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02	19/07/2019	Katie Musgrave	Coastal Processes Survey Scientist	Will Manning	Coastal Processes Survey Scientist	Dean Foden	Hinkley Point Programme Lead
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06	30/01/2020	Katie Musgrave	Coastal Processes Survey Scientist	Andrew Bodle	Survey Scientist	Dean Foden	Hinkley Point Programme Lead
07	17/07/2020	Andrew Bodle	Survey Scientist	Katie Musgrave	Coastal Processes Survey Scientist	Dean Foden	Hinkley Point Programme Lead
08	17/08/2020	Katie Musgrave	Coastal Processes Scientist	Andrew Bodle	Survey Scientist	Dean Foden	Hinkley Point Programme Lead

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Revision	Purpose	Amendment	By	Date
1	Initial publication		Cefas	23/05/2019
2	Revised according to comments from NNB GenCo	Response to comments from NNB GenCo.	Cefas	19/07/2019
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6	Revised according to comments from NNB GenCo	Sections 2.1, 2.2, 3.1, 3.2, and 4.1 amended according to comments from NNB GenCo and regulators.	Cefas	30/01/2020
7	Revised according to comments	Response to comments from NNB GenCo and regulators. Amendments throughout.	Cefas	17/07/2020
8	Revised according to comments	Response to comments from NNB GenCo and regulators. Minor amendments throughout, including reduction of buffer areas (Figure 1) and addition of appendices.	Cefas	17/08/2020

TR502 HPC 2019 sediment sampling plan for dredge disposal. HPC cooling water intakes, outfalls, FRR, and jetty.

TR502 HPC 2019 sediment sampling plan for dredge disposal. HPC cooling water intakes, outfalls, FRR and jetty

Dean Foden and Katie Musgrave

Version and Quality Control

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Non-technical summary

During 2021 NNB GenCo plans to commission dredging as part of the development of Hinkley Point C (HPC) nuclear power station. NNB GenCo will seek permission to dispose of dredged material at authorised disposal sites within the Severn Estuary. During 2018, capital dredge works of the cooling water intake and outfall areas were completed and disposed of at Cardiff Grounds disposal site. This document specifies the sediment sampling and the required analysis that will be required to demonstrate whether the dredged sediments are suitable for dredging and subsequent disposal to sea. The proposed approach to sampling is in line with OSPAR guidelines for disposal of dredge sediment at sea (OSPAR, 2014), which specifies best environmental practice for managing dredged material.

In areas where dredging was previously undertaken (maintenance dredge areas), grab sampling will be undertaken to characterise sediment from the seabed surface. In areas which have not been dredged previously (capital dredge areas), cores will be collected to characterise subsurface sediments to the planned dredge depth. The cores will be subsampled at the surface and at specified depth intervals throughout the core. In total, sampling will take place at 35 sample stations: six stations will be surface sampled to represent the maintenance dredge zones, and 29 stations will be core sampled to represent the capital dredge zones. The number of sample stations is based on the proposed dredge volume and conservative application of OSPAR guidelines (OSPAR, 2014).

Chemical, radiological and particle size analysis will be undertaken on all subsamples. Details and justification for the proposed analytical suite is detailed as follows:

Radiological analysis: radiological assessment based on gamma spectroscopy will be undertaken according to internationally recognised “de minimis” procedures for all subsamples. Additional reassurance monitoring will also be undertaken for two core sample stations, one outfall station and one intake station, as this is where the bulk of the dredging will take place. The additional monitoring will assess the presence of pure-alpha emitting radiation using alpha spectroscopy for Americium and Plutonium, to provide additional assurance of results from the “de minimis” assessment. Tritium and Organically Bound Tritium will also be analysed for the two cores used for alpha analysis. This analysis is to provide reassurance that contamination from historical releases from the Amersham site in Cardiff is not present at the proposed dredge site. This is unlikely given the site hydrodynamics and sediment transport regime, however analysis is included as a precautionary measure.

