2.1.13).

Cr and Ni are slightly enriched with the OSPAR assessment at all stations but, since the baseline values for this region are higher than the OSPAR BAC values (refer to Table A1.4.1), all sampling stations show no enrichment is observed when using the baseline approach. No clear temporal trend was observed from 2006 - 2013 for Cr and Ni, by either stations within or outside the disposal site.

Both assessment methods depict the same observations for Cd, showing moderate to high enrichment at NT4, NT3 and NT13. Stations located north of the disposal sites were not enriched, whereas those located south of the disposal site, are slightly enriched.

Cu is moderately enriched at NT3, NT4 and NT13, all within the disposal site, and slightly enriched elsewhere, using both assessment approaches. There has been a slight increase in Cu enrichment levels when compared to the 2011 survey data, however, no temporal trend is observed over the 2006 to 2013 period (Figure A2.1.13).

Hg is moderately to highly enriched according to OSPAR BACs, and, to a lesser extent, enriched mainly for stations within and south of disposal site when assessed against the baseline values. This is comparable to the findings from 2011 survey.

Enrichment is found to be high mainly within the disposal site and moderate elsewhere for Pb with the OSPAR approach (Figure A2.1.12). When assessing against the regional baseline values, the approach only depicts moderate enrichment for two stations (NT3 and NT13; located within the disposal site), enrichment was either slight or not present elsewhere. This is consistent with the findings from 2011 survey.

Moderate enrichment is observed for Zn at stations within the disposal site for both assessment approaches. Elsewhere Zn is slightly enriched with the OSPAR BAC assessment, with a less pronounced enrichment when using the regional baseline approach.

In conclusion, the metals concentrations observed in 2013 tend to be much higher than the OSPAR BAC values especially for Hg, Pb and Zn. This is generally due to the legacy from the historical and current industrial activities of the area. When assessing these concentrations against the proposed regional baseline values, which were derived taking into account regional variability, enrichment is still observed, but to a lesser degree. Similar findings were observed in 2011 survey at the North Tyne disposal site.

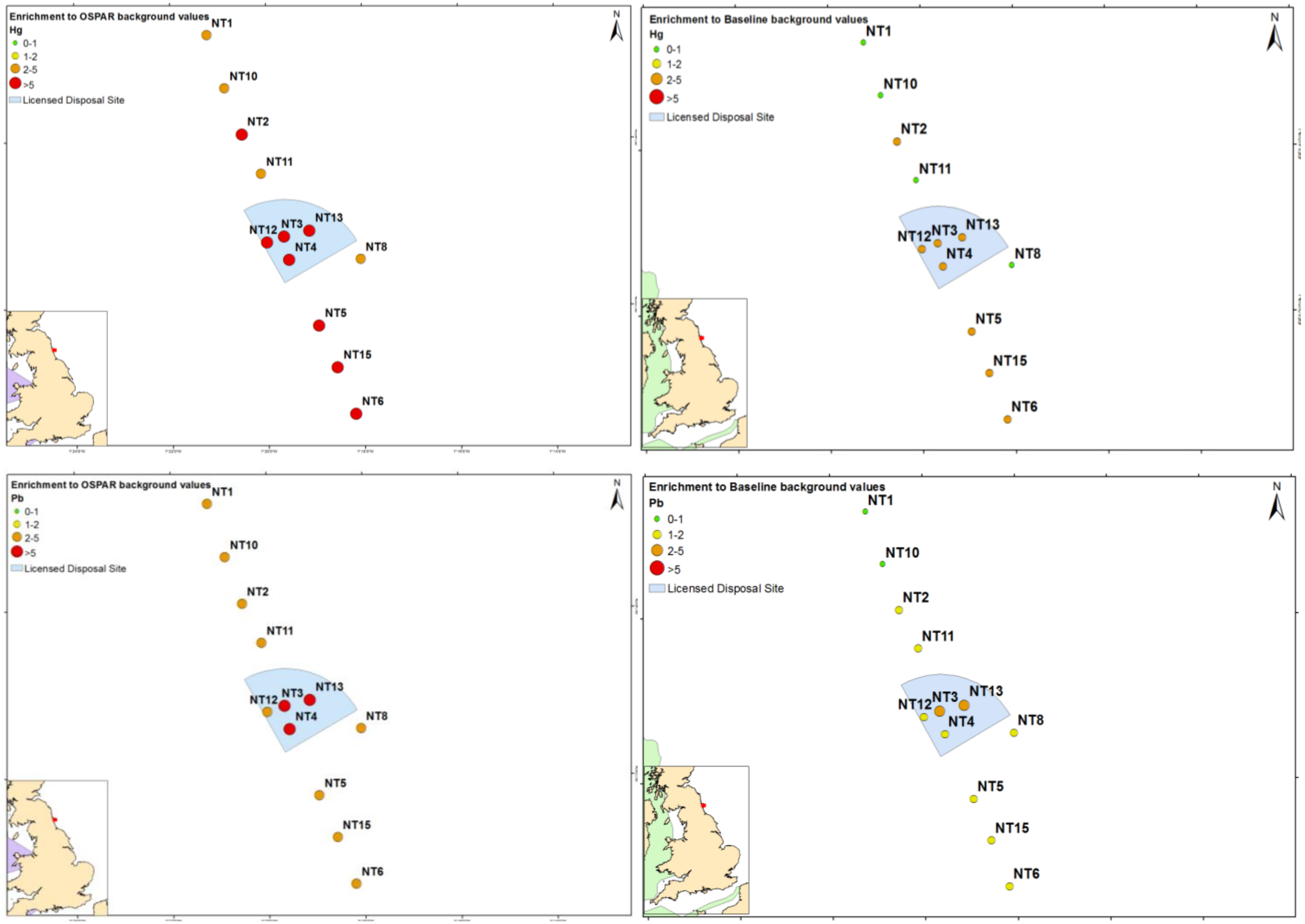


Figure A2.1.12. Enrichment to OSPAR BACs (left) and regional baseline values (right) at North Tyne, 2013, for As, Cr, Cu, Hg, Pb, Cd and Zn.

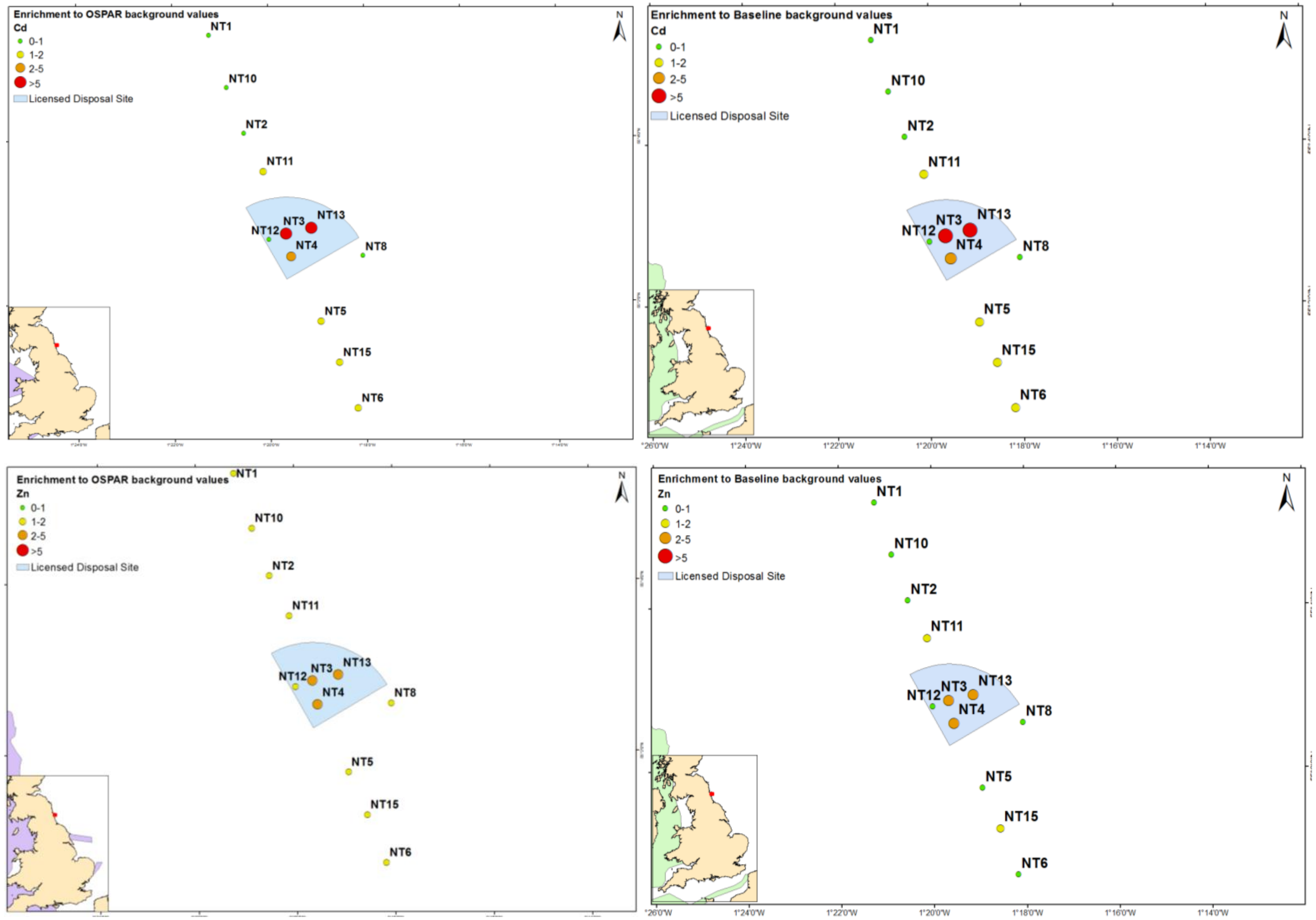
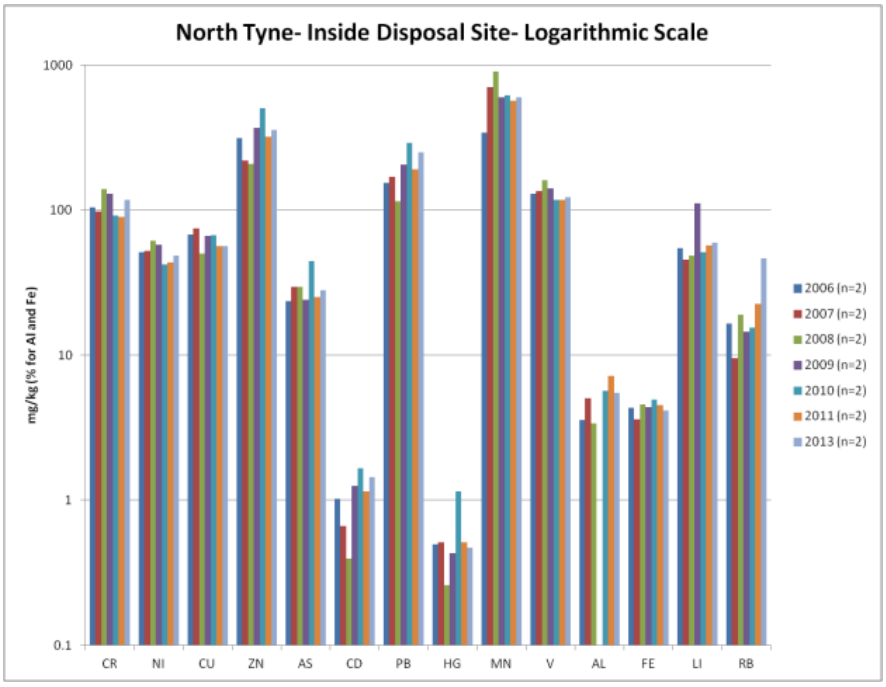


Figure A2.1.12. Continued.



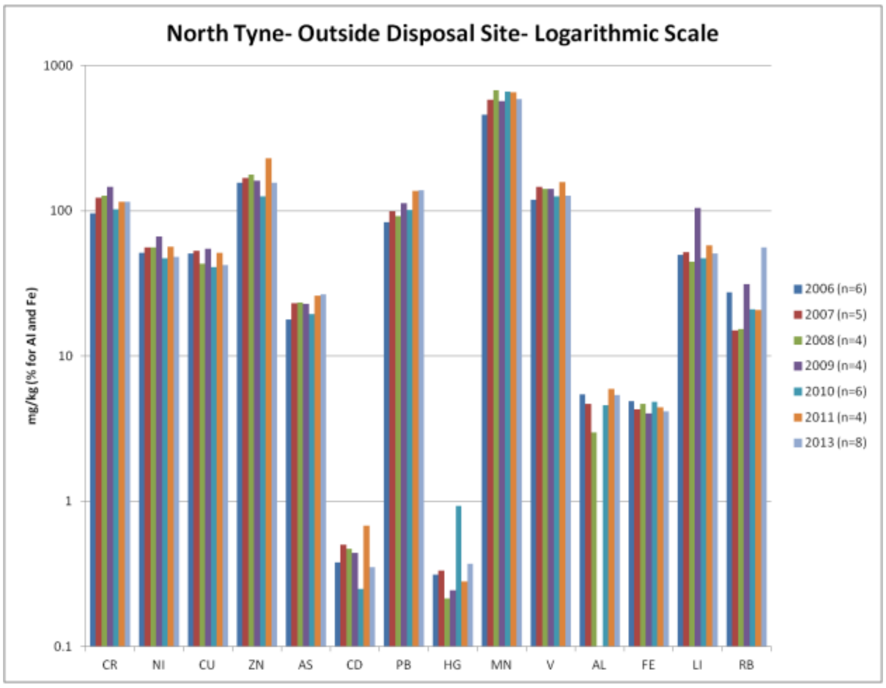


Figure A2.1.13. Temporal data for North Tyne trace metals, 2006-2013. Top: stations inside the disposal site, bottom: those outside.

2.2 Tees (Inner)

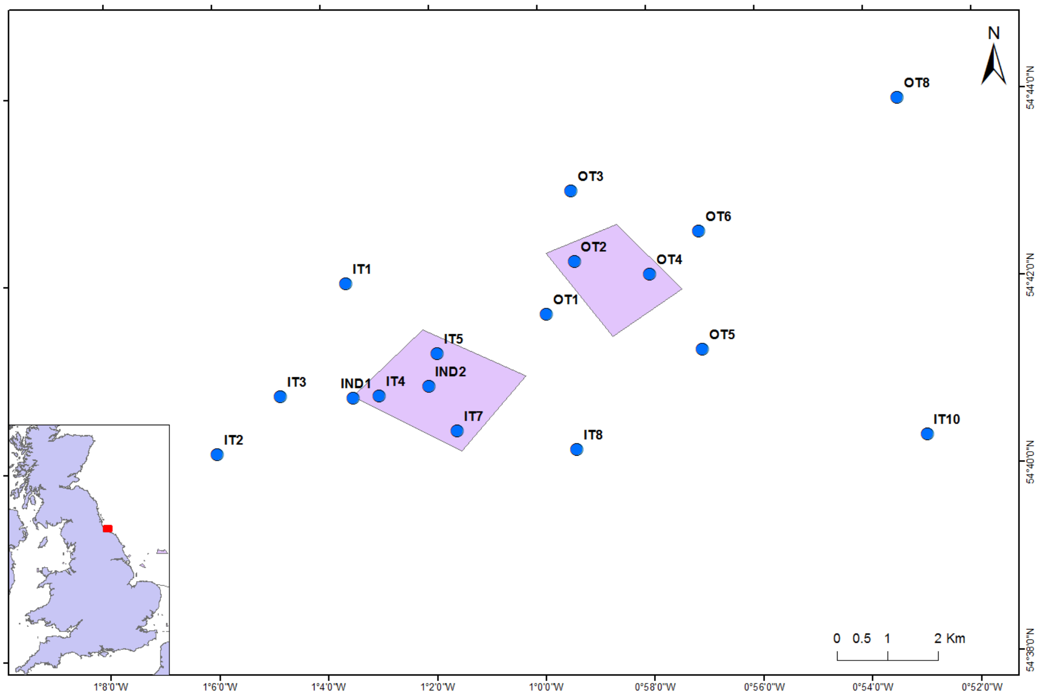


Figure A2.2.1. Location of sample stations at Inner (left) and Outer (right) Tees, 2013.

2.2.1 Background

The two dredged material disposal sites receiving the large quantities of material dredged from the ports of the Tees Estuary are located within close proximity to the mouth of the Tees and to each other (Figure A2.2.1). These sites, the Inner Tees and Outer Tees, have both been the recipient of monitoring under SLAB5 for a number of years (Bolam et al., 2009; 2011; 2012; 2014b). The Inner Tees disposal site has been shown to have a very homogeneous substrate of muddy sand with occasional small lumps of black mud and black flecks indicative of coal particles (Bolam et al., 2009; 2011). This site receives most of the 2.7 Mt of maintenance dredged material per year from the Tees Estuary, the Seaton Channel and Hartlepool. In recent years, the material disposed of to this site was seen to shoal at the western edge. In response to this, the operators, PD Teesport, offered to divide the disposal area into twelve sectors during 2006 and dispose to each on a monthly basis.

Material disposed to Outer Tees is usually comprised of capital dredgings. This is a more dispersive site and the port places more consolidated (i.e. clay) dredged material to this site rather than to the Inner Tees. This is often at the discretion of the operator based on observations of the material being dredged.

There have been a number of high profile construction and disposal at sea applications made with regards to the Tees sites over recent years. In addition to the 2.7 Mt of maintenance dredge material licensed annually for sea disposal, there are also several small scale capital projects ongoing although it is anticipated that the nature of the material arising will be largely 'soft' capital which will be disposed of to the Inner Tees site.

Permission has also been granted for the Northern Gateway container terminal which will include dredging of turning circles and berth pockets in the Tees resulting in a 2 Mt dredge. Due to the physical nature of some of the material it is anticipated that this material would be divided between the two Tees disposal sites.

The Tees has a large quantity of chemical industries which have resulted in contaminants within dredged sediments. ICI, TiOxide factories and brominated flame retardant producers have all discharged into the Tees in the past. Within the Tees Estuary, there has also historically been a breach in the half-tide embankment allowing erosion of the enclosed mudflat; sediments of which have been contaminated with high levels of lead and zinc. Construction works to repair this breach were subsequently licensed. Additionally, analysis of dredged material from the Tees has displayed some of the highest levels of hydrocarbons found in UK marine sediments.

RAT prioritisation assessment: Tier 1

- where a significant increase in the quantity of material disposed of has occurred.
- where there is the potential for the occurrence of elevated contaminant concentrations (between Cefas AL1 and AL2 in proposed dredge sediments) (Appendix 1) arising from historical or current activities at source (especially heavily urbanised/industrialised estuaries).
- where the material to be disposed of is very different (sediment type) to the receiving environment.
- with agreed increases in quantities of material (including changes in material and contaminant loadings).

2.2.2 Parameters to be assessed:

Sediment particle size
Sediment organic carbon
Sediment contaminants (TBT, PAHs, trace metals)

Assessments of the status of, and impacts at, the two Tees disposal sites are conducted based on data derived from a single survey that comprises stations within each licensed boundary, together with a number of stations located at varying distance outside each site.

2.2.3 Results

2.2.3.1 Sediment particle size

Inner Tees sediments are predominantly muddy sands and unimodal sands, with small but varying amounts of gravel (Table A2.2.1). Temporal changes in sediment group are shown in Table A2.2.2 for each station between 2006 and 2013 inclusive. In 2013, most stations displayed very little change in sediment group, being either in the same or adjacent sediment group compared with previous year(s). The only exceptions were increased sand components at IND1, IT3 (to the west of the site) and IT4; and IND2, IT7, and to a lesser extent IT5, which have all become muddier in composition.

Table A2.2.1 Average sediment descriptions and statistics for each sediment group at Inner Tees.

Sediment group	Number of samples	Sample Type	Sediment description
InT1a	2	Bimodal, Extremely Poorly Sorted	Gravelly Mud
InT2	4	Polymodal, Very Poorly Sorted	Gravelly Muddy Sand
InT3a	7	Bimodal, Poorly Sorted	Slightly Gravelly Muddy Sand
InT3b	9	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand
InT3c	10	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand
InT3d	27	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand
InT4a	23	Unimodal, Moderately Sorted	Slightly Gravelly Sand
InT4b	8	Unimodal, Moderately Well Sorted	Slightly Gravelly Sand

Sediment group	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
InT1a	20.14	7.10	72.76	0.89	0.70	1.16	2.46	1.90
InT2	17.66	64.09	18.25	12.92	17.12	9.82	8.34	15.90
InT3a	0.33	53.53	46.14	0.48	1.24	3.27	11.27	37.27
InT3b	2.57	79.81	17.62	3.47	8.29	15.49	34.62	17.94
InT3c	0.57	82.26	17.18	0.47	0.96	2.28	11.61	66.93
InT3d	0.40	85.68	13.92	0.64	1.85	5.65	35.50	42.05
InT4a	1.12	94.15	4.73	1.49	3.67	10.58	51.93	26.49
InT4b	0.14	98.30	1.55	0.29	1.47	16.20	70.20	10.15

Table A2.2.2 Sediment groups for each station sampled between 2006 and 2013 at Inner Tees.

	Year							
Sample code	2006	2007	2008	2009	2010	2011	2012	2013
IND1	InT3d	InT3d	InT4a	InT3d	InT3d	InT3d	n	InT4a
IND2	InT4a	InT4a	InT4a	InT1a	InT3b	InT4a	n	InT1a
IND4	n	InT4a	InT3d	InT3d	InT4a	InT3d	InT4a	n
IND5	n	InT4a	InT4b	InT4b	InT4b	InT4a	InT4b	n
IT1	InT3d	InT3d	InT3c	InT3c	InT2	InT3a	InT3a	InT3b
IT2	n	n	n	InT4b	InT4b	n	n	n
IT3	InT4a	InT3a	InT3b	n	InT3a	InT4b	InT3b	InT4b
IT4	InT3d	InT3d	InT3d	InT3d	InT3d	InT3d	InT3d	InT4a
IT5	InT4a	InT3d	InT4a	InT4a	InT3d	InT4a	InT4a	InT3d
IT6	InT4a	InT3b	InT3b	InT3d	InT4a	InT4a	InT4a	n
IT7	InT3d	InT4a	InT3d	InT3d	InT3d	InT3d	InT3d	InT3a
IT8	InT3c	InT3c	InT3c	InT3c	InT3c	InT3c	InT3c	InT3c
IT10	InT3b	InT3b	InT2	InT3b	InT2	InT3b	n	InT2
IT11	n	n	n	n	n	n	InT3a	n
IT12	n	n	n	n	n	n	InT3a	n

Figure A2.2.1 demonstrates the predominantly sandy nature of the sediment across this survey area. The stations which display the greatest silt/clay fractions are those within the disposal site boundary (Figure A2.2.2). Silt/clay content in a subset of dredge sediments for licensing applications to dispose of at Inner Tees was 66% (+/- 8 %, 95% CI). Most monitoring samples contained less silt/clay than this, except sediments in sediment group InT1, tentatively indicating that the finer fractions of the material disposed are being dispersed.

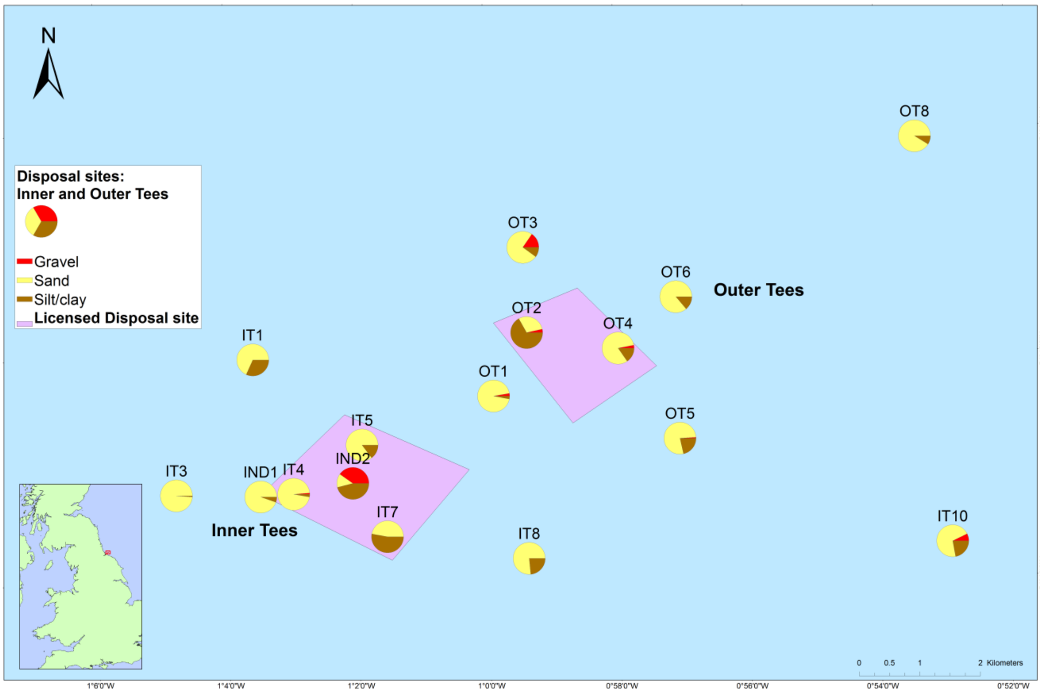


Figure A2.2.2. Pie charts of gravel, sand and silt/clay at Inner and Outer Tees, 2013.

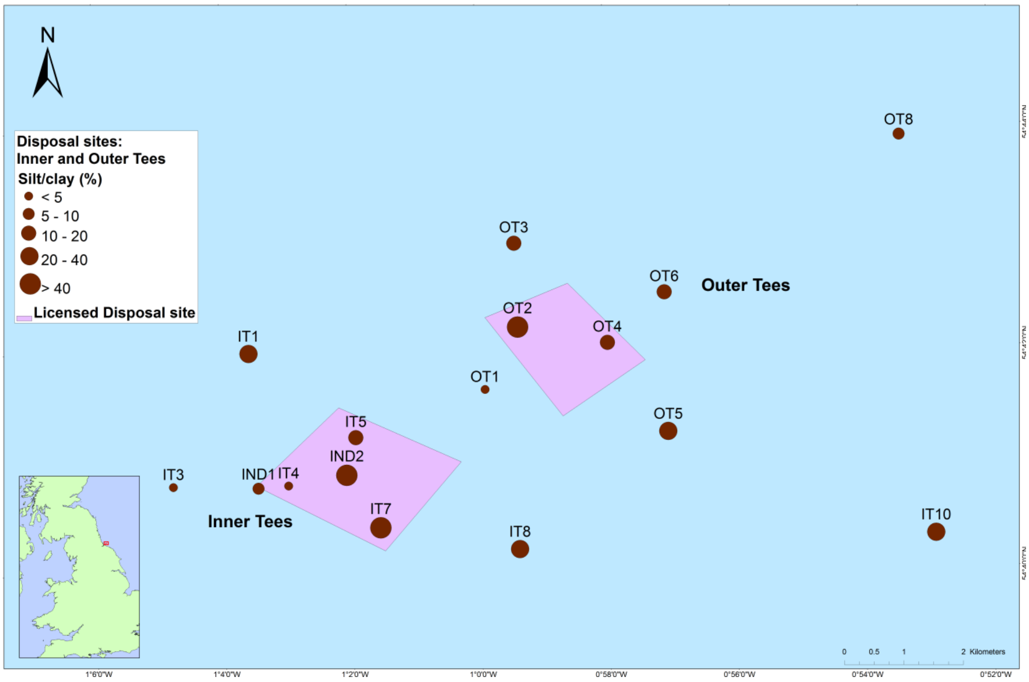


Figure A2.2.3. Silt/clay (%) at Inner and Outer Tees, 2013.

Sediments at Outer Tees, in parallel with those of Inner Tees, are predominantly muddy sands, with some gravelly sands and unimodal sands (Table A2.2.3). Table A2.2.4 indicates that there have been minimal changes in sediment groups between 2012 and 2013 at Outer Tees. However, at OT2, inside the disposal site, the sediment contains a significantly higher proportion of fines compared to previous years, while those of OT4 (also within the site) have changed from gravelly muddy sand to gravelly sand (Table A2.2.4).

Table A2.2.3. Average sediment descriptions and statistics for each sediment group at Outer Tees.

Sediment group	Number of samples	Sample Type	Sediment description
OuT1	11	Bimodal, Poorly Sorted	Slightly Gravelly Muddy Sand
OuT2	12	Polymodal, Very Poorly Sorted	Gravelly Muddy Sand
OuT3	14	Unimodal, Moderately Sorted	Slightly Gravelly Muddy Sand
OuT4	15	Unimodal, Poorly Sorted	Gravelly Sand

Sediment group	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
OuT1	0.71	66.02	33.28	1.04	1.53	4.66	26.43	32.35
OuT2	15.40	67.14	17.46	13.12	13.45	11.56	15.38	13.62
OuT3	0.36	89.51	10.13	0.50	1.90	6.00	54.52	26.59
OuT4	5.35	87.88	6.77	4.40	7.35	17.68	48.75	9.70

Table A2.2.4. Sediment groups for each station sampled between 2006 and 2013 at Outer Tees.

	Year						
Sample code	2006	2007	2008	2009	2010	2011	2013
OT1	OuT4	OuT4	OuT4	OuT4	OuT4	OuT4	OuT4
OT2	OuT4	OuT2	OuT4	OuT2	OuT2	OuT2	OuT1
OT3	OuT1	OuT4	OuT4	OuT2	OuT2	OuT2	OuT2
OT4	OuT4	OuT3	OuT2	OuT4	OuT4	OuT2	OuT4
OT5	OuT1	OuT1	OuT1	OuT1	OuT1	OuT1	OuT1
OT6	OuT3	OuT3	OuT3	OuT3	OuT1	OuT3	OuT3
OT7		OuT2	OuT1		OuT2		
OT8	OuT3	OuT3	OuT3	OuT3	OuT3	OuT3	OuT3

2.2.3.2 Sediment organic carbon

In 2013, organic carbon values (on the <63 µm sediment fraction) at Inner Tees ranged from 2.0 to 5.8 % (Figure A2.2.4). IT3 possessed low silt/clay content (1.0 %) and so it was not possible to measure the organic carbon for this station. In general, sediment organic carbon contents were similar to those obtained in previous years (Bolam et al. 2009; 2011, 2012; 2014b).

For the Outer Tees site, organic carbon values (on the <63 µm sediment fraction) ranged from 2.3 to 4.5 % (Figure A2.2.4). As for the Inner site, these values at Outer Tees are similar to those observed in previous years.

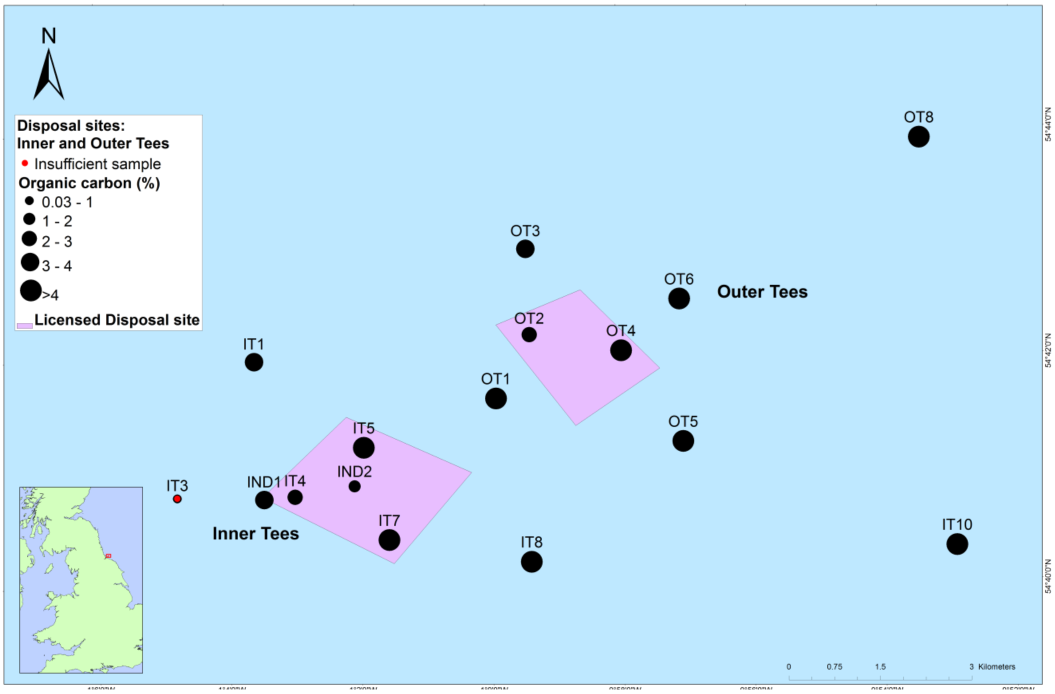


Figure A2.2.4. Organic carbon (%) in the silt/clay fraction (<63 µm) at Inner and Outer Tees, 2013.

2.2.3.3 Sediment contaminants

2.2.3.3.1 TBT

During the 2013 survey, sediment samples for TBT analysis were collected at 10 (five within the disposal site) and seven (two within) stations at Inner and Outer Tees disposal sites. From the surficial samples derived from the grabs, only two stations recorded levels of TBT above the LOD: IT7 and IT2 with 0.02 and 0.01 mg/kg, respectively. These levels are well below Cefas AL1.

In general, levels of TBT are relatively low (i.e. either <Cefas AL1 or <LOD) for all stations. This observation is comparable when assessed against previous years' TBT levels (Bolam et al. 2009; 2011; 2012; 2014b).

2.2.3.3.2 PAHs

The highest summed PAH concentration during 2013, for the Inner Tees area (115,700 µg kg^{-1} dry weight), was sampled at IT7 on the southern corner of the disposal site (Figure A2.2.5). High concentrations were also found at IT4 and IND1, both at the western edge of the disposal site (92,700 and 77,000 µg kg^{-1} dry weight, respectively; Figure A2.2.5). The lowest summed PAH concentration (10,100 µg kg^{-1} dry weight) found either within or surrounding the Inner site in 2013 was located east of the disposal site, at IT3 (Figures A2.2.5 & A2.2.6).

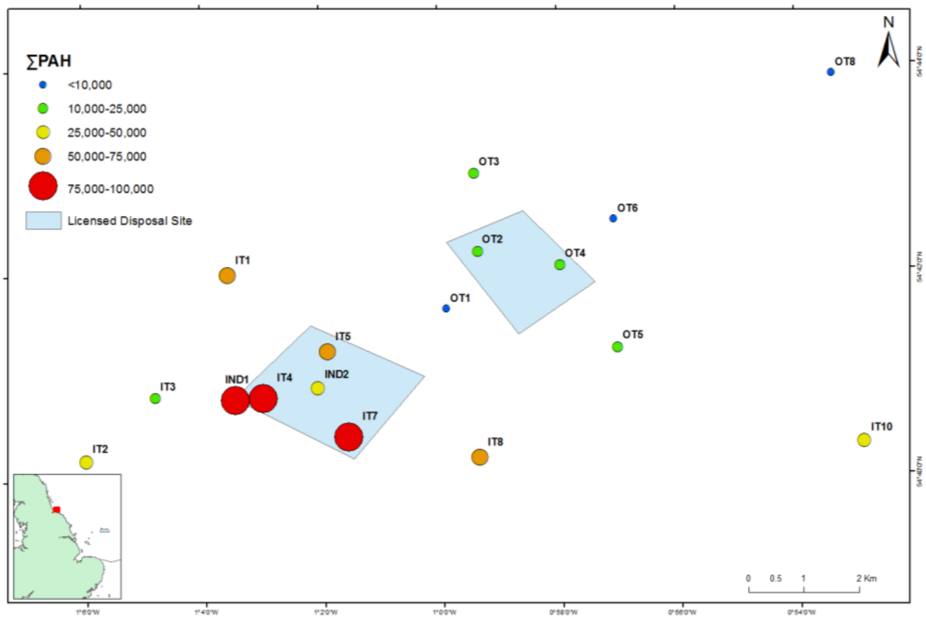
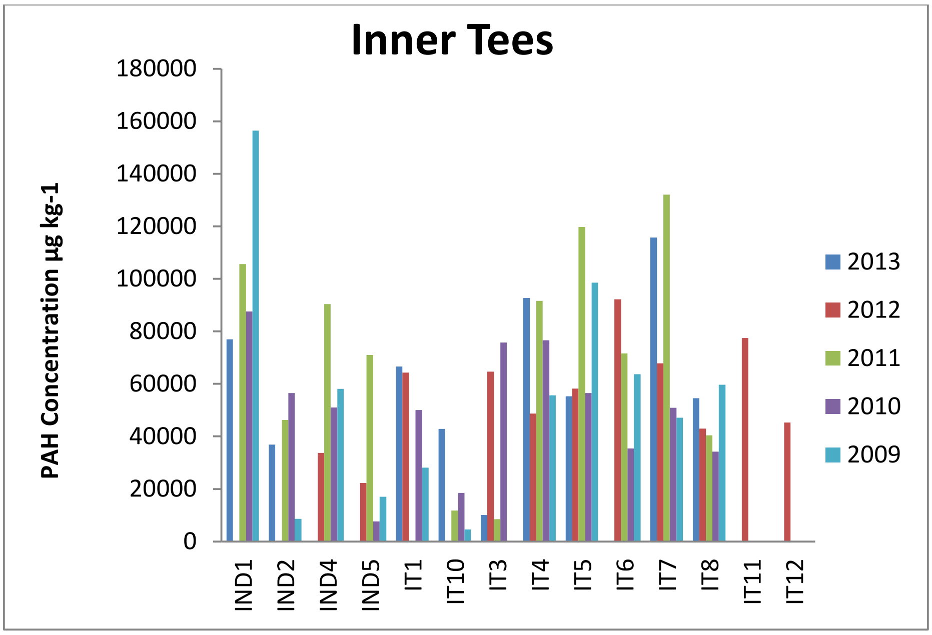


Figure A2.2.5. Summed PAH concentrations (µg kg^{-1}dry weight) for stations sampled at Inner and Outer Tees, 2013.



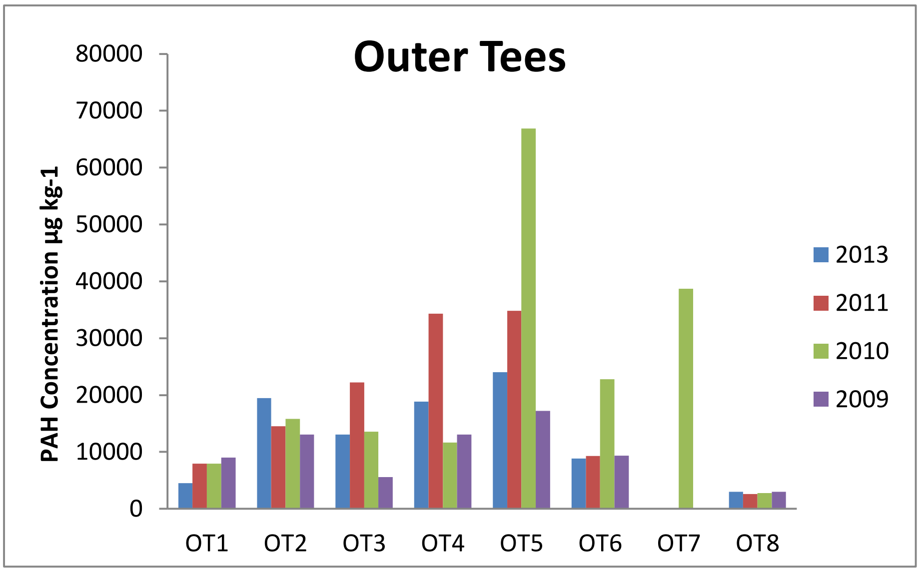


Figure A2.2.6. Concentrations observed during 2009-2013 at Inner (top) and Outer (bottom) Tees disposal site.

Sediments from all sampling stations for the Inner Tees were found to exceed the ERL for LMW PAHs. The ERM for the LMW PAH was breached at all stations except for IT3. The ERL for the HMW PAH was breached at IT1, IT4, IT5, IT8 and IND2; no station exceeded the ERM for the HMW PAHs.

The amount of material being disposed of to the Inner Tees site has increased by 0.5 Mt tonnes in 2013 compared to 2012. This increase could account for the higher concentrations found at IT4 and IT7 within the licensed disposal site compared to those in 2012.

Evaluation of the PAH data indicated that the predominant source in all the sediment samples, except IND2, was petrogenic, with >88% of the PAH content arising from oil sources. The phenanthrene/anthracene (P/A) ratio was greater than 10 at IND1, IT2, IT3 and IT5, which is also indicative of a predominantly petrogenic source.

The Outer Tees disposal site area has often displayed much lower summed PAH concentrations than the Inner Tees area (Bolam et al., 2009; 2012). The highest summed PAH concentration for the Outer Tees area in 2013 (24,000 µg kg^{-1} dry weight) was found at OT5, to the south-east of the disposal site (Figure A2.2.5). The Outer Tees was not surveyed during 2012, but the highest concentration observed in 2011 was similarly found at OT5, with a summed PAH concentration of 34,800 µg kg^{-1} dry weight (Figure A2.2.6). The lowest summed PAH concentration found in 2013 was at OT8 (3,000 µg kg^{-1} dry weight), to the northeast of the Outer site (Figure A2.2.5).

Sediments from all sampling stations within and surrounding the Outer Tees site were found to exceed the ERL for LMW PAHs. The ERM for the LMW PAH was breached at OT2, OT4 and OT5; no station exceeded the ERL or ERM for the HMW PAHs.

There has only been 60,000 tonnes of capital dredged material disposed of to the Outer Tees site since 2009, which probably accounts for the low concentrations found compared to those at the Inner Tees disposal site.

Evaluation of the PAH data indicated that the predominant source in all the Outer Tees sediment samples was petrogenic, with > 83% of the PAH content arising from oil sources. The phenanthrene/anthracene (P/A) ratio was found to be 10 at OT2, which is also indicative of a predominantly petrogenic source.

2.2.3.4.4 Trace metals

Levels of enrichment for Inner and Outer Tees stations using OSPAR BAC and regional baseline values are represented in Figure A2.2.7. When assessing against the OSPAR BAC approach, high enrichment in Cr is observed at stations situated around and within the Outer Tees disposal site, slight enrichment is denoted elsewhere (except for IT7 inside the Inner site). This enrichment is reduced when assessed using the baseline method. This is due to the fact that the proposed baseline values for the above metals are higher than the OSPAR BAC value, to take into consideration regional variability (Table A1.4.1).

Arsenic at IT1 and IT3 (both located northwest of Inner Tees disposal site) is highly enriched with OSPAR BAC approach. Elsewhere, As enrichment is either slight or not enriched. Levels of As are higher at the Inner Tees disposal site relative to those at Outer Tees. Similar observations are found for the baseline approach. The observation can be due to the fact that very little dredged materials have been disposed of to the Outer Tees site for the last 5 years.

Enrichment comparison for Cd is similar using both assessment approaches with overall slightly or not enriched, with the exception of IT7 where Cd was found to be highly enriched. Similar observations were found for Zn.

Pb shows a moderate enrichment for most stations at the two Tees disposal sites, with two very enriched stations, IT8 (located south of the Inner Tees disposal site) and OT8 (northeast of the Outer Tees disposal site) (Figure A2.2.7) when assessment was conducted using the OSPAR BAC approach. Using the regional baseline method, however, most stations are slightly or not enriched for Pb.

As for previous years' data, the difference in enrichment factors between the two assessment approaches was more pronounced for Hg. For example, Hg shows a moderate to high enrichment for most stations using the OSPAR BAC approach, with four very enriched stations located within the Inner and Outer Tees disposal sites (IT5, IT7, IND1 and OT4), these same highly-enriched stations were found to be slightly enriched according to the baseline assessment (except for IT7), with no enrichment being observed for the remaining stations. This is due to the fact that the proposed baselines values for the above metals are higher than the OSPAR BAC value (Table A1.4.1), to take into consideration regional variability.

Similar findings apply to the Tees area where the assessment of metal concentration enrichment is more appropriately conducted using the proposed baseline values, although these baseline values could potentially be further refined as metal concentrations at Tees are lower than those studied for Tyne areas.