Chemical analysis: all contaminants from the primary list of determinants defined in OSPAR Guidelines (OSPAR, 2014) will be analysed, including Cadmium, Copper, Chromium, Lead, Mercury, Zine, Nickel, Arsenic, seven polychlorinated biphenyl congeners (PCBs), and nine polycyclic aromatic hydrocarbons (PAHs) and organotins. In addition, further hydrocarbons (PAHs) and PCBs from the secondary determinants list will also be analysed. All results will be compared to Cefas Action Levels for each type of contaminant to determine their suitability for disposal to sea (Cefas, 2015). Based on a source-pathway-receptor model, it is not proposed that other secondary determinants are analysed, due to the limited history of industrial activity in the direct vicinity of the site, and the open coastal location, which is subject to significant tidal flushing due to the extremely large tidal range, limiting contaminant accumulation at the site.

Physical analysis: particle size analysis will be completed for all samples according to the NMBACQ methodology, and percent solids will be also determined as an intermediary step of metals analysis. Further physical determinants defined by OSPAR will not be analysed, which is in line with standard practise for dredge disposal applications in England and Wales. Total Organic Carbon is used an indicator of contamination when full chemical analysis is not proposed, and therefore its determination is not deemed necessary in this case, as the full suite of chemical analyses will be completed. Specific gravity/density will not be analytically determined, as it can be determined to a sufficient level of accuracy based on PSA results.

Following analysis of the sediment samples, the results of the analyses undertaken will be reported to the appropriate regulatory body together with an assessment of whether the analysis results indicate that the sampled sediments are suitable for disposal to sea. The results and assessment will be submitted to the appropriate regulatory body for approval prior to dredging works commencing.

1 Introduction

During 2021 NNB GenCo plans to commission dredging as part of the development of Hinkley Point C (HPC) nuclear power station. Installation of the cooling water intake and outfall structures requires these locations to be dredged down to bedrock, with the dredged material being taken to a designated disposal site. Similarly, dredging and subsequent disposal is required at the site of a fish return and recovery system (FRR) outfall structure and to create a berthing pocket at the head of the HPC temporary jetty. The locations of these sites are shown in Figure 1. NNB GenCo will seek permission to dispose of this dredged material at authorised disposal sites within the Severn Estuary designated area as per the HPC Development Consent Order (S.I. 2013 No. 648). During 2018, capital dredge works of the cooling water intake and outfall areas were completed under Marine Management Licence (MMO) Marine Licence L/2013/00178/4 including disposal to LU110 under Natural Resources Wales (NRW) Marine Licence 12/45/ML.

The purpose of this document is to specify the sediment sampling that will be required to demonstrate whether the dredged sediments are suitable for dredging and subsequent disposal to sea. The planned window within which the sampling proposed within this report will take place is between July and December 2020.

The scope of this sampling campaign will be submitted to the regulating authority for approval prior to the disposal of any material. Dredged material will be disposed of at authorised sites within the Severn Estuary.

The current version of the sampling plan (version 11.00) has been produced for approval in the context of sub-sampling and analysis.