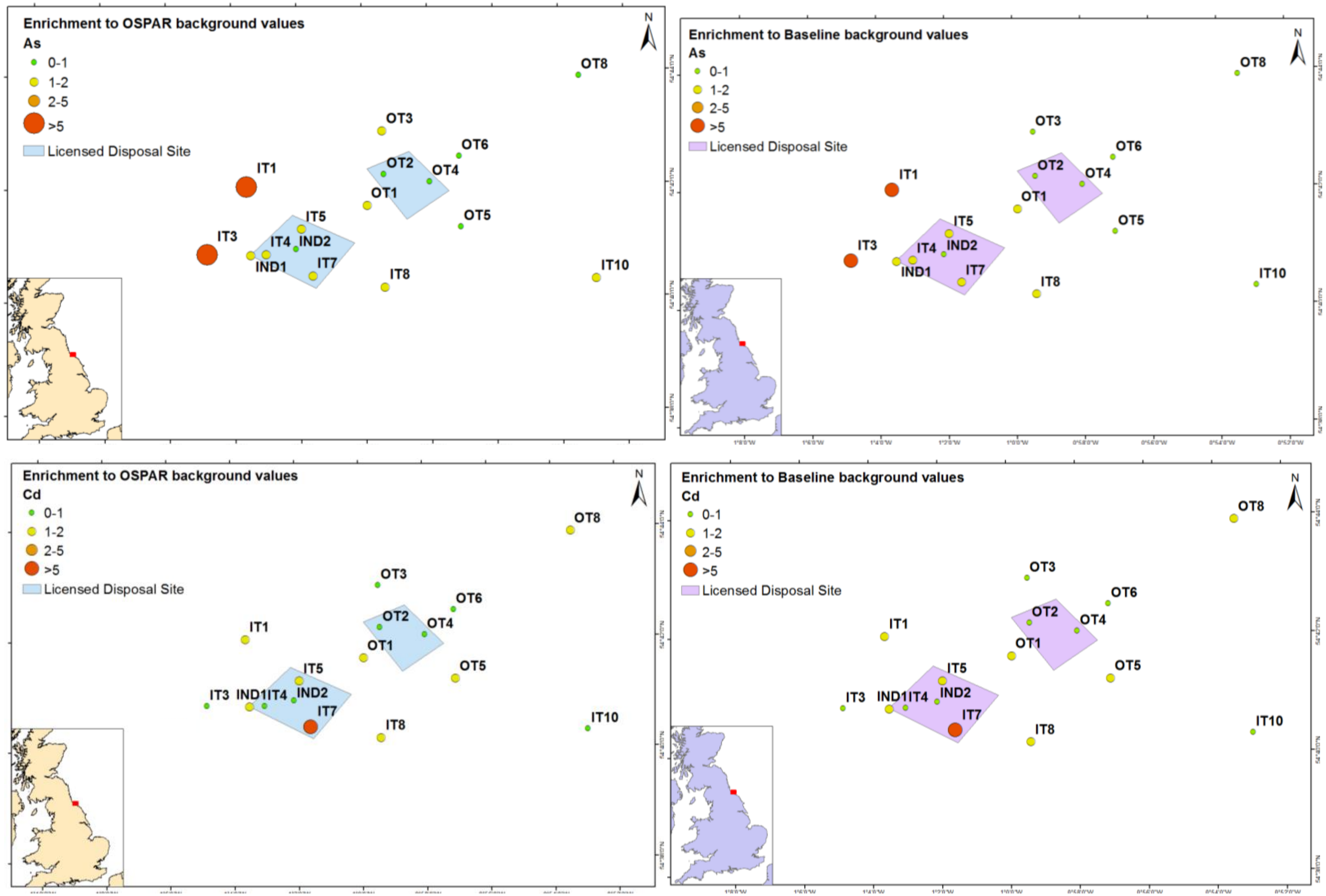
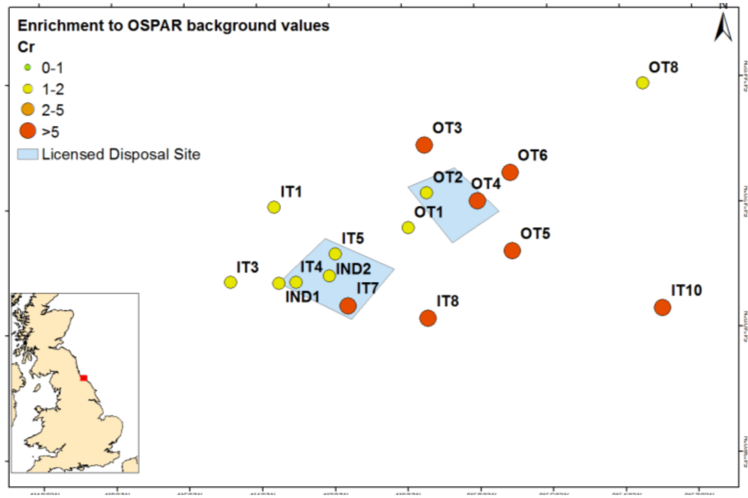
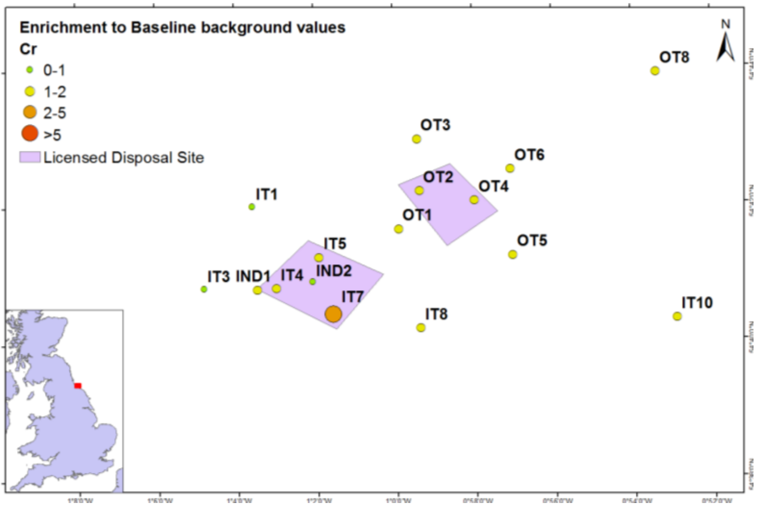
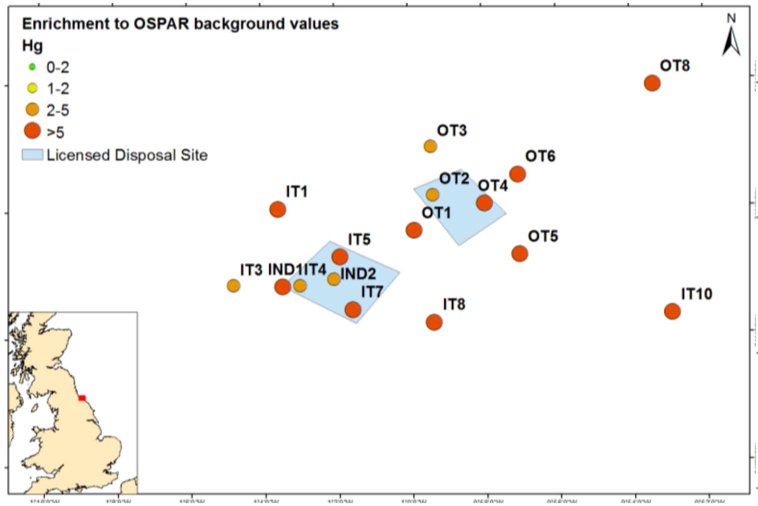
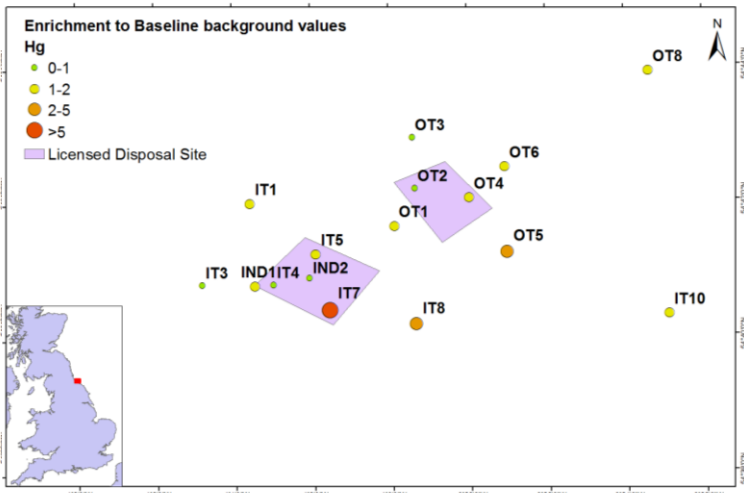


Figure A2.2.7. Enrichment to OSPAR BACs (left) and regional baseline values (right) at Inner and Outer Tees, 2013, for As, Cd, Cr, Hg and Pb.


Enrichment to OSPAR background values
Cr
0-1
1-2
2-5
>5
Licensed Disposal Site
OT8
OT3
OT6
OT2
OT4
IT1
OT1
IT5
OT5
IT3
IT4
IND2
IT7
IND1
IT8
IT10


Enrichment to Baseline background values
Cr
0-1
1-2
2-5
>5
Licensed Disposal Site
N
OT8
OT3
OT6
OT2
OT4
IT1
OT1
IT5
OT5
IT3
IND1
IT4
IND2
IT7
IT8
IT10


Enrichment to OSPAR background values
Hg
0-2
1-2
2-5
>5
Licensed Disposal Site
N
OT8
OT3
OT6
OT2
OT4
IT1
OT1
IT5
OT5
IT3
IND1
IT4
IND2
IT7
IT8
IT10


Enrichment to Baseline background values
Hg
0-1
1-2
2-5
>5
Licensed Disposal Site
N
OT8
OT3
OT6
OT2
OT4
IT1
OT1
IT5
OT5
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IND1
IT4
IND2
IT7
IT8
IT10

Figure A2.2.7. Continued.

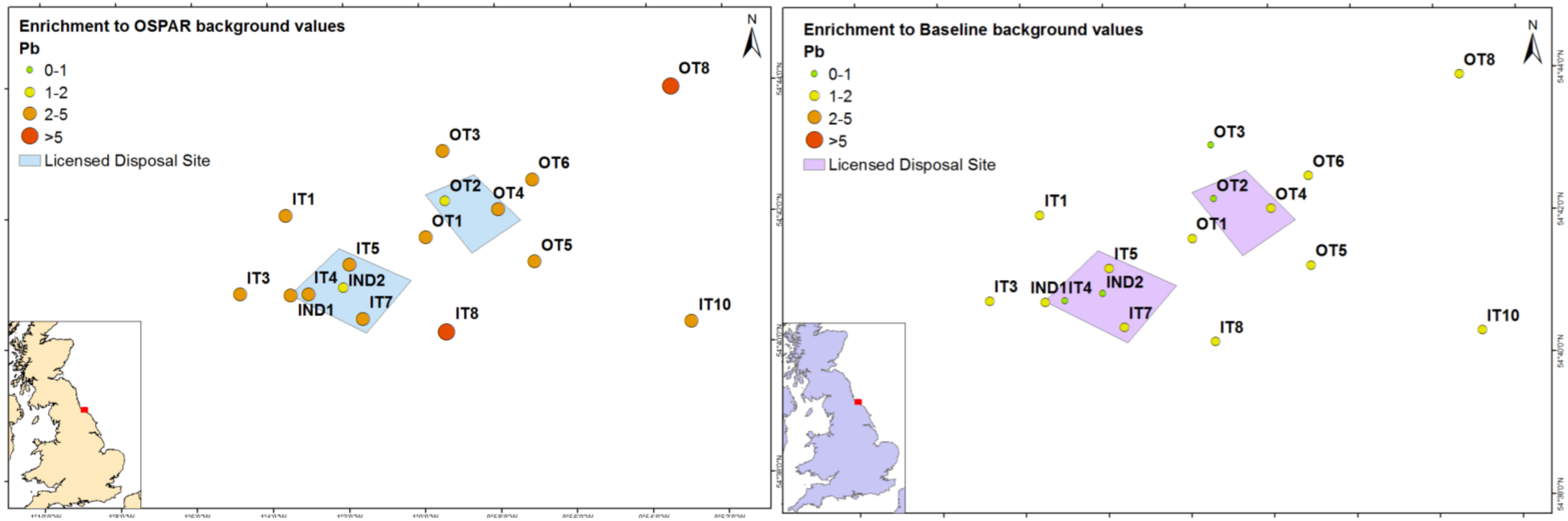
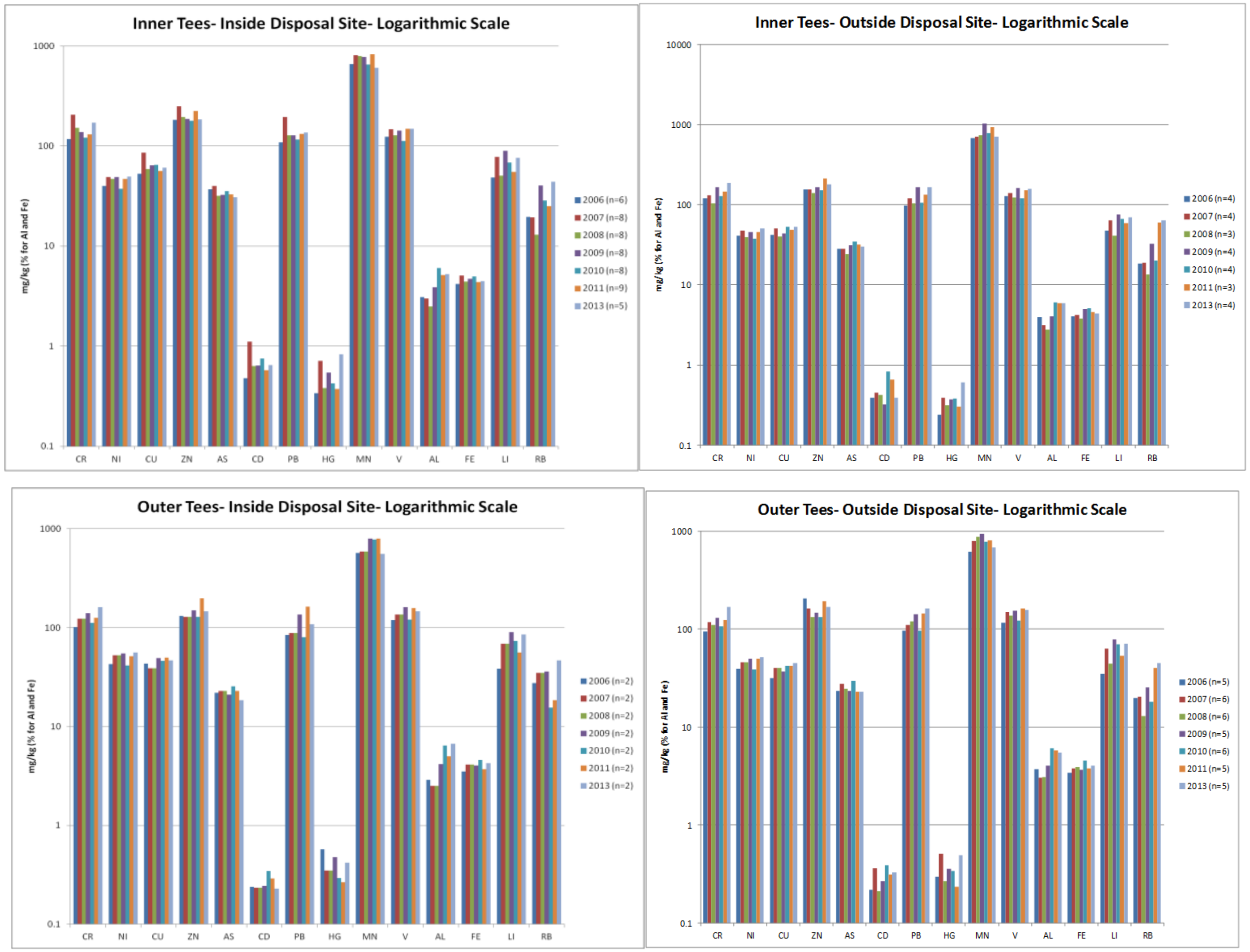


Figure A2.2.7. Continued.



Figures A2.2.8. Trace metals concentrations for Inner (top) and Outer Tees (bottom) stations, 2006-2013.

2.3 South Falls

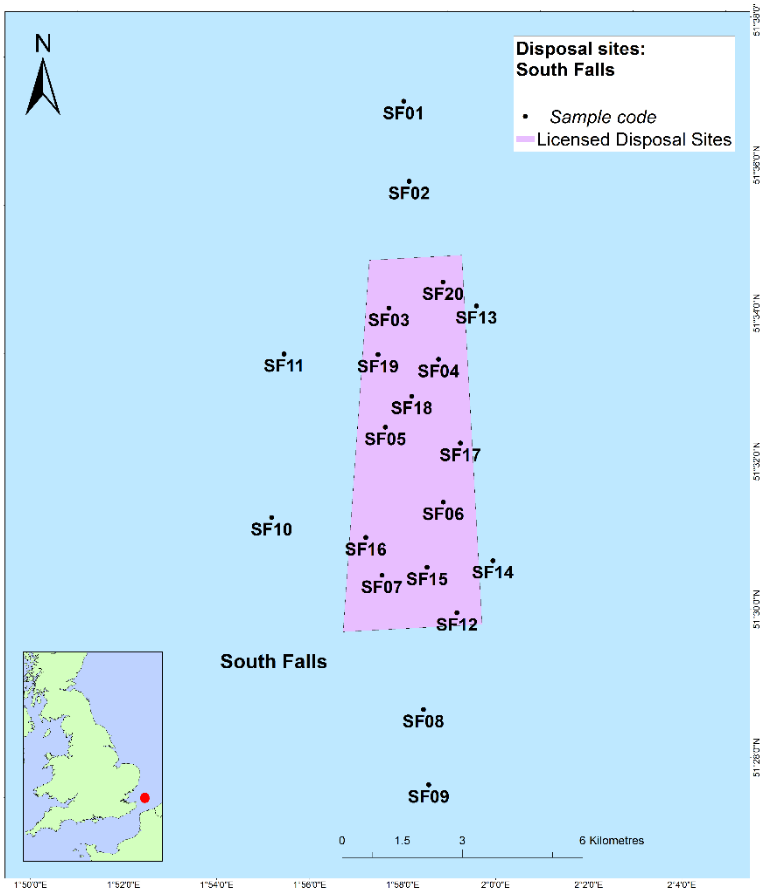


Figure A2.3.1. Location of sampling stations at South Falls, 2013.

2.3.1 Background

South Falls (TH070) is a designated dredge disposal site located in the southern North Sea, approximately 110 km east of Gravesend (Figure A2.3.1). The licensed site has an area of approximately 27 km^2 in a roughly trapezoidal shape (Figure A2.3.1), a depth of approximately 55 m, and experiences a tidal range of 4.6 m with maximum current velocities of 1.1 m/s. The bed sediments in the vicinity of South Falls are fine to medium sand, becoming progressively finer towards the south.

South Falls receives both capital and maintenance dredge material. Currently, the site is receiving maintenance dredge silts and sand from the River Medway with a total permitted quantity of 280,000 t per annum of silt, and a further operator from the Thames area has been licensed to dispose of coarse sand on a periodic basis. During 1993/1994, the Port of Ramsgate was licensed to dispose up to 0.7 Mt of capital material and in 2000/2001, Medway Port held a licence to dispose of up to 0.8 Mt of capital material. More recently, the annual disposal quantity has varied from 1,000 t to over 0.2 Mt.

Recently, Dredging International applied to dispose of approximately 6 Mt (3 Mm^3) of capital dredged material from the approach channel to the London Gateway Port development in the Thames estuary. This material comprises a mixture from silty sand to London clay. The total tonnage estimated for the different material types was as follows; clay (1.48 Mt); silty sand (3.28 Mt) and; gravelly sand (1.26 Mt).

Following consultation, the licence was issued and disposal of this material to TH070 commenced during June 2013. The total amount of material the site is expected to receive under this licence (6 Mt) obviously represents a significant increase for this site, and, thus, monitoring under SLAB5 was required. The focus of this monitoring was on the physical changes to the seabed (depth and sediment characteristics) and to those of the biological assemblages. Monitoring was conducted during November 2013 and, at that time, 4 Mt of the anticipated 6 Mt had been deposited. Thus, the results obtained allow an assessment of the characteristics during the disposal regime and subsequent monitoring (during 2014) would be required to assess these features after the cessation of the disposal campaign.

RAT prioritisation assessment: Tier 1

2.3.2 Parameters monitored:

Sediment particle size
Acoustics
Macrofaunal assemblages

2.3.3 Results

2.3.3.1 Sediment particle size

Sediment in the region of South Falls are predominantly unimodal sands, with some gravels and, to a lesser extent, muds (Table A2.3.1). No temporal comparisons with previous surveys were possible due to a lack of historic data. However, it is interesting to conduct a comparison between the PSA data derived from the two different grab types (i.e. mini-Hamon grab and Shipek grab) used to collect samples (Table A2.3.2). Sediment groups for the stations are similar for each grab type except for SF03, where the sample from the Shipek grab is less muddy than that from Hamon grab. As the Hamon grab penetrates deeper into the sediment matrix and the whole grab is mixed prior to PSA sample extraction (unlike that of the Shipek where a surficial scrape from the undisturbed sediment is taken), this may indicate the presence of a mud layer beneath the surface sediment at SF03.

Table A2.3.1 Average sediment descriptions and statistics for each sediment group at South Falls.

Sediment group	Number of samples	Sample Type	Sediment description
SoF1	5	Polymodal, Extremely Poorly Sorted	Gravelly Muddy Sand
SoF2	5	Bimodal, Very Poorly Sorted	Muddy Sandy Gravel
SoF3	14	Unimodal, Poorly Sorted	Gravelly Sand
SoF4a	20	Unimodal, Moderately Well Sorted	Slightly Gravelly Sand
SoF4b	15	Unimodal, Well Sorted	Slightly Gravelly Sand

Sediment group	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
SoF1	29.39	46.30	24.31	4.00	13.27	18.04	6.90	4.09
SoF2	67.60	28.18	4.22	2.82	11.33	11.49	1.93	0.61
SoF3	14.08	83.72	2.19	3.63	31.79	38.33	8.42	1.55
SoF4a	4.91	95.08	0.02	1.74	46.17	46.14	0.96	0.06
SoF4b	0.44	99.56	0.00	0.89	63.92	34.70	0.05	0.00

Table A2.3.2. Sediment groups for each sample code in 2013 (Shipek grab and Hamon grabs) at South Falls.

Sample	SH	HG_A	HG_B	HG_C
SF01	SoF4b	SoF4b	SoF4b	SoF4b
SF02	SoF4b	SoF4a	SoF4b	SoF4b
SF03	SoF3	SoF1	SoF1	SoF1
SF04	SoF4b	SoF4b	SoF4b	SoF3
SF05	SoF4a	SoF4a	SoF4a	SoF4b
SF06	SoF3	SoF3	SoF3	SoF3
SF07	SoF4a	SoF4a	SoF4a	SoF4a
SF08	SoF4a	SoF4a	n	n
SF09	SoF3	SoF2	n	SoF2
SF10	SoF4a	SoF4a	SoF4a	SoF4a
SF11	SoF4b	SoF4b	SoF4a	SoF4a
SF12	SoF2	SoF2	SoF1	SoF2
SF13	SoF4a	SoF4a	SoF4a	SoF4b
SF14	SoF3	SoF3	SoF3	SoF3
SF15	SoF4a	n	n	n
SF16	SoF3	n	n	n
SF17	SoF3	n	n	n
SF18	SoF1	n	n	n
SF19	SoF4b	n	n	n
SF20	SoF3	n	n	n

The spatial variation in the proportional representation of gravel, sand and silt/clay for each sampling station and grab type in 2013 is shown in Figure A2.3.2 and the percentages of silt/clay content for each grab type in Figure A2.3.3. Note, Shipek grabs were also collected at sampling stations SF15 to SF20 inclusive. The highest levels of silt/clay were found in the northern sector of the disposal site at SF03 (~30%) and at the southern edge of the disposal site at SF12 (~10%) collected using a Hamon grab, and at SF18 (37%) in the centre of the site, collected with a Shipek grab only. As silt/clay was not found to be present in such proportions elsewhere, the silt/clay observed at these three stations is likely to reflect disposed material.

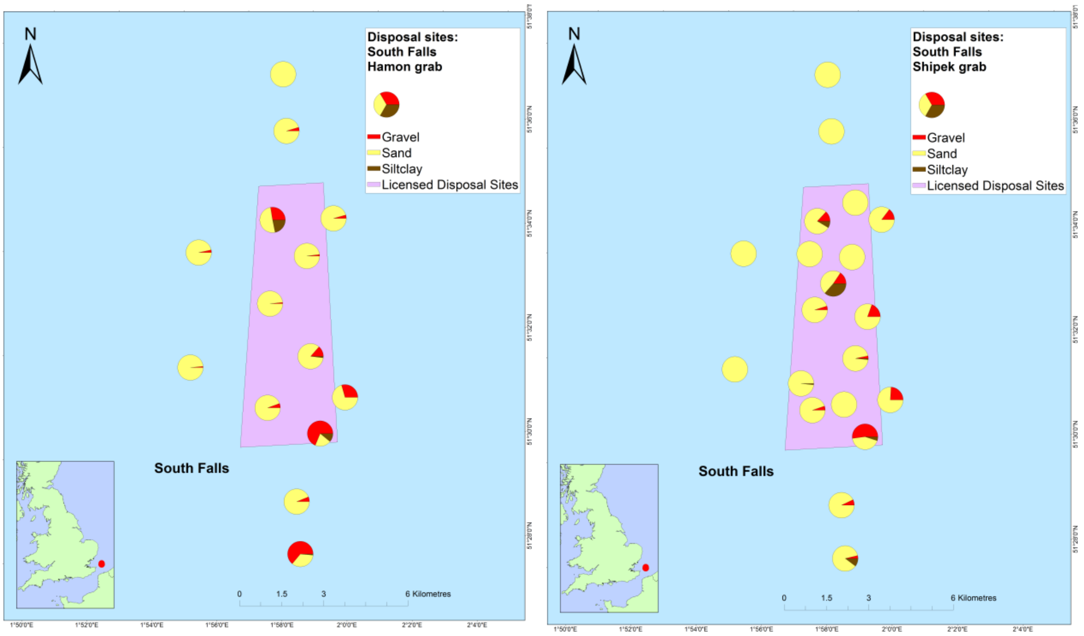


Figure A2.3.2. Pie charts of gravel, sand and silt/clay at South Falls in 2013. Data from sediments sampled by mini Hamon grab (left) and Shipek grab (right) are shown. See text (Section 2.3.3.2) for description of why two types of grab were used for sediment sampling.