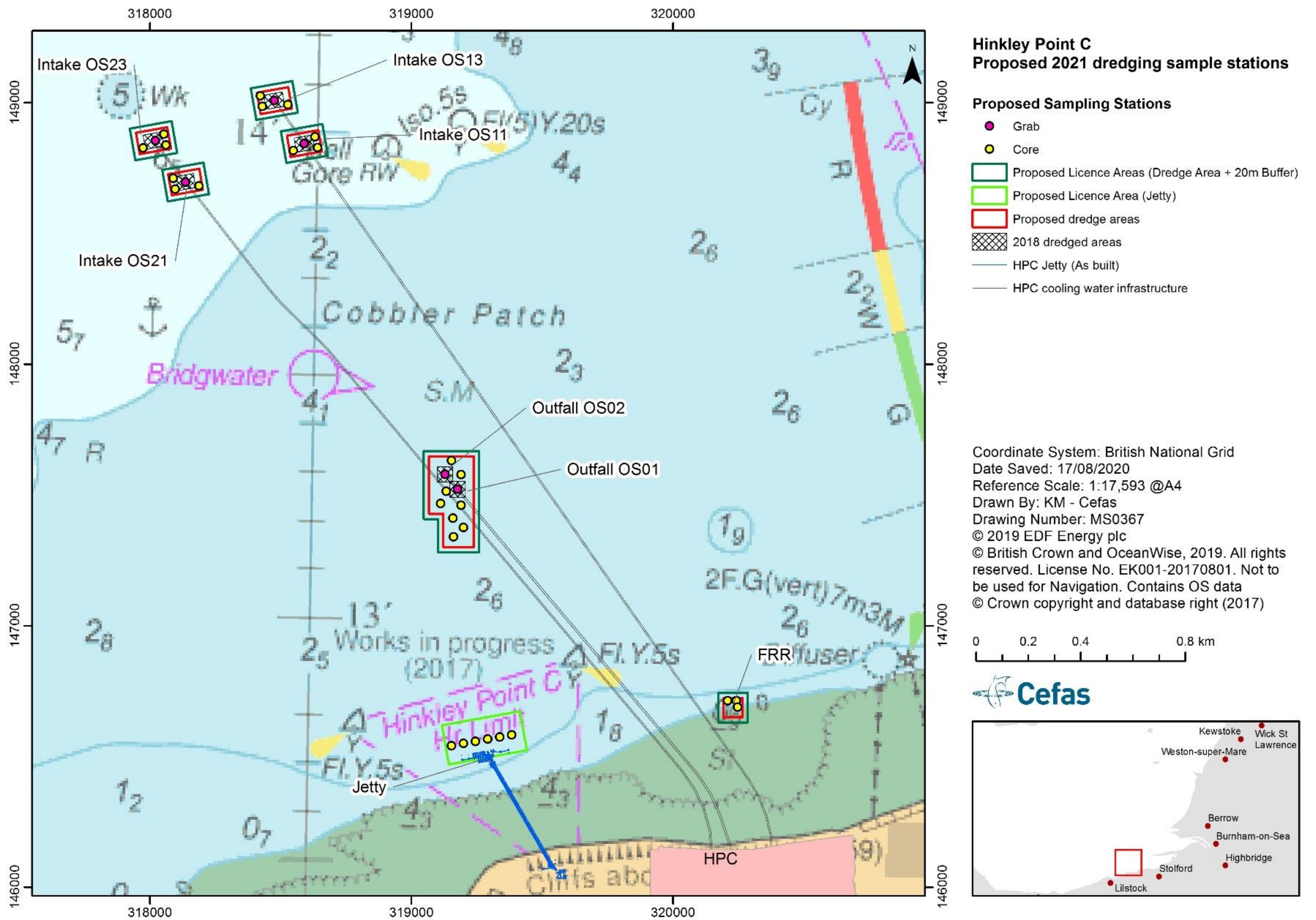

Figure 1. Proposed sampling area and indicative distribution of proposed sample station locations. Note that the area of the jetty berthing pocket dredge has yet to be finalised and the area shown is indicative. The number of sampling locations and the dredge volume for each area are shown in Table 2.

2 Sampling strategy

2.1 Number of sample stations

Sampling requirements to demonstrate that sediments are suitable for disposal to sea are based upon OSPAR guidelines (OSPAR, 2014) which specify the number of sampling stations required according to the volume of sediment to dredged. The sampling specified in the OSPAR guidelines is shown in Table 1.

Table 1. The number of sediment sampling stations required for different dredge volumes (from OSPAR, 2014)

Volume dredged (m^3)	Number of stations
Less than 25,000	3
25,000 - 100,000	4 - 6
100,000 - 500,000	7 - 15
500,000 - 2,000,000	16 - 30
Greater than 2,000,000	An extra 10 per million m^3

For the 2021 Hinkley Point dredge campaign, the dredge volumes proposed for each dredge location are shown in Table 2 together with the number of sampling stations required to comply with OSPAR guidance. The proposed works include a mixture of maintenance and capital dredging at the locations of the intakes and outfalls, the FRR and the jetty berthing pocket. The total number of sampling stations based on conservative application of OSPAR guidance is 35. To facilitate flexibility in the dredging plan, permission is sought for a contingency of up to 45 sampling stations in total to be sampled.

Table 2. The proposed volumes of sediment to be dredged from each location and the number of sampling stations required. Dredge volumes presented are highly conservative and may be subject to further reduction once detailed designs are available. This will not impact the proposed sampling plan, as changes are likely to be immaterial and there are no plans to further reduce the number of samples.