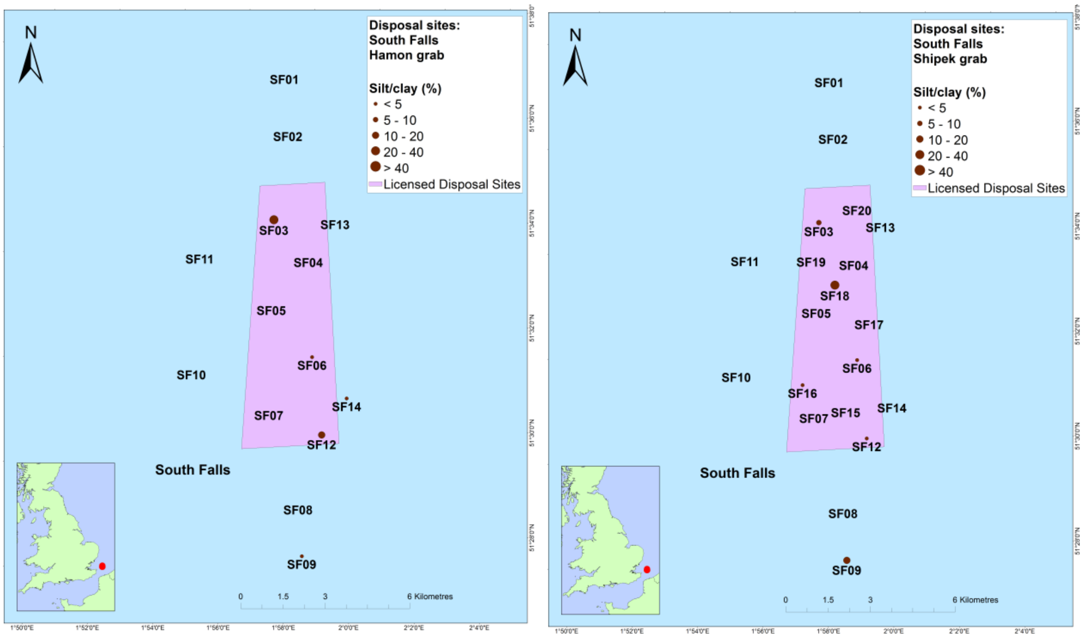


Figure A2.3.3. Silt/clay content (%) of sediments sampled at South Falls in 2013. Data from sediments sampled by mini Hamon grab (left) and Shipek grab (right) are shown. See text (Section 2.3.3.2) for description of why two types of grab were used for sediment sampling.

2.3.3.2 Acoustics

The acoustic and ground truth survey at South Falls dredged disposal site was designed to enable the characterisation of the site and disposal regime therein. The multibeam data were collected using a Kongsberg EM2040 multibeam echosounder onboard the *Cefas Endeavour* during 25-27th November 2013. Bathymetry data were processed employing CARIS HIPS and SIPS 7.1 SP2 and backscatter mosaics were produced using QPS Fledermaus Geocoder Toolkit (FMGT) software. [As a point of interest, during acquisition of the acoustic data, a dredger was operating in the area, disposing of material within the disposal site.]

Samples to support the acoustic data were gathered using a Shipek and Hamon grab to enable a surface (Shipek) Particle Size Analysis (PSA) and an integrated (Hamon) PSA sample to be collected and thus a comparison of sediment results to be made. A total of 20 stations were sampled with the Shipek grab and 14 with the Hamon grab (with replicates) inside and outside of the licensed disposal boundary (see section 2.3.3.1).

The data obtained revealed that the seabed at South Falls is dominated by large sand waves running across the site, interspersed with mega-ripples (Figure A2.3.4). The seabed is shallower in the northeast and deeper to the southwest with depths ranging from 33 to 55 m below Chart Datum (Figure A2.3.4). The larger sand waves are found in the southwestern section and follow the sediment transportation of the area.

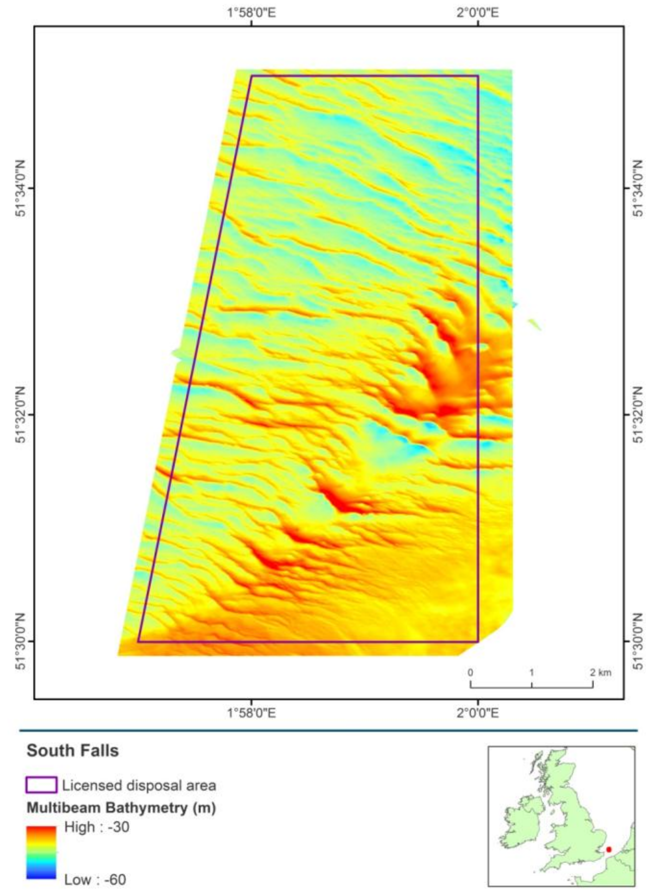


Figure A2.3.4. *Multibeam bathymetry at South Falls collected in November 2013.*

The medium intensity return of the multibeam backscatter data (Figure A2.3.5) depicts a site largely comprised of sandy sediments. Additionally, there is clear evidence of disposed material on the seabed. Plumes of material and impact signatures are identified as having a higher intensity return and are contained within the disposal site outline (Figures A2.3.5 & A2.3.6). Due to the homogeneous sand found on the seabed at South Falls dredged disposal site, it is difficult to distinguish sediment types where disposal activity has taken place. Interpretation therefore constituted the detection of the dredged material from the naturally occurring sandier sediments therein.

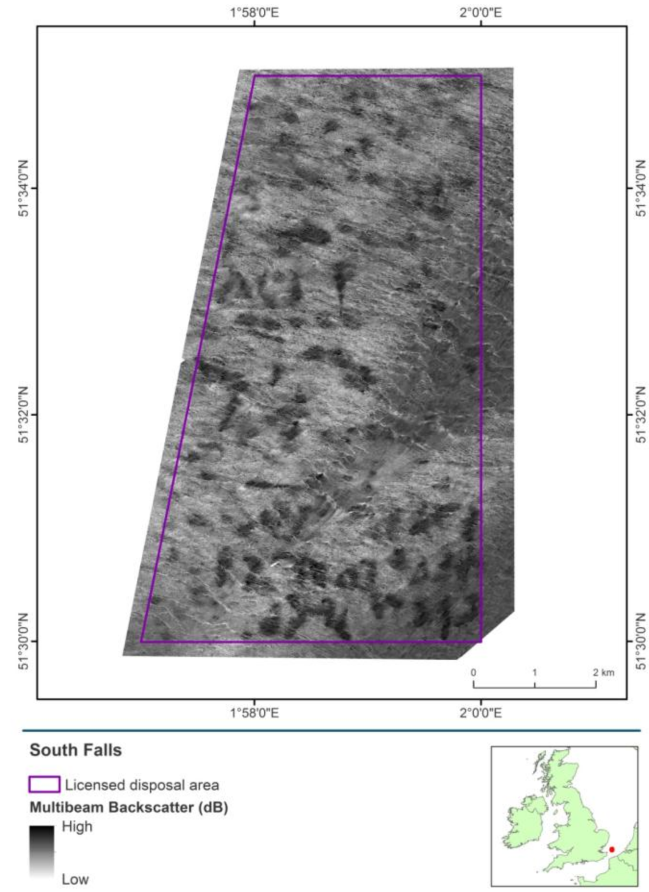


Figure A2.3.5. Multibeam backscatter derived from bathymetry collected at South Falls disposal site, November 2013.

The PSA data obtained from the grabs (section 2.3.3.1) correlate well with the information gained from the acoustic data and, taken together, clearly suggest a seabed largely comprised of sand. The sediments disposed of, and subsequently grabbed, were a mixture of silt/clay to the north and gravel to the south. Manual interpretation of these data was conducted in Arc 10.1 to map sediment boundaries within South Falls (Figure A2.3.7). The majority of the site is comprised of sandy sediments, supported by the evidence of prominent sand wave and mega ripple features on the multibeam bathymetry data (Figure A2.3.4). The disposal material can be seen across the entirety of the site although it appears in relatively large quantities in the northern section of the site (Figure A2.3.7). The eastern side of the site has a coarse signature suggesting a seabed of coarse sand and gravel; this signature appears to coincide with a depth change and can be seen in a slightly deeper trench running from the north east to south west and where the larger sand waves are located. These sand waves are likely to be orientated with the sediment transportation direction of the area.

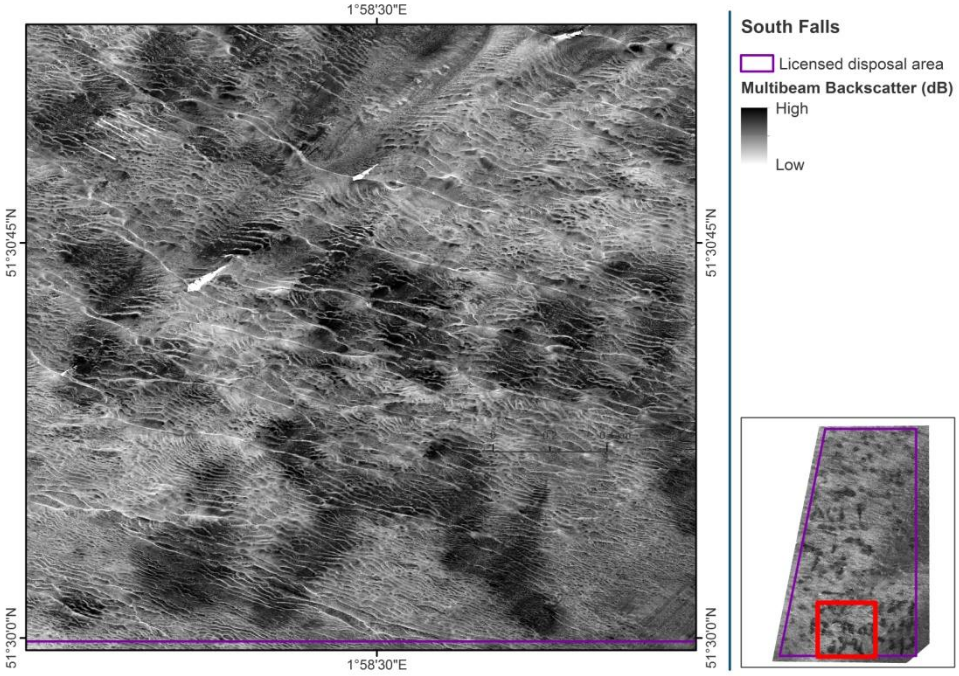


Figure A2.3.6. Detail of multibeam backscatter with evidence of dredged material disposal, South Falls, November 2013.

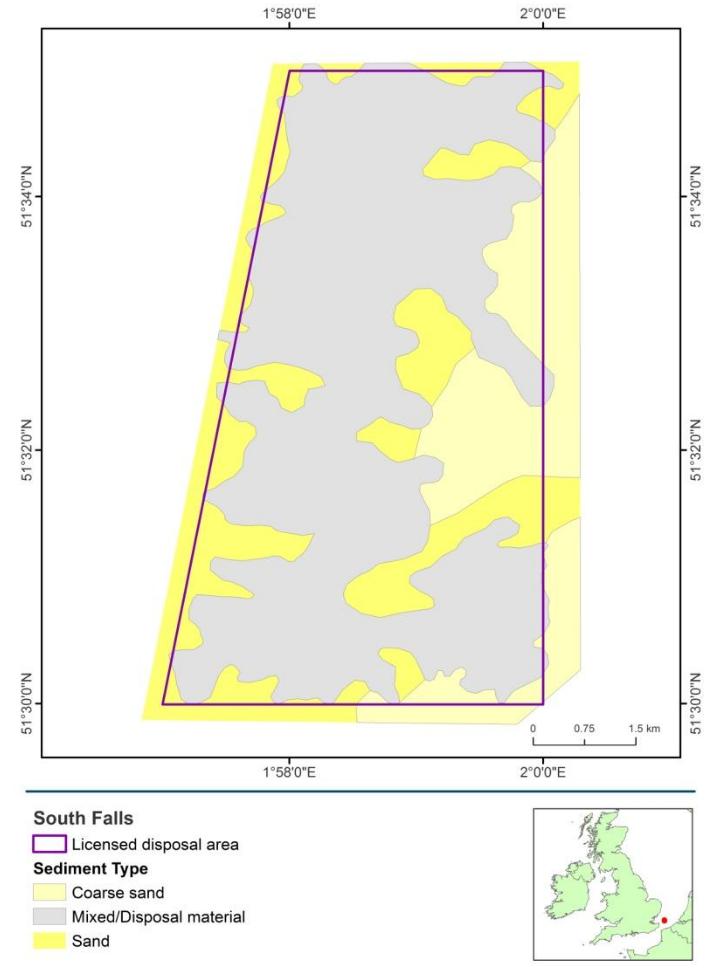


Figure A2.3.7. Sediment composition of the South Falls disposal site, November 2013. Acoustic backscatter data, together with PSA data derived from the Shipek and Hamon grabs, were used to classify the sediment regions shown.

2.3.3.3 Macrofaunal assemblages

A total of 1063 individuals were sampled from the 39 samples (across 14 stations) taken at South Falls. The most abundant across the whole survey were the annelid worms *Aonides paucibranchiata* (8.7% of specimens), *Notomastus latericeus* (4.4%) and *Syllis garciai* (4.0%) and the most ubiquitous, or taxa found in the largest number of samples, were Gymnolaemata (a class of bryozoans) (66% of samples), *A. paucibranchiata* (62%) and *N. latericeus* (46%).

Figure A2.3.8 displays the relative similarities in assemblage structure (based on square-root transformed abundance data) of each station (replicates shown separately) in 2-dimensions in an ordination plot following non-metric multidimensional scaling (nMDS). The stations have been coloured according to their broad location outside of the disposal site (i.e. east, west, north and south) and inside the disposal site. This plot reveals two main features of the macrofaunal assemblage structures. Firstly, the assemblages of the six stations located inside the boundary of the South Falls disposal site vary, but the magnitude of this variability matches that observed for the assemblages of the stations surrounding the disposal site. The assemblage of SF05 inside the site, however, does show a relatively large degree of within-station variability. Secondly, there are some differences between the assemblages of each region outside the disposal site. For example, the assemblages of the one and two replicates sampled at the southerly-located stations SF08 and SF09 respectively, are located together at the top right of the plot while those of stations to the north of the site (except for one replicate of SF02) are generally located at the bottom left. The assemblages of SF13 and SF14 (apart from one replicate of SF13), east of the site, are located towards the centre of the ordination plot.

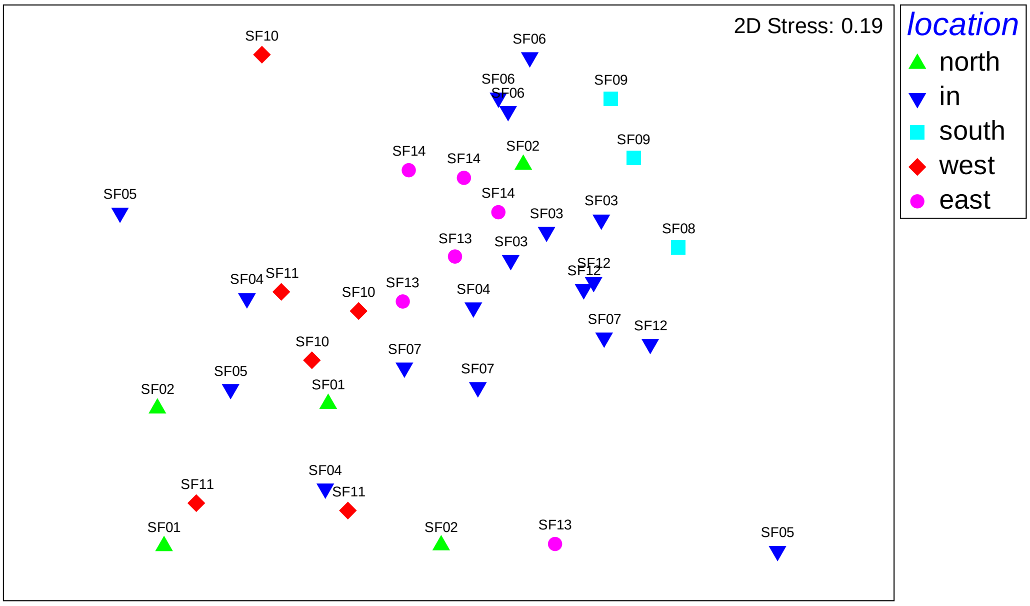


Figure A2.3.8. nMDS ordination plot showing the relative similarities of the macrofaunal assemblages of the stations sampled at South Falls, 2013. Abundance data were square-root transformed prior to the derivation of a Bray-Curtis similarity matrix. Stations are colour-coded according to their locations either inside the disposal site (blue triangles) or outside and direction from the disposal site.

Along the gradient of assemblage similarities presented in Figure A2.3.8 is a gradient in a number of univariate metrics of community structure. The assemblages to the top right of the plot, in which SF08 and SF09 and a number of assemblages within the disposal site are located, possess the highest number of individuals and species (Figure A2.3.9 (a & b)), and, perhaps less clear-cut, the highest diversity (Figure A2.3.9 (c)). The trend in total wet biomass of the assemblages shows a more variable pattern with relative assemblage similarity, although the assemblages of SF06 (inside the disposal site) and SF14 (east of the disposal site) both display greater biomass values than those of other stations (Figure A2.3.9

(d)). Assemblages of SF09, which display a similar community structure and high numbers of individuals and species to those with the highest biomasses, are low in total biomass.

In summary, the macrofaunal assemblages at South Falls show a gradient in spatial structuring, both in terms of their univariate metrics and multivariate community structures, but this pattern does not appear to reflect an inside-outside disposal site boundary relationship.

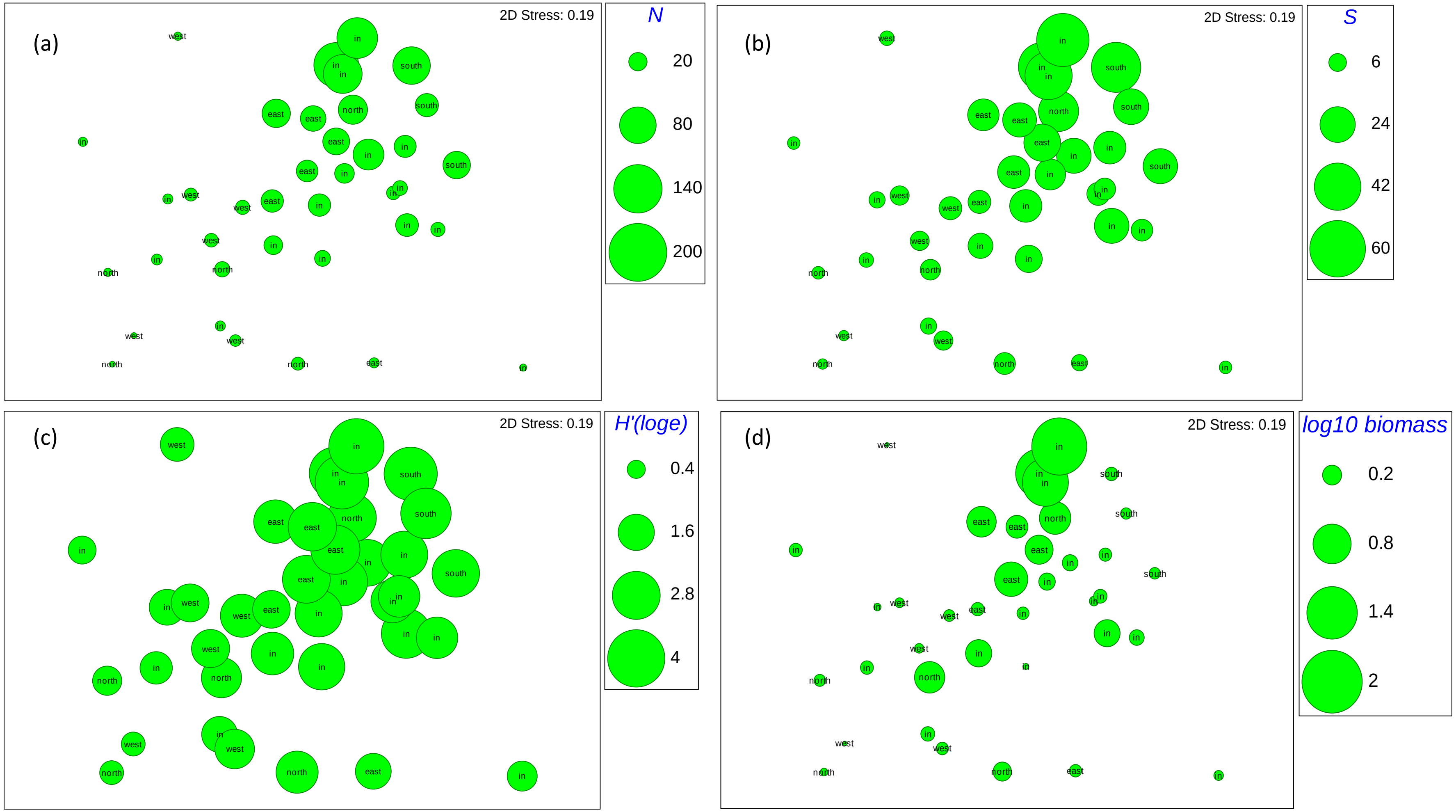


Figure A2.3.9(a-d). nMDS ordination plots of the assemblage structures of the macrofauna of the stations sampled at South Falls, 2013. Figures show the values of (a) total number of individuals; (b) total species; (c) Shannon-Wiener diversity index; and (d) total wet biomass (logten scale) of each assemblage.

2.4 Site Y

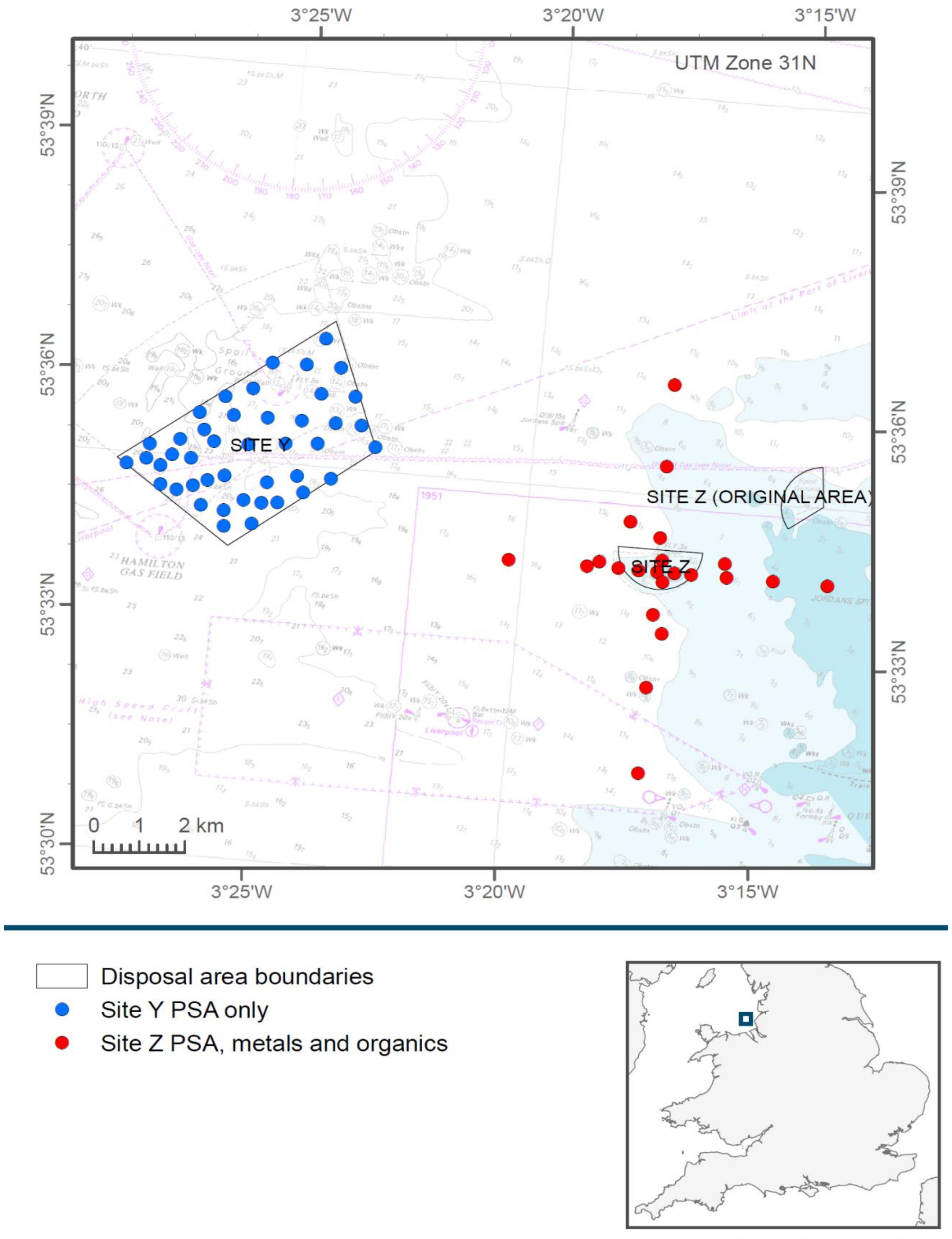


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Figure A2.4.1. Locations of the sampling stations for ground-truthing at Site Y, December 2013. Location of Site Z (and sampling stations) is also shown to reveal the close proximity of the two disposal sites.

2.4.1 Background

Site Y and Site Z, are situated within Liverpool Bay on the west coast of the UK (Figure A2.4.1). Both sites are licensed to receive dredged material resulting from dredging of the maintenance docks and navigation channels, and that of capital projects, in the Mersey Channel. Wave action in the area results principally from south westerly winds. Furthermore, residual bottom currents flow in a predominantly landward (eastward) direction; thus causing the deposited dredged material to potentially shoal.

Site Y (IS150), the largest of the two sites by area, has a seabed sloping to the south western edge of the site, with large sand waves to the western side of the site orientated north to south. The average water depth for the disposal site is 20 m below Chart Datum with the northeastern section shallowing to approximately 16 m, while the deeper waters (27 m below Chart Datum) can be found in the northwest. The sediments within this site are generally moderately well sorted, slightly gravelly sand. Approximately 1.8 MT (wet weight) of capital dredge material was disposed of to Site Y during 2013. This capital material was derived from the construction of the new deep water container terminal, Liverpool II, at the old Seaforth docks. To prevent shoaling at Site Y, the stiff, consolidated material was licensed to be disposed of in a grid fashion, with the subsequent finer maintenance dredge material to be disposed as evenly as possible over the disposal site. As the disposal site is bisected by the Hamilton pipeline, a buffer of 500 m was imposed as another condition of the disposal licence. Although the capital material from Liverpool II is geological and, therefore, not expected to pose a contamination risk, there are issues associated with its non-dispersive characteristics leading to potential shoaling, or from the formation of clay balls that have the potential to interfere with fishing gear in the area.

In addition, extensive sampling of the Seaforth Triangle at Liverpool docks has been undertaken by the developers to redefine an excluded area that was, initially, not considered acceptable for disposal to sea. Although all the resulting contaminants data for the material permitted the material for disposal to sea (i.e. all concentrations were below Cefas AL2), there remained the potential for elevated levels of certain heavy metals, particularly Hg, and PAHs, than material previously received at this disposal site.

Site Z (IS140), which has been in use as a disposal site since the late 1800's, was moved to the present location in 1982 (Figure A2.4.1) to the west of the 'old' Site Z as a result of shoaling in the centre of the licensed area. This site is shallower than Site Y and has sediments comprising predominantly unimodal sands with some sandy muds/muddy sands. 1.16 MT (wet weight) of capital and 0.4 MT (wet weight) of maintenance dredge material were disposed of to Site Z during 2013. This is more-or-less in line with average annual tonnages disposed of to this site (1.7 MT per annum since 1986). The maintenance material is derived from the Liverpool and Birkenhead docks and the approach channel to the river Mersey; this region naturally shallows due to the deposition of fine material and requires frequent dredging to maintain viable depths. The site also received some of the less-stiff capital dredge material from the construction of Liverpool II. As the site shoals, quantities of capital dredge material disposed to this site are limited and very dependent on their physical characteristics.

2.4.2 Parameters to be assessed

Sediment particle size

Multibeam acoustics

2.4.3 Results

2.4.3.1 Sediment particle size

The seabed sediments within the Site Y disposal site are predominantly unimodal sands and muddy sands (Table A2.4.1). No temporal comparisons are possible for this site as it is the first time that a comprehensive spatial seabed survey has been undertaken here under SLAB5. At Y14, the sediment collected contained a clay lump which has been analysed independently from the rest of the samples. Members of the sediment group SiY1, namely Y03, Y05, Y10, Y14 (clay lump), Y20, Y40, Y41 and Y42, are all located towards the deepest, southwestern region of the disposal site. The sediments have greater proportions of silt/clay and, in some cases, gravel, than the slightly gravelly sand sediments found across the rest of the survey region (Table A2.4.2, Figures A2.4.2 and A2.4.3).

Table A2.4.1 Average sediment descriptions and statistics for each sediment group at Site Y.

Sediment group	Number of samples	Sample Type	Sediment description
SiY1	8	Bimodal, Very Poorly Sorted	Gravelly Muddy Sand
SiY2	1	Trimodal, Very Poorly Sorted	Muddy Sandy Gravel
SiY3a	9	Unimodal, Moderately Sorted	Slightly Gravelly Sand
SiY3b	3	Unimodal, Moderately Sorted	Slightly Gravelly Sand
SiY3c	12	Unimodal, Moderately Well Sorted	Slightly Gravelly Sand
SiY3d	11	Unimodal, Moderately Well Sorted	Slightly Gravelly Sand

Sediment group	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
SiY1	9.39	68.61	22.00	2.24	13.06	31.06	18.91	3.35
SiY2	59.02	31.23	9.75	2.76	8.35	12.17	6.07	1.87
SiY3a	1.57	93.56	4.87	0.79	13.52	51.89	26.85	0.51
SiY3b	4.10	93.56	2.34	2.06	40.76	44.24	6.34	0.16
SiY3c	0.58	98.67	0.75	0.53	17.22	64.57	16.34	0.01
SiY3d	0.44	99.34	0.23	1.23	29.66	58.88	9.56	0.00

Table A2.4.2 Sediment groups for each sample code in 2013 at Site Y.

Sample	Sediment group
Y01	SiY3b
Y02	SiY3b
Y03	SiY1
Y04	SiY3b
Y05	SiY1
Y06	SiY3d
Y07	SiY3a
Y08	SiY3d
Y09	SiY3d
Y10	SiY1
Y11	SiY3d
Y12	SiY3c
Y13	SiY3a
Y14_clay	SiY1
Y14_sand	SiY3a
Y15	SiY3c
Y16	SiY3a
Y17	SiY3c
Y18	SiY3d
Y19	SiY3a
Y20	SiY1
Y21	SiY3c
Y22	SiY3d
Y23	SiY2
Y24	SiY3c
Y25	SiY3a
Y26	SiY3c
Y27	SiY3c
Y28	SiY3d
Y29	SiY3a
Y30	SiY3c
Y31	SiY3d
Y32	SiY3c
Y33	SiY3a
Y34	SiY3c
Y35	SiY3c
Y37	SiY3d
Y38	SiY3c
Y39	SiY3d
Y40	SiY1
Y41	SiY1
Y42	SiY1
Y43	SiY3d
Y44	SiY3a

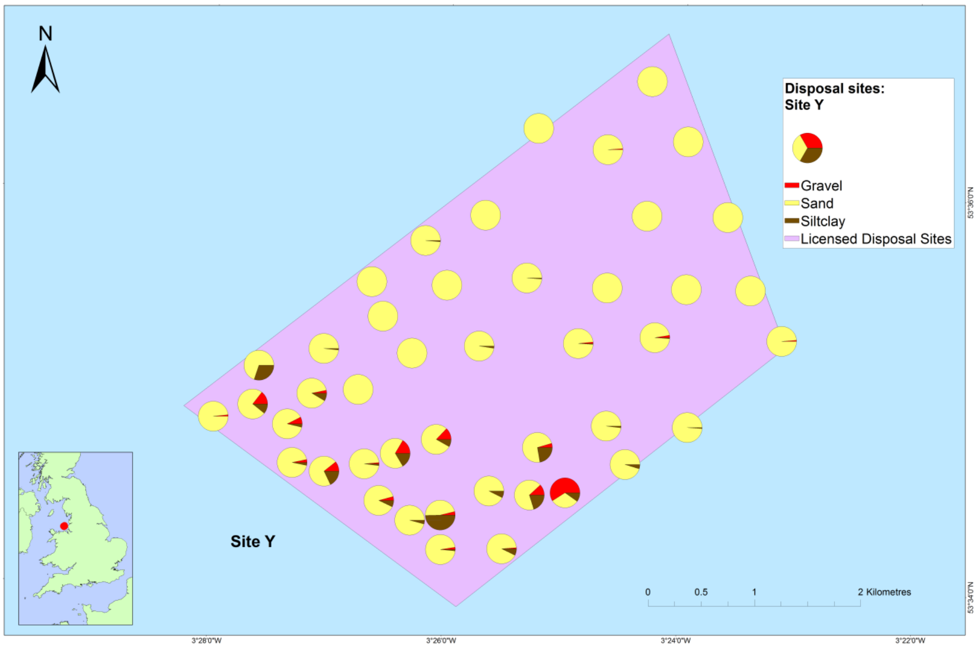


Figure A2.4.2. Pie charts of gravel, sand and silt/clay at Site Y, 2013.

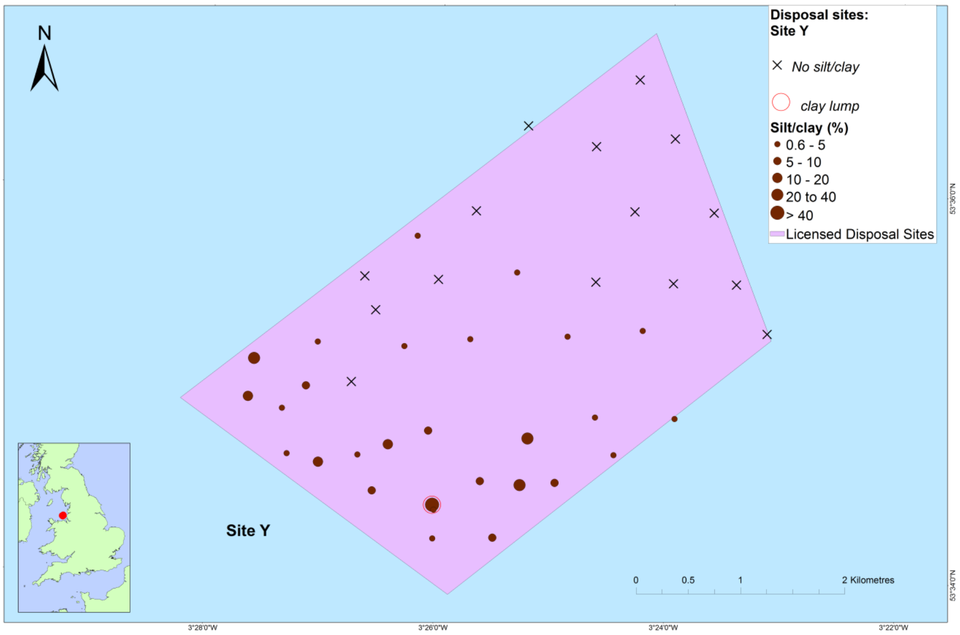


Figure A2.4.3. Silt/clay content (%) of sediments sampled at Site Y, 2013.

2.4.3.2 Acoustics

To enable the characterisation of Site Y licensed disposal site, an acoustic and ground truth survey was conducted in December 2013 on board the RV *Prince Madog*. The School of Ocean Sciences, University of Bangor, were sub-contracted by Cefas to acquire the multibeam bathymetry and backscatter data. A Reson Seabat 7125 SV multibeam echosounder was used to gather the acoustic data operating at 400 kHz in auto pilot mode. In addition, GPS and motion sensor data were acquired using an Applanix POSMV system.

To support the interpretation of acoustic data, the site was additionally investigated by grab sampling. A Shipek grab was utilised to collect a complete sample of the seabed within the disposal area at pre-planned sample locations. A sampling grid was devised, to provide a good spatial coverage, and additional sample locations were subsequently chosen on-board while some pre-determined stations were moved depending on survey requirements. For example, a pipeline and subsequent exclusion zone for the Douglas Complex Oil Field runs across the centre of the site, resulting in the inability to collect seabed samples from within the buffer zone (Figure A2.4.4). The sediment data that were acquired from the Shipek grabs are presented in Section 2.4.3.1.

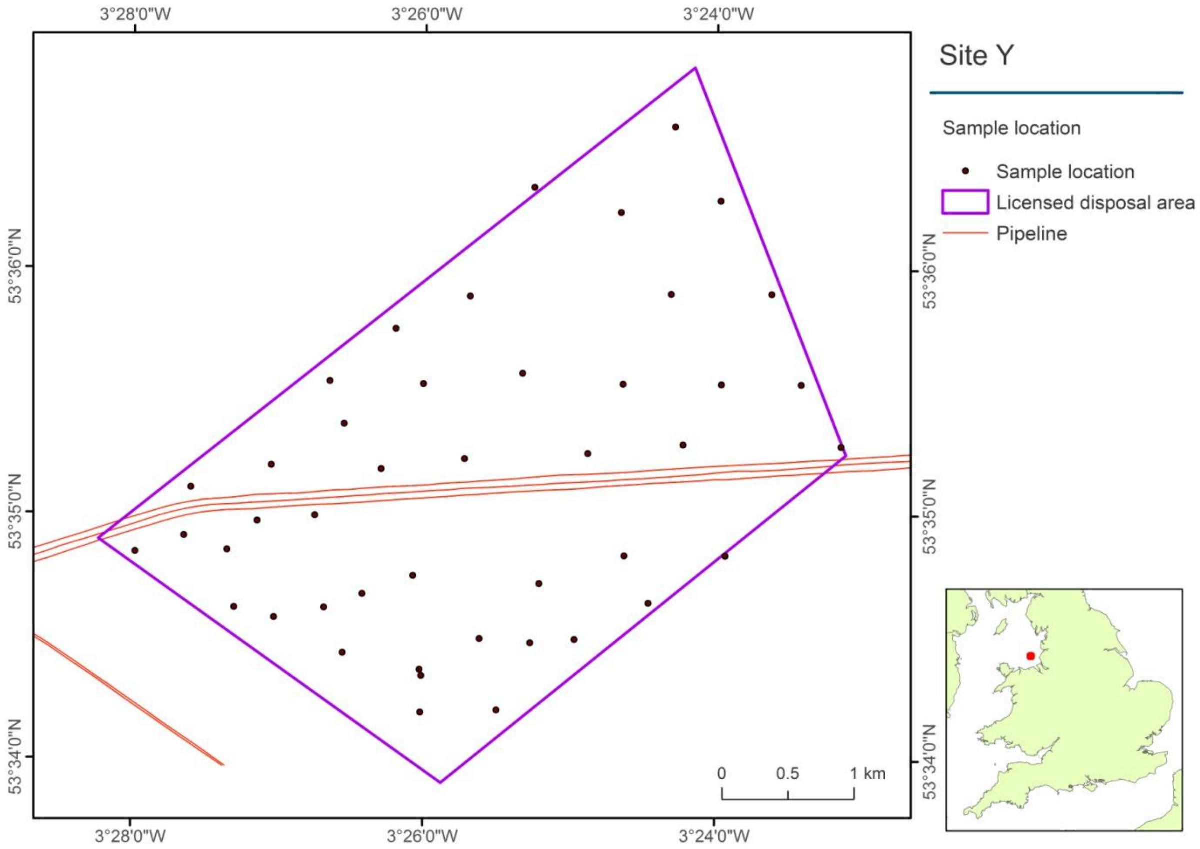


Figure A2.4.4. Site Y location map with pipelines and sample point locations identified.

The multibeam bathymetry data gathered were of a good quality and identified a seabed sloping to the south western edge of the site. Large sand waves can be seen to the western side of the site orientated north to south (Figure A2.4.5). The average water depth for the site is 20 m below Chart Datum with the north eastern section shallowing to approximately 16 m. The deeper waters can be found in the northwest, reaching around 27 m depth (Figure A2.4.5).

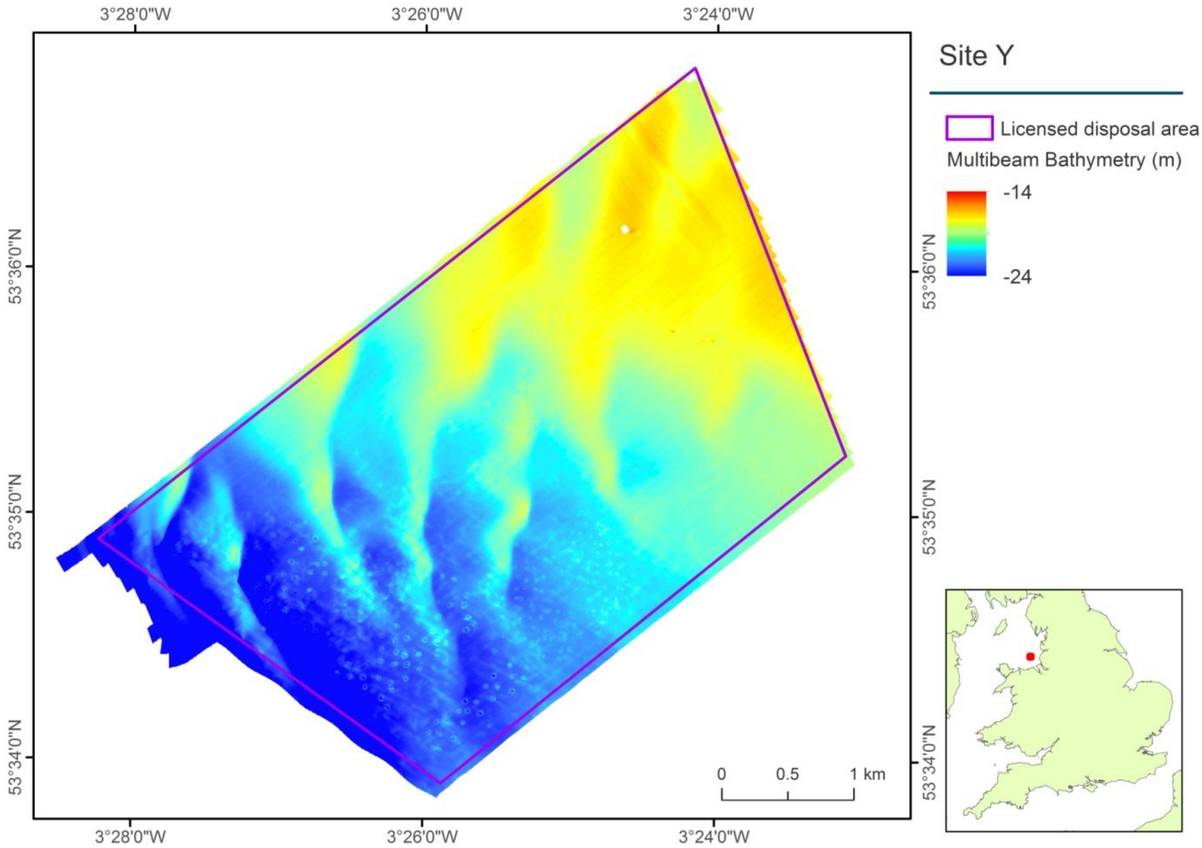


Figure A2.4.5. Multibeam bathymetry at Site Y collected in December 2013.

Multibeam backscatter derived from the bathymetry can be seen in Figure A2.4.6. The site appears to be relatively homogenous and largely comprised of a medium backscatter return indicating a seabed consistent with sandy sediments. The disposal of dredged material has altered the physical characteristics of the seabed; impact craters can be clearly seen on the multibeam backscatter as low intensity returns. These circular ring craters have an average diameter of 25 m and range between 0.5 and 1 m in depth. Figure A2.4.7 ***Figure*** presents a detailed view of an example disposal feature in the southwest of the site using QPS Fledermaus geo-spatial software. The profile displays a section covering 90 m in distance across the disposal material, the impact crater reaches 2 m in depth with a slope of approximately 1°. The greyscale image displays the multibeam backscatter draped over the bathymetry from a 3D view. A vertical exaggeration of 0.5 m has been applied to the image which clearly portrays a disposal feature’s geomorphology and sediment constitution.