Dredge purpose	Location	Dredge volume (m^3)			Number of sampling stations	
		Capital	Maintenance	Total	Stations in capital zones	Stations in maintenance zones
Intakes	OS11	24,757	36,743	61,500	3	1
	OS13	24,757	36,244	61,001	3	1
	OS21	24,757	36,897	61,654	3	1
	OS23	24,757	37,202	61,959	3	1
Outfalls and flotation pocket	OS01 and OS02	118,657	72,914	280,228	8	2
	Flotation pocket	88,657				
FRR	FRR	20,000	-	20,000	3	-
Jetty berthing pocket*	Jetty	53,657	-	53,657	6	-
	Subtotal:	**380,000**	**220,000**	**600,000**	**29**	**6**
Additional contingency sampling stations**:					10	
				Total:	**45**	

* The extent and exact volume of the jetty dredge has yet to be finalised. **Ten additional stations are included as contingency in the case of amendments to dredging plans. These additional stations would either be core sampled or grab sampled, determined based upon whether the station was located within capital (core) or maintenance (grab) dredging zones, and subjected to the same subsampling and analysis as for all other sample stations.

Proposed sample station locations are shown in Figure 1 and are provided in tabulated form in Appendix A. The sampling plan has been designed to be representative of all dredged areas and dredged material. Although the pocket dredge area associated with the HPC jetty has not been finalised, enough samples will be collected to characterise it in case dredging of this area is undertaken in the next three years. Sample stations will be evenly spaced within each dredge area to provide representative coverage of both capital and maintenance dredging zones. It is likely that sampling will be undertaken from a jack up barge. As a result, the final position of each sample station and the jack up leg placement will be influenced by ground conditions encountered, however where possible the sampling locations will remain evenly distributed. The final placement of stations will ensure that an accurate representation of the dredged material can be determined. Stations would be evenly distributed in areas of planned dredging. A 20 m operational buffer around the planned dredge areas is also included in case of minor changes to infrastructure locations (likely c. 2 – 5 m only) which would require minor changes to dredging plans, and in case dredging operations cause minor surface disturbance slightly outside of the boundary of the planned dredge area. The stations are evenly distributed across the planned dredge area, rather than the surrounding buffer area, as this means that samples will be most representative of the *volume* of material that will be dredged, rather than the *area* of dredging.

At each sampling station within capital dredging zones (the area within the “proposed licence areas” in Figure 1, excluding the previously dredged black hashed areas), sediment samples should be obtained by coring. Either vibrocores, rotary cores, or Shelby tubes will be used, depending on ground conditions encountered. The cores should extend to the maximum dredge depth, or until expert geotechnical examination reveals that undisturbed geological material has been reached, or the sample consists almost exclusively of sand, gravel, or rock. The maximum core length would be 7.5 m, depending on planned dredge depth at the location. The cores should be subsampled, and the subsamples should be tested for chemical and radiological contamination and subjected to particle size analysis (PSA). Subsamples should be taken from the sediment surface and then at depth intervals from the sediment core. The depths of subsamples to be taken, the required analyses and the required subsample volumes are shown in Table 3 and the analyses are described in section 3 and 4. It is assumed that enough samples will be taken at each core sample station to ensure sufficient material is available to collect a full set of replicate subsamples, and to allow contingency in case required subsample volumes vary according to the requirements of the laboratory selected for the analysis.

At each sampling station within maintenance dredging zones (inside black hashed areas in Figure 1), surface grab samples should be obtained by grab sampling. A 0.1 m^2 stainless steel van veen or day grab (or similar) should be used. Sampled material should be subsampled, and the subsamples should be tested for chemical and radiological contamination and subjected to particle size analysis (PSA) as described in section 3 and 4.

If the proposed 2021 dredge depths exceed 2018 dredge depths, sample stations in the maintenance dredge areas would still be grab sampled, to characterise surficial sediments deposited since the 2018 dredge. For operational and engineering reasons, it is not possible to undertake coring within the maintenance dredge zones. However, a conservative number of capital dredge sample stations have been specified according to the proposed capital dredge volumes, which will characterise sediment to the planned dredge depth. Therefore, the already proposed core stations would characterise these areas sufficiently, and additional cores sample stations would not be completed to replace the grab stations in the maintenance zones if the 2021 dredge depth exceeded the 2018 dredge depth. The core stations located within the capital dredge areas encircle each maintenance dredge area, and are in close proximity, therefore the subsurface samples from these stations would adequately characterise subsurface sediments at depth across both capital and maintenance areas.