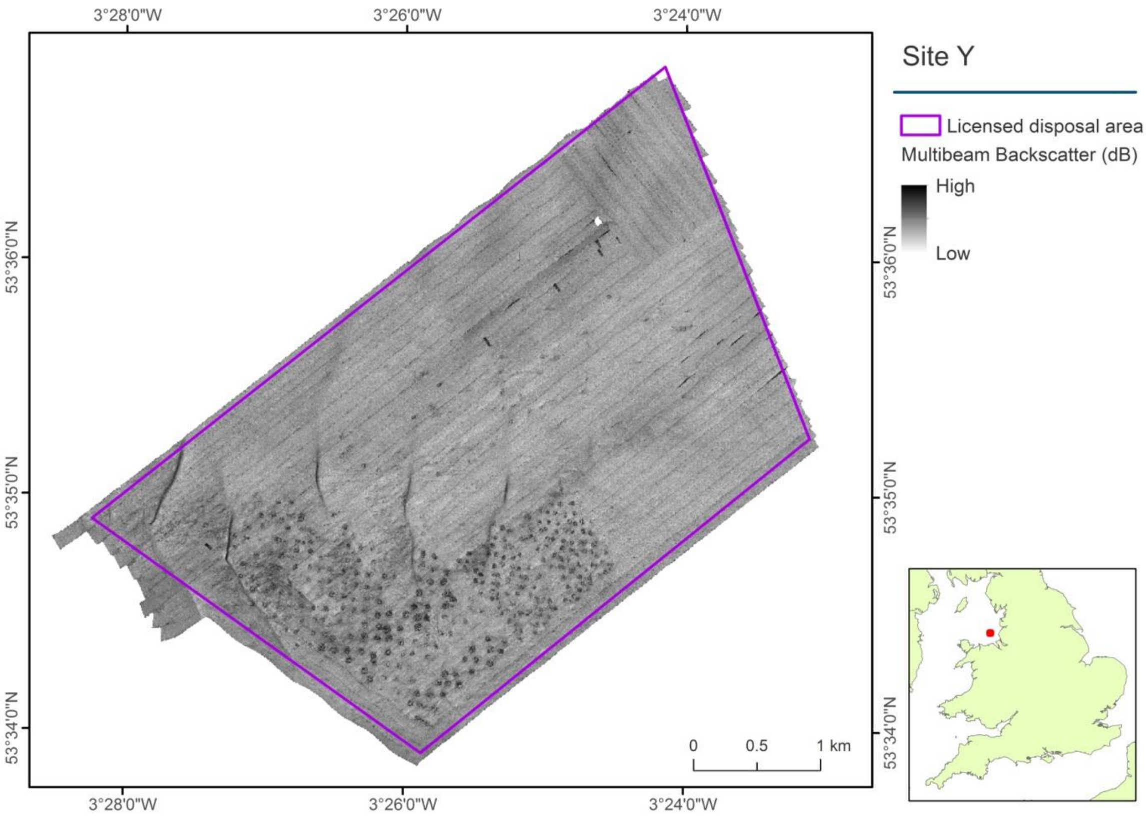
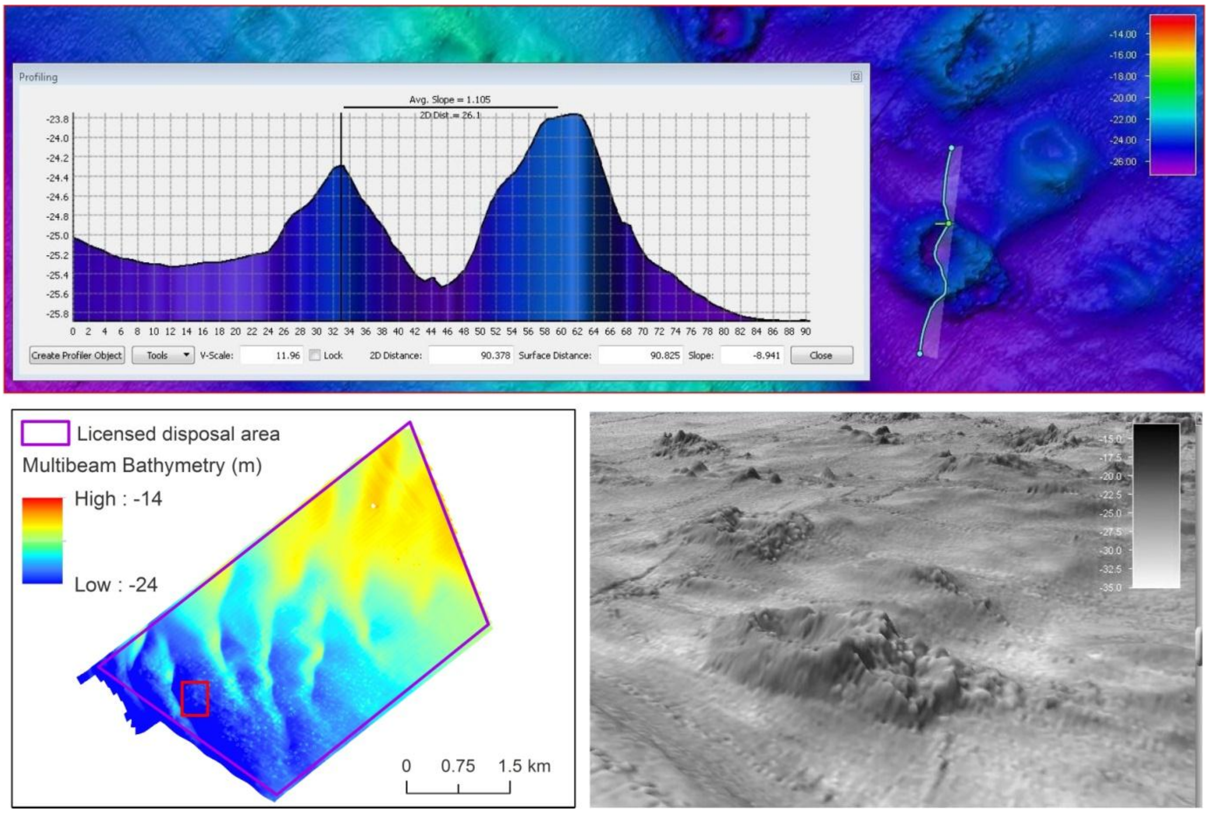


Figure A2.4.6. Multibeam backscatter derived from bathymetry collected at Site Y disposal site.


Avg. Slope = 1.105
2D Dist. = 26.1

V-Scale: 11.96 ☐ Lock 2D Distance: 90.378 Surface Distance: 90.825 Slope: -8.941

Figure A2.4.7. Disposal material 3d profile and backscatter draped over bathymetry (vertical exaggeration 0.5 m applied to the drape).

Manual interpretation of the acoustic and sediment particle size data from the grabs was conducted using Arc 10.1 to derive sediment boundaries within Site Y (Figure A2.4.8). The majority of the site is comprised of sandy sediments, supported by the evidence of prominent sand wave features on the multibeam bathymetry data. The dredged material appears to have been disposed according to a structured grid. Furthermore, the disposal regime has clearly concentrated on the deeper, southern parts of the site as per the license condition 3.2.15 (see below). The backscatter returns in this particular area suggest sediments of a mixed nature with possible gravel constituents. Due to their impact nature and backscatter intensity readings (Figure A2.4.9), the material disposed of to create the craters is likely to include clay deposits.

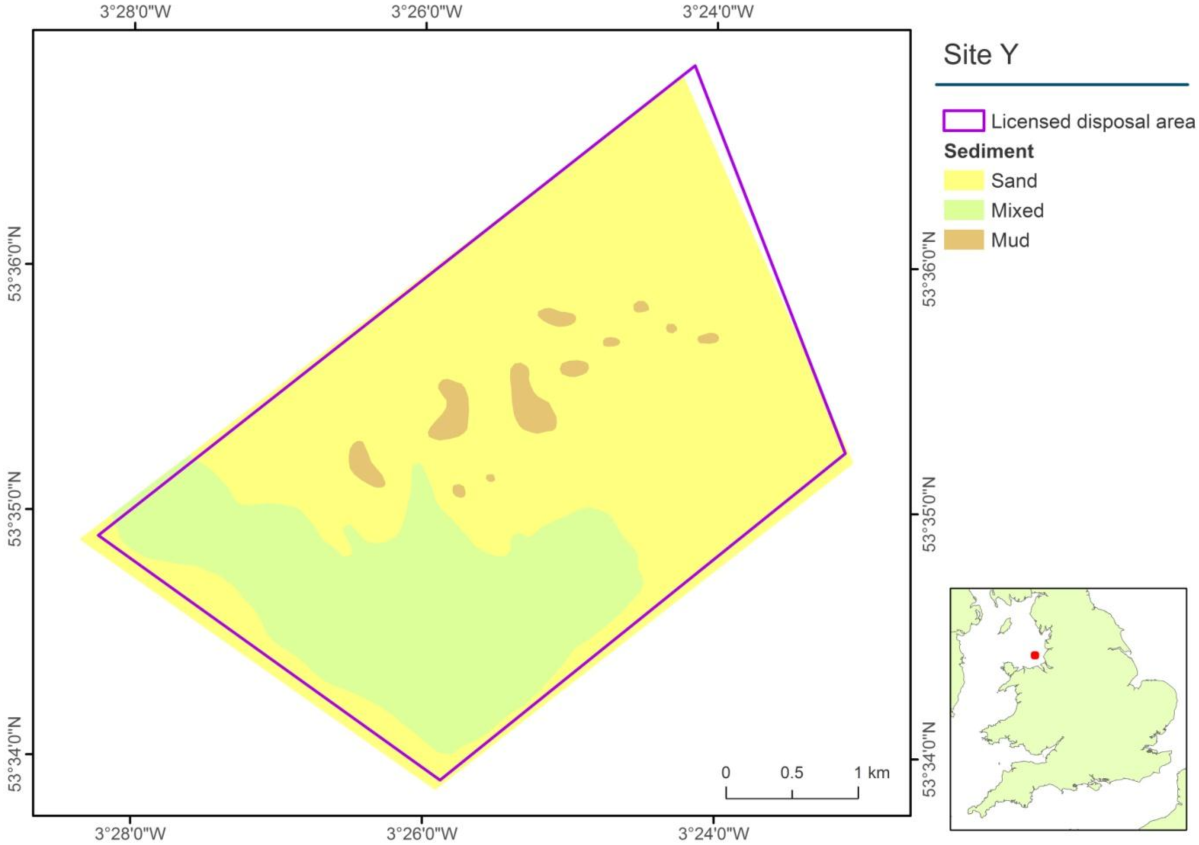


Figure A2.4.8. Sediment composition within the Site Y disposal site, December 2013.

The following license conditions were attributed to Site Y licensed disposal site:

3.2.15 The Licence Holder must ensure that the limit on shallowing of 18 m water depth at disposal Site Y is not breached.

Although tidal datum has not been indicated in the licence condition, the lowest shallowing depth observed from the December 2013 survey was 17 m to the north eastern edge. The majority of the licensed site remains navigable, therefore, the possibility of a breach of 18 m is negligible considering tidal shifts.

3.2.16 The Licence Holder must ensure that stiff clay is deposited at least 100 m from the boundary of Site Y.

An average distance of 175 m has been achieved from the licensed boundary to the first contact with disposal material (see Figure A2.4.9).

3.2.17 The Licence Holder must ensure that a zoned approach is taken to the disposal of stiff clay at Site Y.

The stiff clay has been disposed of in a gridded approach ensuring zoning and an even disposal regime is achieved. The impact craters observed on the bathymetry and backscatter are clear evidence of this.

3.2.18 The Licence Holder must ensure that there is a buffer zone of at least 100 m around the gas pipelines which pass through Site Y.

Dredged material is absent from the majority of the pipeline route and the associated buffer area, however, there are a few instances where disposed material appears in the vicinity of, or directly on top of, the pipelines. These pipelines are submerged and no evidence of their presence appears on the multibeam data (see Figure A2.4.10). These craters do not appear to correspond with the otherwise gridded disposal pattern elsewhere within the disposal site, implying that they possibly reflect either accidental loss of material or sediment drifting following material release.

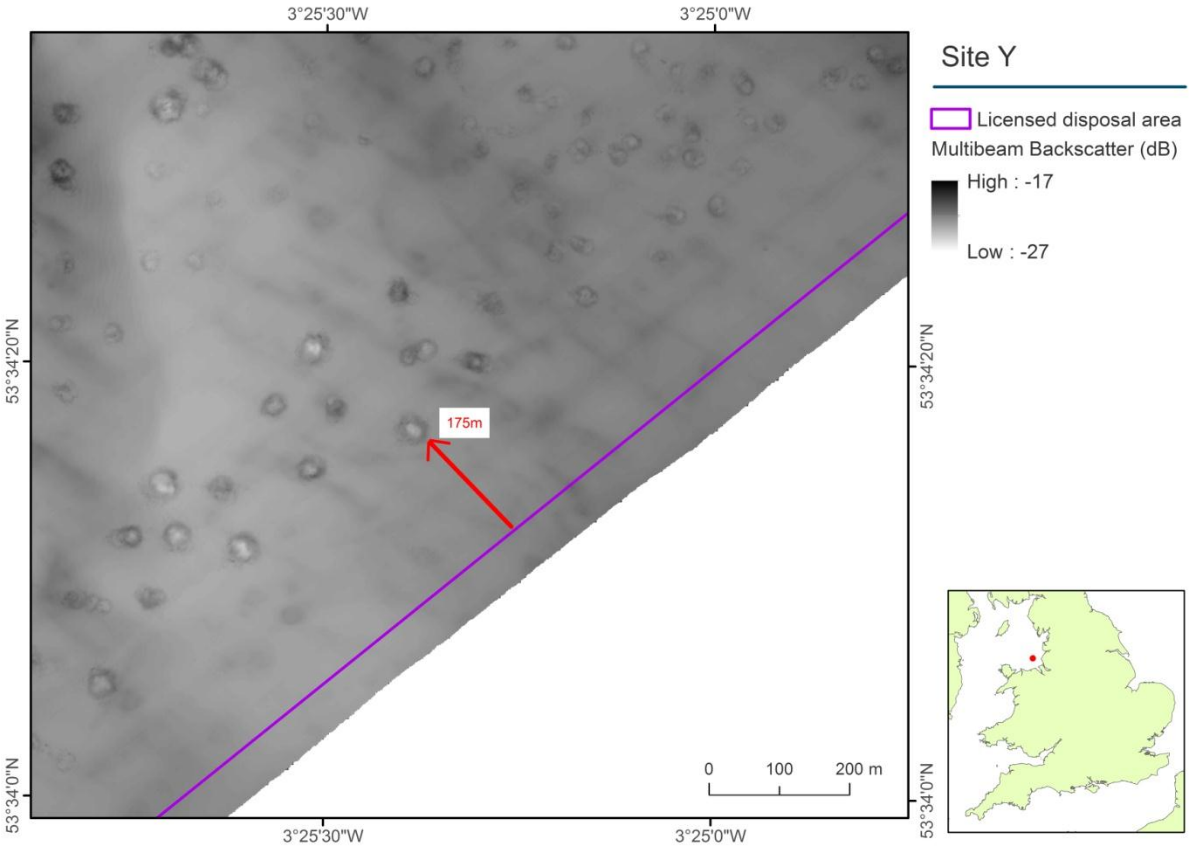


Figure A2.4.9. Multibeam backscatter with the buffer zone as per License Condition 3.2.16 (see text).

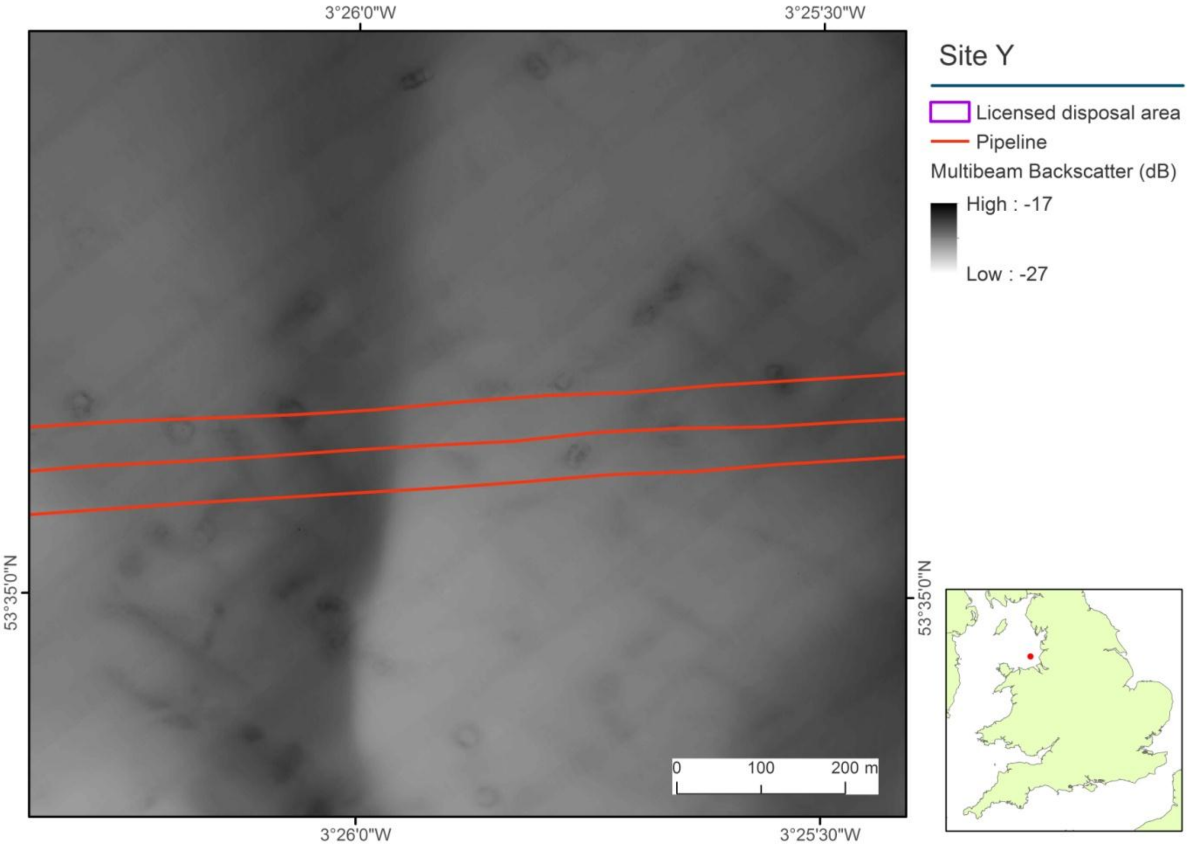


Figure A2.4.10. Multibeam backscatter and the pipeline route as per License Condition 3.2.18 (see text).

2.6 Site Z

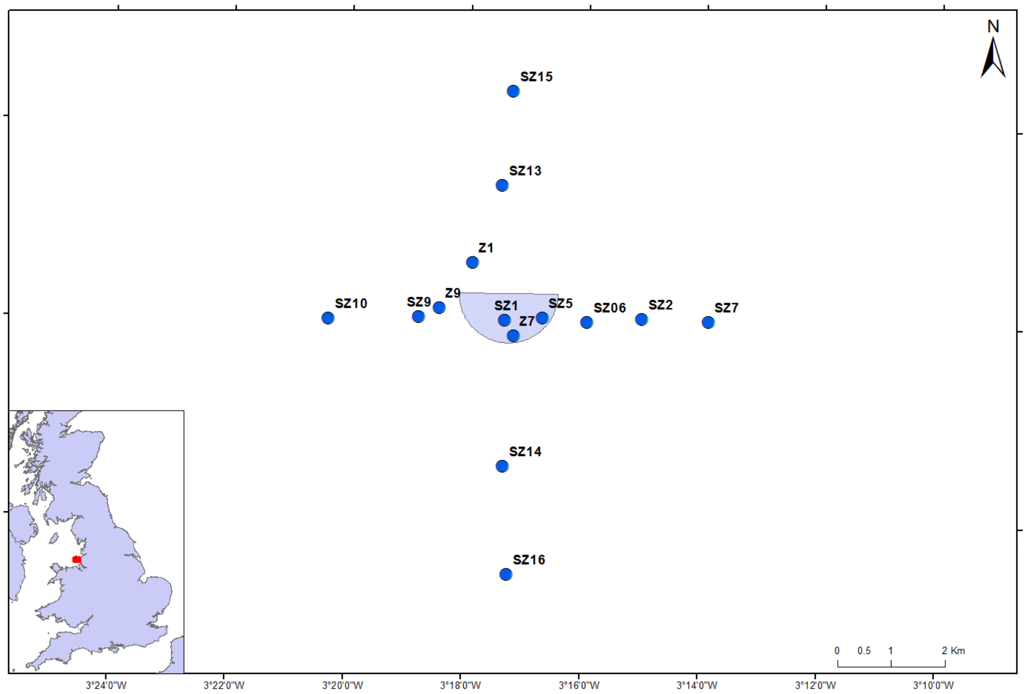


Figure A2.5.1. Location of the stations sampled at Site Z disposal site, December 2013.

2.5.1 Background

The background pertaining to Site Z is presented together with that for Site Y due to the inherent inter-relationships and shared issues of these two sites (see Section 2.4.1).

RAT prioritisation assessment: Tier 2.

2.5.2 Parameters monitored:

Sediment particle size

Sediment organic carbon

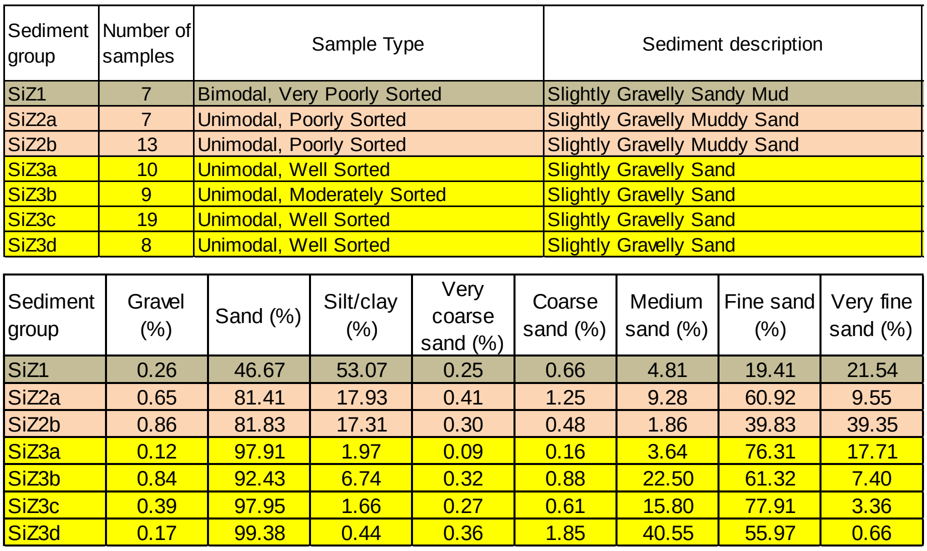
Sediment contaminants (TBT, PAHs, organohalogens, trace metals)

2.5.3 Results

2.5.3.1 Sediment particle size

The sediments within and surrounding the Site Z disposal site are predominantly unimodal sands, with some muddy sands and muds (Table A2.5.1). The temporal changes in sediment groups for sampling stations since 2006 (or 2010 for most stations) are minimal except at SZ14 (south of the disposal site), SZ9 (west of the site), Z1 (immediately northwest of the site) and, to a lesser extent, within the disposal site at Z7 (Table A2.5.2).

Table A2.5.1 Average sediment descriptions and statistics for each sediment group at Site Z.



Sediment group	Number of samples	Sample Type	Sediment description
SiZ1	7	Bimodal, Very Poorly Sorted	Slightly Gravelly Sandy Mud
SiZ2a	7	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand
SiZ2b	13	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand
SiZ3a	10	Unimodal, Well Sorted	Slightly Gravelly Sand
SiZ3b	9	Unimodal, Moderately Sorted	Slightly Gravelly Sand
SiZ3c	19	Unimodal, Well Sorted	Slightly Gravelly Sand
SiZ3d	8	Unimodal, Well Sorted	Slightly Gravelly Sand

Sediment group	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
SiZ1	0.26	46.67	53.07	0.25	0.66	4.81	19.41	21.54
SiZ2a	0.65	81.41	17.93	0.41	1.25	9.28	60.92	9.55
SiZ2b	0.86	81.83	17.31	0.30	0.48	1.86	39.83	39.35
SiZ3a	0.12	97.91	1.97	0.09	0.16	3.64	76.31	17.71
SiZ3b	0.84	92.43	6.74	0.32	0.88	22.50	61.32	7.40
SiZ3c	0.39	97.95	1.66	0.27	0.61	15.80	77.91	3.36
SiZ3d	0.17	99.38	0.44	0.36	1.85	40.55	55.97	0.66

The spatial variation in the proportional representation of gravel, sand and silt/clay for each sampling station in 2013 is shown in Figure A2.5.2 and the percentages of silt/clay content in Figure A2.5.3. SZ9 and SZ16 have the highest silt/clay content (>50%). These data support the notion of the slightly gravelly muddy sand and slightly gravelly sand sediment groups obtained from the full PSA data for the area, the former group (with an elevated silt/clay component) being found particularly to the west and south of the disposal site.

Table A2.5.2. Sediment groups for each sampling station between 1996 and 2013 inclusive at Site Z.

	Year						
Sample code	1996	2001	2002	2003	2006	2010	2013
SZ1	nm	nm	nm	nm	nm	SiZ3c	SiZ3a
SZ2	nm	nm	nm	nm	nm	SiZ3c	SiZ3c
SZ3	nm	nm	nm	nm	nm	SiZ3c	nm
SZ4	nm	nm	nm	nm	nm	SiZ2b	nm
SZ5	nm	nm	nm	nm	nm	SiZ3a	SiZ3a
SZ6	nm	nm	nm	nm	nm	SiZ3a	SiZ3a
SZ7	nm	nm	nm	nm	nm	SiZ3c	SiZ3c
SZ8	nm	nm	nm	nm	nm	SiZ3a	nm
SZ9	nm	nm	nm	nm	nm	SiZ2b	SiZ1
SZ10	nm	nm	nm	nm	nm	SiZ2a	SiZ2a
SZ11	SiZ3b	nm	nm	nm	nm	SiZ3d	nm
SZ12	SiZ3b	nm	nm	nm	nm	SiZ3c	nm
SZ13	nm	nm	nm	nm	nm	SiZ3d	SiZ3c
SZ14	nm	nm	nm	nm	nm	SiZ3c	SiZ1
SZ15	nm	nm	nm	nm	nm	SiZ3d	SiZ3d
SZ16	nm	nm	nm	nm	nm	SiZ1	SiZ1
Z1	SiZ3b	SiZ2a	SiZ3c	SiZ3c	SiZ3c	SiZ3b	SiZ2a
Z2	SiZ3b	SiZ3d	SiZ3c	SiZ3c	SiZ3c	SiZ3c	nm
Z3	SiZ3b	SiZ2b	SiZ3b	SiZ3c	SiZ3c	SiZ3c	nm
Z4	nm	SiZ3a	SiZ2b	SiZ2a	SiZ2b	SiZ2b	nm
Z6	nm	nm	nm	SiZ3d	SiZ3d	SiZ3d	nm
Z7	SiZ3b	nm	nm	nm	SiZ1	SiZ3a	SiZ2b
Z8	nm	nm	nm	SiZ3b	nm	nm	nm
Z9	nm	nm	nm	SiZ2b	SiZ2b	SiZ2b	SiZ2b
Z10	nm	nm	nm	nm	SiZ2a	nm	nm
Z11	nm	nm	nm	nm	SiZ2b	nm	nm
Z12	nm	nm	nm	nm	SiZ2b	nm	nm
Z13	nm	nm	nm	nm	SiZ1	nm	nm
Z14	nm	nm	nm	nm	SiZ3a	nm	nm
Z15	nm	nm	nm	nm	SiZ2a	nm	nm
Z16	nm	nm	nm	nm	SiZ1	nm	nm
Z17	nm	nm	nm	nm	SiZ3a	nm	nm

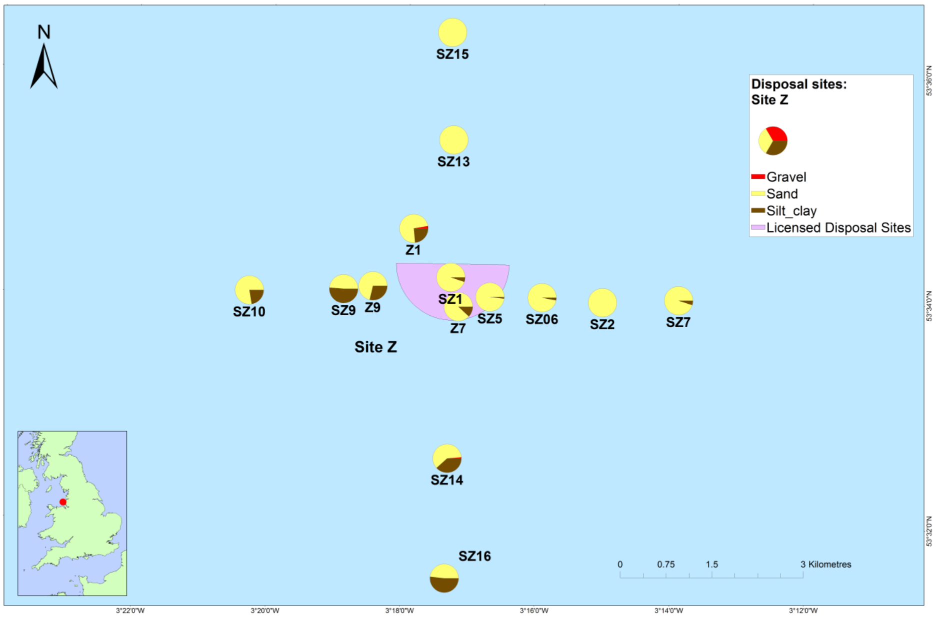


Figure A2.5.2. Pie charts of gravel, sand and silt/clay at Site Z in 2013.

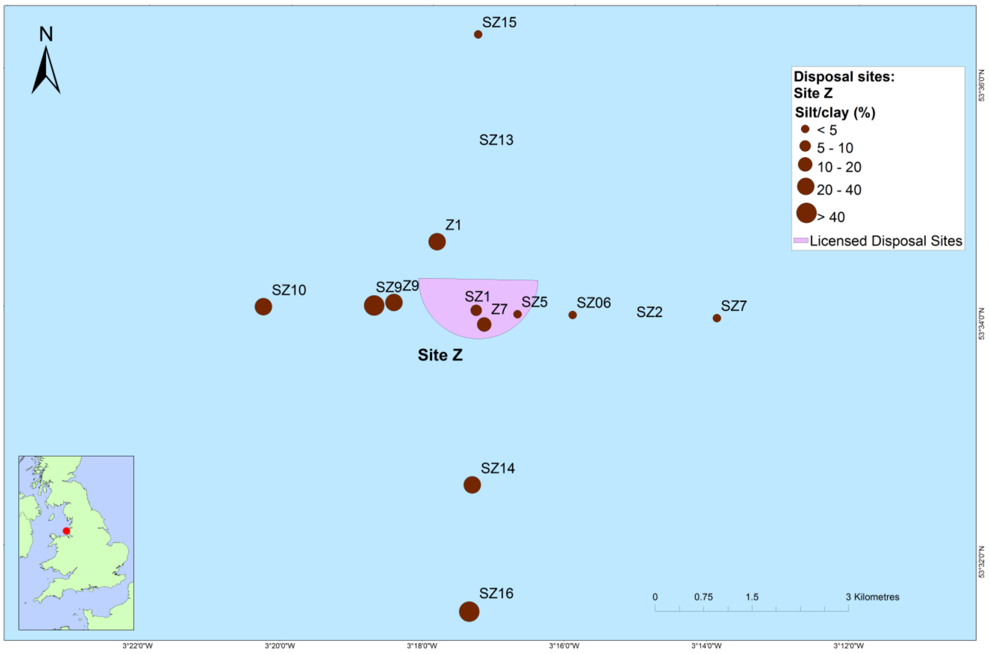


Figure A2.5.3. Silt/clay content (%) of sediments sampled at Site Z in 2013.

2.5.3.2 Sediment organic carbon

Organic carbon values (in the <2 mm sediment fraction) range from 0.03 to 0.91 % (Figure A2.5.4), while those of the <63 µm sediment fraction range from 1.14 to 2.13 % (Figure A2.5.5). SZ2 and SZ13 had low silt/clay content (1 % silt/clay) and so it was not possible to measure the organic carbon in the <63 µm sediment fraction for these stations. In general, these organic carbon content values are similar to those observed in previous years for this survey area (Bolam et al., 2011).

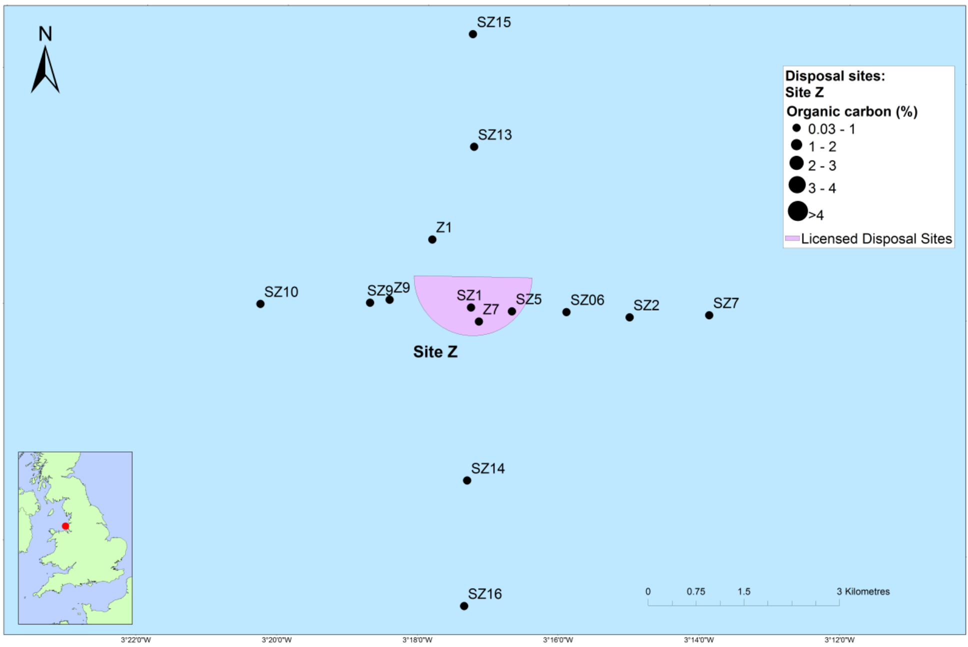


Figure A2.5.4. Organic carbon (%) in the <2 mm fraction at Site Z in 2013.

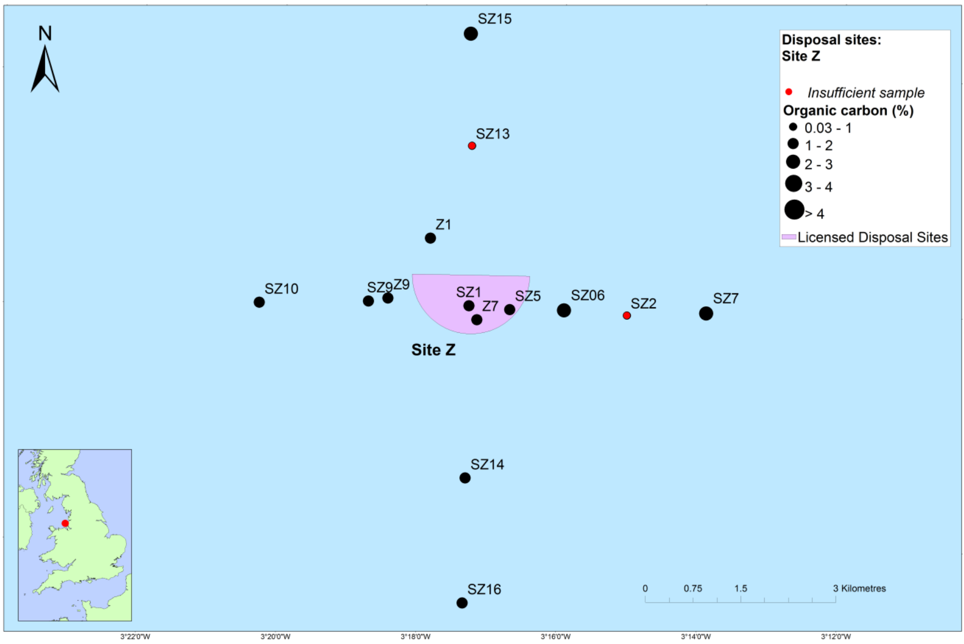


Figure A2.5.5. Organic carbon (%) in the silt/clay fraction (<63 µm) at Site Z in 2013.

2.5.3.3 Sediment contaminants

2.5.3.3.1 TBT

During the 2013 survey, 14 samples were collected for TBT and DBT analysis within and outside the Site Z disposal site. The results obtained from analysis of these samples reveal that concentrations of both DBT and TBT are below the LOD for all stations. This finding is consistent with the previous years' TBT levels (Bolam et al., 2011).

2.5.3.3.2 PAHs

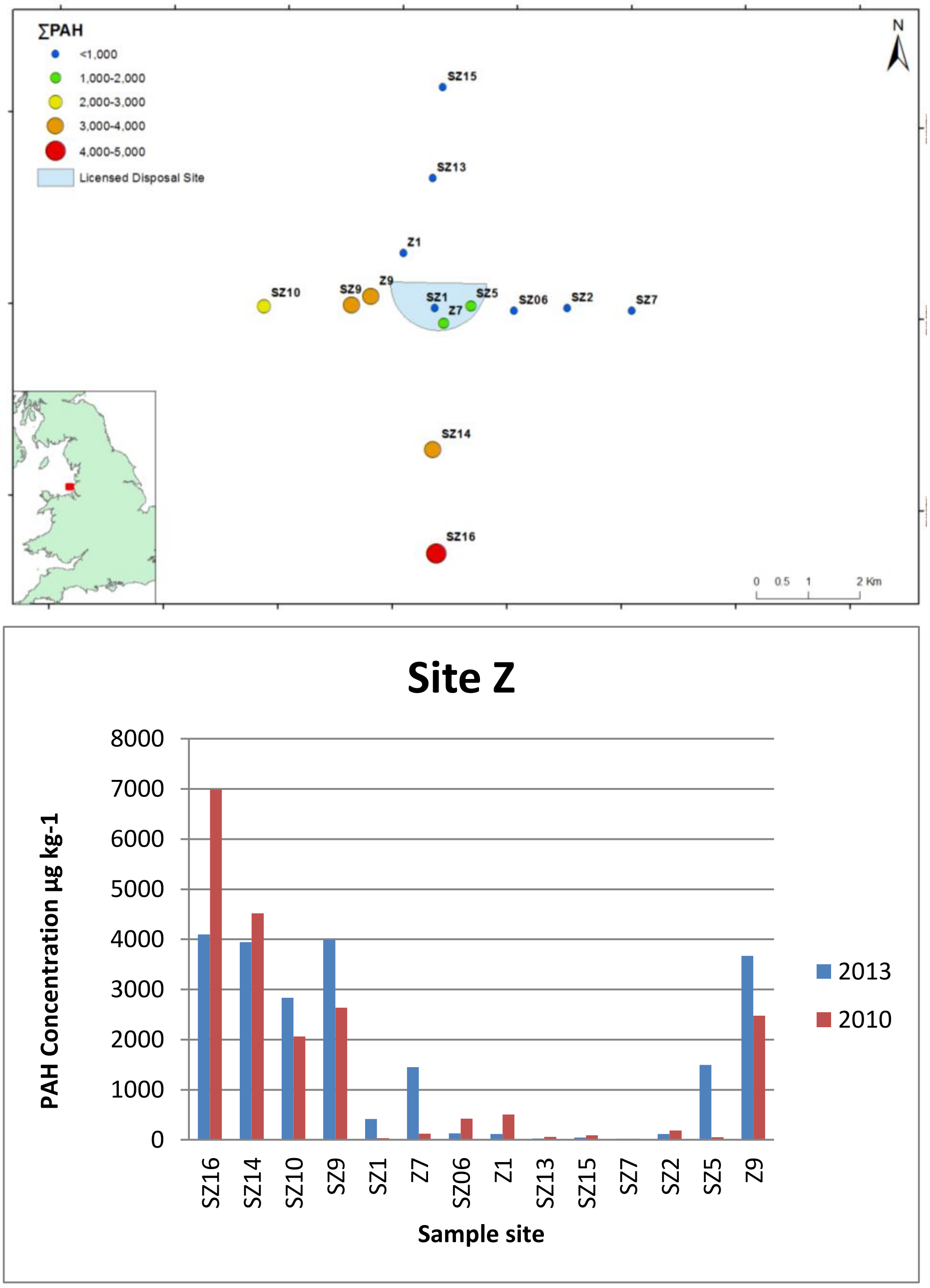


Figure A2.5.6. Summed PAH concentrations (µg kg^{-1} dry weight) for stations sampled in 2013 (top) and concentrations observed in 2010 and 2013 (bottom) at Site Z.

The highest summed PAH concentration at Site Z was found to the south of the disposal site at SZ16 (4,100 µg kg^{-1} dry weight) which is slightly lower than the highest value (6,990 µg kg^{-1} dry weight) found in 2010 at this station (Figure A2.5.6). The lowest concentrations were found in samples to the north and east of the disposal area (Figure A2.5.6). At SZ7, approximately 2.5 Km from the eastern boundary of the disposal site, the summed PAH concentration was 23 µg kg^{-1} dry weight, with comparably low values being observed to the north and east of the disposal site (Figure A2.5.6). Relatively high PAH concentrations were found to the west and south of Site Z. The ERL for LMW PAHs was breached at SZ16 to the south of the disposal area and at SZ10 to the west, but the ERM for LMW PAHs was not exceeded at any station. Furthermore, no stations exceeded the ERL and ERM for HMW PAHs.

A dominant combustion/petrogenic PAH source was observed for SZ10 (within the disposal site), which showed a 75% petrogenic source. Dredging disposal volume at Site Z was 1.14 MT higher in 2012 than in the previous year, this increase could perhaps be responsible for the general PAH increases in concentrations found in 2013 compared to those found in 2010 (Figure A2.5.6). It is interesting to note, that the three stations inside the disposal site show an increase in PAH concentration in 2013 compared to 2010, while the two stations to the south display a decline from their previously very high concentrations.

2.5.3.3.3 Organohalogens

At Site Z, ICES 7 CBs were only detected at six of the 14 stations (∑ ICES 7 CBs range <0.7-3.5 µg/kg dw). The highest concentration (3.5 µg/kg dw) was at SZ16, the most southerly station sampled (Figure A2.5.7). ∑ ICES 7 CB concentrations were <1 µg/kg at all other stations apart from SZ9, SZ14 and Z9 (2.7, 2.6 and 3.2 µg/kg dw, respectively), all outside of the disposal site (Figure A2.5.7). Levels at all stations within the disposal site were below limits of quantification.

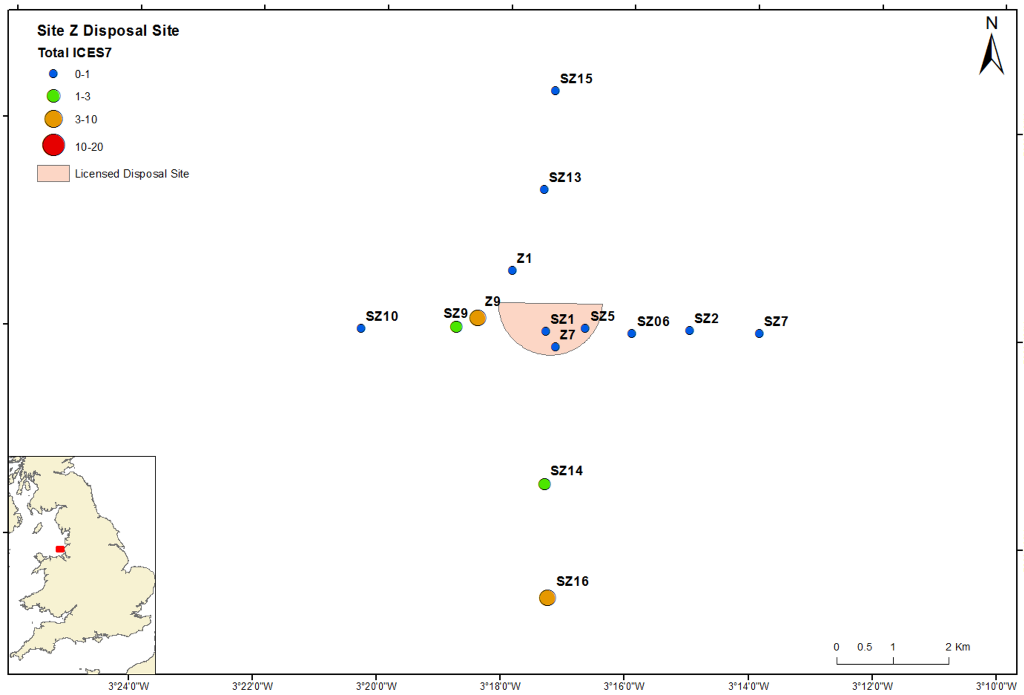


Figure A2.5.7. ∑ ICES7 CB concentrations for the Site Z stations, 2013.

At Site Z, BDEs were detected in seven of the 14 stations (∑ 11 BDEs range <0.11-0.65 µg/kg dw). One of the highest concentrations (0.63 µg/kg dw) was at SZ16. ∑ 11 BDEs concentrations were <0.3 µg/kg dw at all other stations apart from SZ9, SZ14 and Z9 (0.65, 0.59 and 0.32 µg/kg dw, respectively). Levels at all stations within the disposal site were low. Thus, there was a noticeable spatial correlation between the concentrations of ICES 7 CBs and BDEs. BDE47 and BDE99 are the dominant congeners present, indicative of the pentaBDE technical mixture, but BDE183 was also detected, suggesting that the octaBDE or decaBDE technical mixture was also in use.

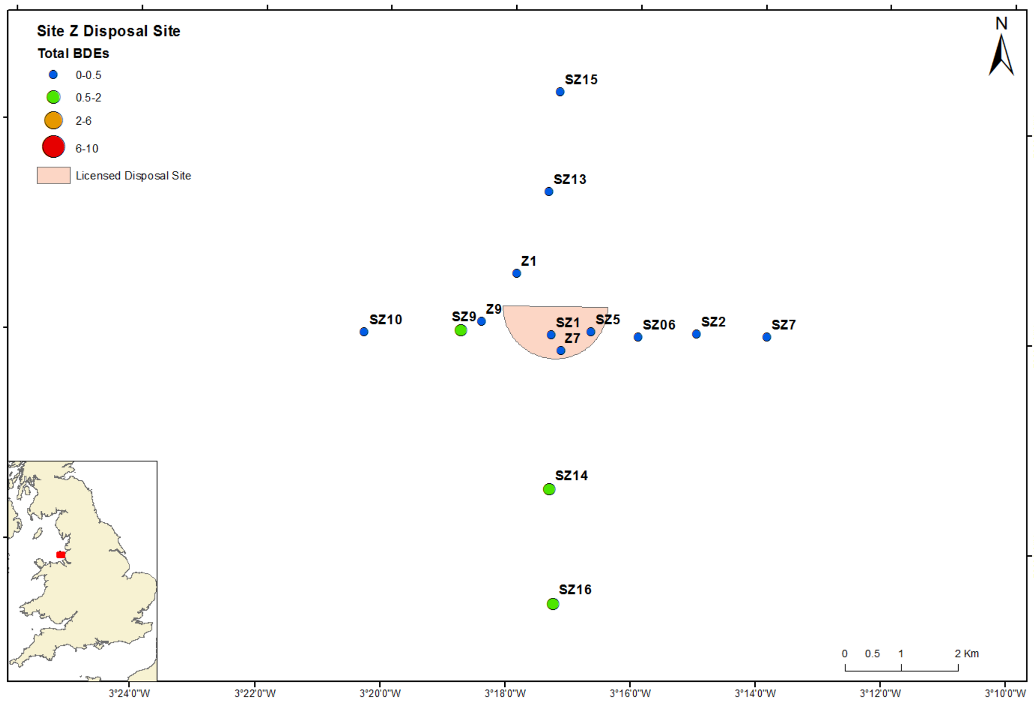


Figure A2.5.8. ∑ 11 BDEs concentrations for the Site Z stations, 2013.

BDE209 was detected in all 14 stations at Site Z, making it the most ubiquitous contaminant analysed (range 0.48-303 µg/kg dw). BDE209 made up >81% of total 12 BDEs (range 81-100%). Highest concentrations were at SZ16 and SZ14 (303 and 249 µg/kg dw, respectively) (Figure A2.5.9). High values of 207, 232 and 111 µg/kg dw were also present at stations Z9, SZ9 and SZ10, respectively, to the west of the disposal site. Within the disposal site, reasonably high values of 75 and 82 µg/kg dw were present at Z7 and SZ5, with 18.7 µg/kg dw at SZ1. All other stations had BDE209 concentration <5 µg/kg dw.

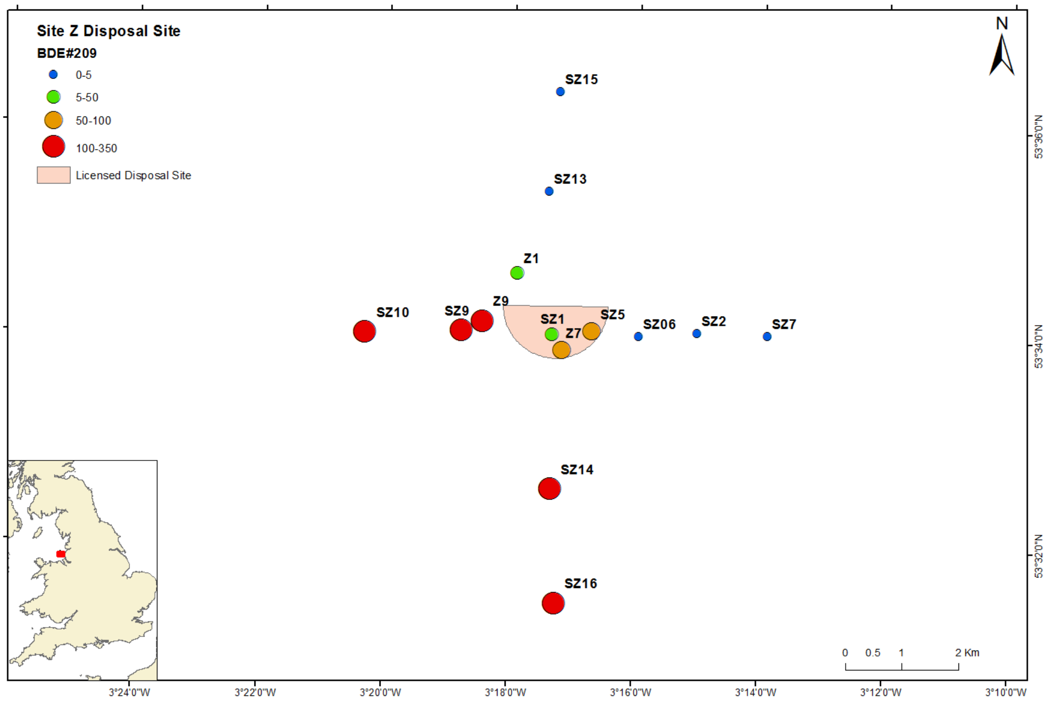


Figure A2.5.9. BDE209 concentrations for the Site Z stations, 2013.

Concentrations of CBs at all stations were below Cefas AL1, while no Cefas ALs exist for BDEs including BDE209. According to the OSPAR guidelines, most stations had ‘good’ environmental status for all ICES 7 CBs and ‘good’ status overall. Exceptions, with one CB representing ‘bad’ environmental status but ‘good’ status overall, were Z7 (for CB28), and SZ9, SZ10, SZ14 and Z9 (for CB118). Station SZ16 had ‘bad’ environmental status for CB28 and CB118 and, therefore, was considered as ‘bad’ status overall. No other stations were classified as ‘bad’ status overall. No OSPAR guidelines exist for BDEs at present.

There are limited data available for some stations at Site Z from 2002, 2003, 2006 and 2010 with which to compare CB and BDE concentrations, and from 2010 with which to compare BDE209 concentrations (see Tables A2.5.3 to A2.5.5). Within the disposal site, at SZ1, Z7 and SZ5, levels of BDE209 increased by 1-2 orders of magnitude between 2010 and 2013, whereas other BDEs and CBs remained relatively low.

Table A2.5.3. Temporal trends (2002-2013) of ∑ICES 7 CBs concentration (in µg/kg) at Site Z in the stations sampled during 2013.

Station	∑ICES 7 CBs concentration (in µg/kg)							
	2002	**2003**	**~**	**2006**	**~**	**2010**	**~**	**2013**
SZ16						5.2		3.46
SZ4				1.13		*0.7*		
Z3	*0.7*	*0.7*		1.22		*0.7*		
SZ12						*0.7*		
SZ10						0.91		0.92
SZ9						1.44		2.68
Z9	2.07	*2.48*		2.57		1.06		3.16
Z4	1.56					0.99		
SZ15						*0.7*		*0.7*
SZ13						*0.7*		*0.7*
Z1		*0.7*		1.14		*0.7*		*0.7*
SZ11						*0.7*		
Z2	*0.7*			0.81		*0.7*		
SZ14						0.9		2.59
SZ1						0.81		*0.7*
Z7	*0.7*			2.4		0.84		0.82
SZ3						*0.7*		
SZ5						*0.7*		*0.7*
Z6	*0.7*	*0.7*		0.7		*0.7*		
SZ6						*0.7*		
SZ2						*0.7*		*0.7*
SZ7						*0.7*		*0.7*
SZ8						*0.7*		

Note, concentrations in italic represent estimates of concentrations for samples where all ICES 7 congener concentrations were below LODs. *Cell colours for 2013 reflect change in concentration compared to the previous observation for that station where green = decrease, and red = increase in concentration.*

Table A2.5.4. Temporal trends (2003-2013) of ∑11 BDEs concentration (in µg/kg dw) at Site Z in the stations sampled during 2013.

Station	∑ 11 BDEs concentration (in µg/kg dw)						
	2003		**2006**		**2010**		**2013**
SZ16					1.95		🟩 0.627
SZ4			*0.69*		*0.11*		
Z3	0.71		*0.69*		0.18		
SZ12					0.93		
SZ10					0.75		🟩 0.273
SZ9					1.49		🟩 0.645
Z9	0.75		1.58		0.23		🟥 0.33
Z4					0.20		
SZ15					*0.11*		*0.11*
SZ13					*0.11*		*0.11*
Z1	*0.69*		*0.69*		0.13		🟩 *0.11*
SZ11					*0.11*		
Z2			*0.69*		*0.11*		
SZ14					*0.11*		🟥 0.593
SZ1					0.31		🟩 0.292
Z7			0.79		*0.11*		🟥 0.185
SZ3					*0.11*		
SZ5					*0.11*		*0.11*
Z6	*0.69*		*0.69*		*0.11*		
SZ6					*0.11*		*0.11*
SZ2					*0.11*		*0.11*
SZ7					*0.11*		*0.11*
SZ8					*0.11*		

Note, limits of detection for BDEs improved between 2007 and 2008 and therefore values assigned to congeners below LOD are lower from 2008 onwards, resulting in a step decrease in ∑11 BDEs concentration for samples with congeners below LODs. *Cell colours for 2013 reflect change in concentration compared to the previous observation for that station where green = decrease, and red = increase in concentration.*

Table A2.5.5. Temporal trends (2010-2013) of BDE209 concentration (in µg/kg dw) at Site Z in the stations sampled during 2013.

Station code	BDE209 concentration (in µg/kg dw)		
	2010		**2013**
SZ16	302		303
SZ4	0.899		
Z3	15.9		
SZ12	15.6		
SZ10	79.0		111
SZ9	94.7		232
Z9	102		207
Z4	73.5		
SZ15	3.51		2.05
SZ13	0.822		0.66
Z1	35.6		7.59
SZ11	5.59		
Z2	1.26		0.753
SZ14	112		249
SZ1	1.56		18.7
Z7	4.52		75.3
SZ3	*0.05*		
SZ5	*0.05*		81.7
Z6	1.17		
SZ6	11.1		4.04
SZ2	*0.05*		
SZ7	*0.05*		0.478
SZ8	3.68		

Cell colours for 2013 reflect change in concentration compared to the previous observation for that station where green = decrease, and red = increase in concentration.

2.5.3.3.4 Trace metals

During the 2013 survey, 14 samples were collected for trace metals concentration assessment. Levels of enrichment for these Site Z stations using OSPAR BAC and regional baseline values are represented in Figure A2.5.10.

Concentrations of As at most stations are lower than the OSPAR BAC, indicating no enrichment. However, with the proposed baseline being lower than the OSPAR BAC (Table A1.4.1), some of the stations (including 1 station within the disposal site, Z7) were found to be slightly enriched for As when comparing with the baseline values, but the majority were not enriched for both assessments.

All stations are slightly enriched for Cd, with a higher degree of enrichment for SZ5 (within the disposal site) and station SZ2 (the east of station from the disposal site). This general finding is similar for both assessment methods.

Generally, Cu is slightly enriched at most stations except for the easterly station (SZ7) with moderate enrichment when using the OSPAR BAC approach. This enrichment is less pronounced with the baseline assessment.

The degree of trace metals enrichment is generally lower compared with the data from 2010. This can also be observed in the temporal trend showing a decrease in Cu for the stations outside the disposal site over the 3 surveys (2006, 2010 and 2013) (Figure A2.5.11).

Hg concentrations are generally more elevated than the OSPAR BAC making Site Z area very enriched in Hg. When using baseline approach, levels become slightly enriched at most stations except for ZS1 and Z7 (within and north of disposal site) where moderate enrichment was found. These findings are consistent with those from 2010 survey. There is a slight decreasing trend for Hg at stations outside the disposal site over the 3 survey period.

Slight enrichment is observed for most stations with the OSPAR BAC approach for Ni while no enrichment was depicted when assessing against the regional baseline values. Pb enrichment is moderate for all stations when assessing against OSPAR BAC, this enrichment is still present to a lesser extent with the baseline value approach. Finally, when assessment was conducted using the OSPAR BAC approach for Zn, this trace metal shows a slight enrichment for most stations at Site Z disposal site, with 3 moderately enriched stations (Z1, SZ1 and Z7) whereas enrichment is not observed, or is observed to a lesser extent, according to the regional baseline method (Figure A2.5.10).

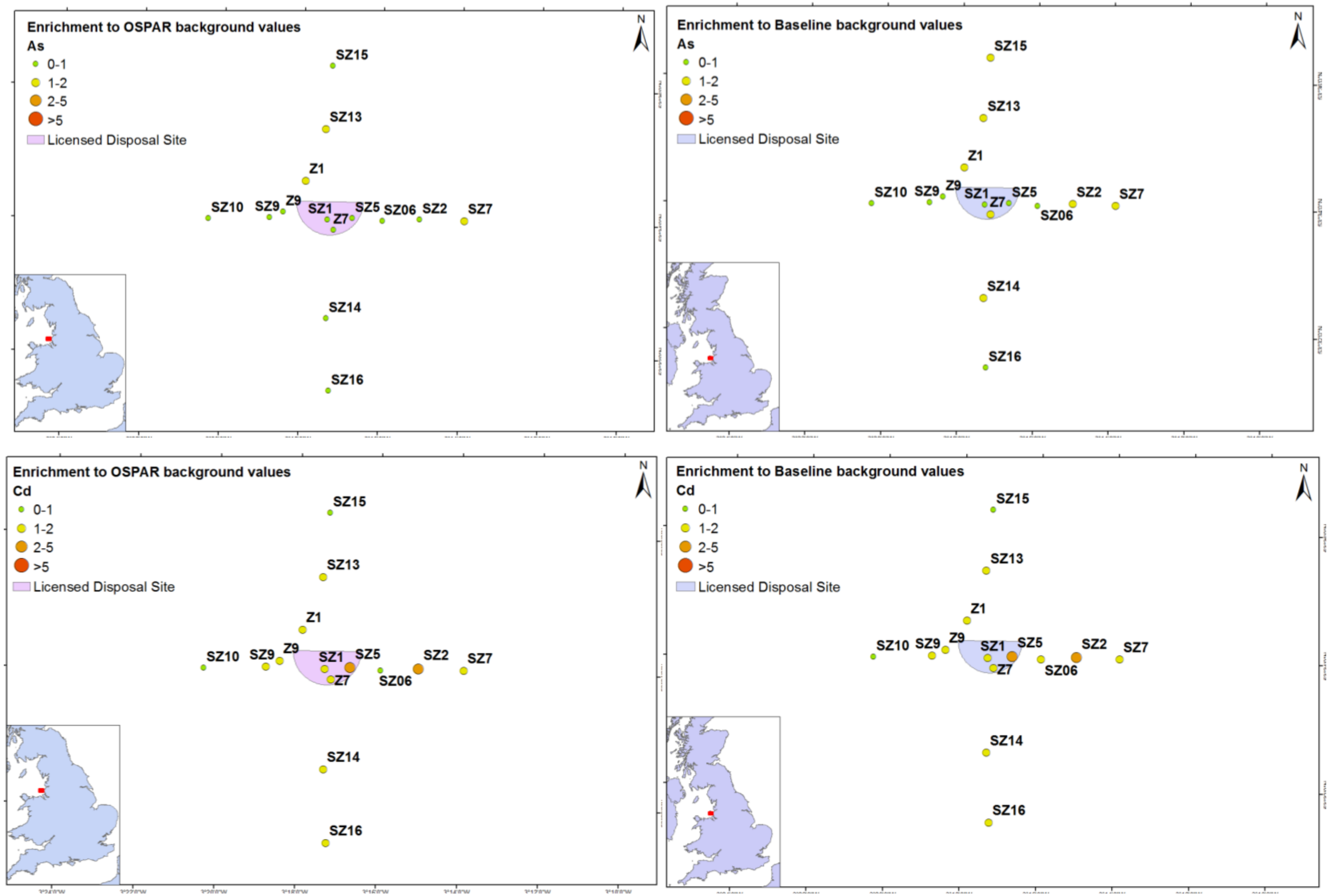


Figure A2.5.10. Enrichment to OSPAR BACs and Baseline values at site Z in for As, Cd, Cr, Hg and Pb.

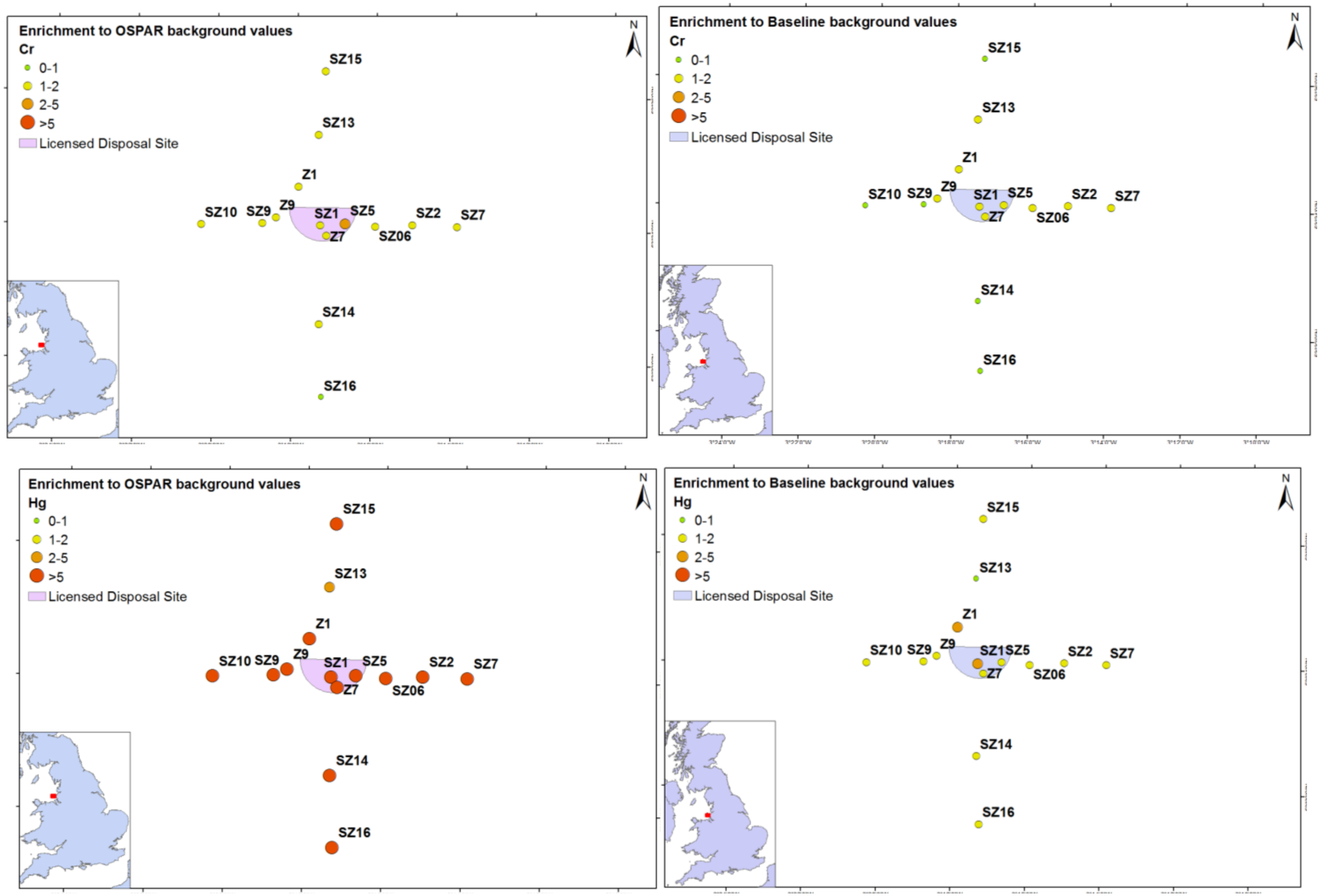


Figure A2.5.10. Continued.

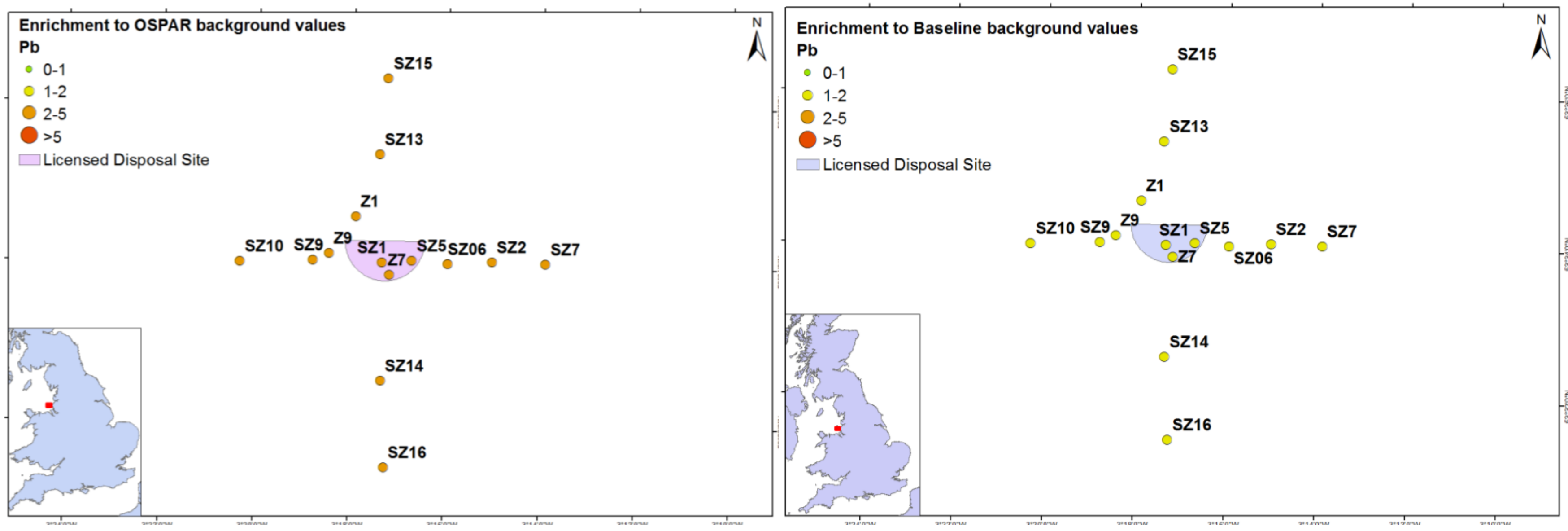


Figure A2.5.10. Continued.

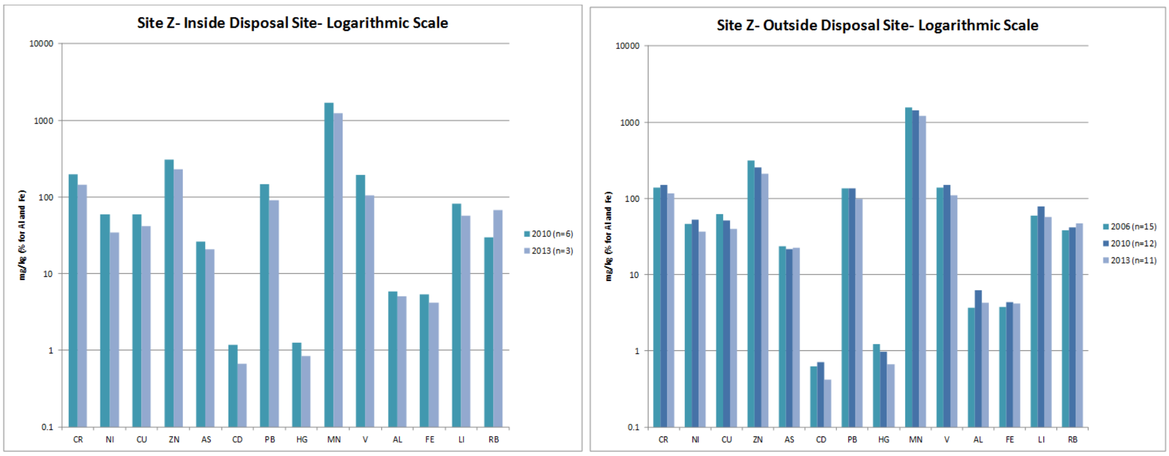


Figure A2.5.11. Trace metals concentrations for stations inside (left) and outside (right) the Site Z disposal site for 2006 (outside only), 2010 and 2013.

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