In the event that insufficient material is collected during a sample removal attempt (if a partial sample was recovered, for example), or where unsuitable ground conditions were encountered, collection of further samples may be required. This would be undertaken at the same station to minimise the area of seabed influenced by sampling activities. The exact site of further sample attempts would be located at the same point as previous attempts if possible, or in the event that seabed conditions after the previous attempts were not suitable, as close as possible to the previous sample attempt, to minimise the area of the seabed influenced by the activity as far as possible. If additional attempts were made, this would be recorded, specifying location, number of attempts, and justification of why additional attempts were required.

Table 3. The subsampling and analysis strategy for sediment cores and estimated subsample volumes. Subsample volume refers to the material required for one subsample set: a second replicate subsample set would also be collected.

Subsample depth (m)	Analysis required			Estimated subsample volume (ml)			
	Radiological	Chemical	PSA	Radiological	Chemical	PSA	Total per replicate**
Sediment surface (or grab samples)	✓	✓	✓	500 - 1000	375	375*	875 - 1750
0.25	✓	X	X	500 - 1000	-	-	500 - 1000
0.5	✓	✓	✓	500-1000	375	375*	875 - 1750
1.0	✓	✓	✓	500-1000	375	375*	875 - 1750
2.0	✓	✓	✓	500-1000	375	375*	875 - 1750
Etc at 1.0 m intervals to the bottom of the core or until undisturbed geological material or almost exclusively sand, gravel or rock are found.	✓	✓	✓	500-1000	375	375*	875 - 1750

*PSA can use chemical sub-sample material, unless coarse gravelly material is sampled, in which case, an additional separate sample should be collected.
** to obtain replicate subsamples, double this volume would be required in total.

2.2 Sampling volumes

The volumes of material which would be removed from the seabed according to different sampling techniques are detailed in Table 4. The maximum volume of material for the full sampling campaign would be approximately **10.30 m^3**, based on values presented in Table 4 and including a factor of 50% to account for minor variations to requirements. For example, if unsuitable ground conditions were encountered, if analysis laboratories required more material than was estimated in Table 3 therefore requiring multiple cores, or if unsuccessful sampling attempts yielded partial samples and repeat sampling was required.

Only surface sampling or core sampling would be undertaken at each sampling station, never both (according to whether it was a capital or maintenance dredging zone). Once collected, the material sampled using these techniques would be subsampled according to methods described in Section 3.

Table 4. Sediment sampling volumes (Note: this details the total volume of material removed from the seabed and differs from the volume of material that will be subsampled for analysis).

	Sample type					
	Surface grab sample	**6 m vibrocore sample (ø 0.084 m)**	**6 m rotary core sample (ø 0.102 m)**	**7.5 m rotary core sample (ø 0.102 m)**	**Contingency***	
					6 m rotary core	**7.5 m rotary core**
Number of stations using this sampling type	6	29	27	2	19	1
Number of sample type per station	1	3	2	2	1	1
Sediment volume per sample attempt (m^3)	0.015	0.0333	0.049	0.0613	0.049	0.0613
Total sample volume per sample type (m^3)	0.09	2.89	2.65	0.245	0.932	0.0613
Total volume of sediment sampled for all sample types (m^3)						**6.87**

*Additional contingency samples may be either grab or core samples, according to whether they were located within maintenance or capital dredge areas, respectively, but are assumed to be core sampled here for the purposes of providing a worst-case volume estimate.

3 Subsampling methodology

Cores should be subsampled by scientifically trained staff according to the methodology below in order to prevent contamination of the samples.

During the sampling campaign, the contractor will keep detailed survey logs. Each station will be assigned a unique name and the sample depth will be used to record where the subsample was taken from the core. In addition to this and as a minimum, logs will also include: date, time, sample position (in appropriate geodetics), sediment description, any issues encountered, general comments. Sample containers and labels will be prepared ahead of time where feasible. Labels will be waterproof and pre-printed or will be hand-written with an appropriate permanent marker. Labels will uniquely identify each sample and enable them to be cross-checked and matched to the sampling logs. As samples are shipped off the vessel to a laboratory, they will be checked off the sample list created from the survey logs. The samples will be checked off the list again when they arrive at the laboratory to ensure that they are all accounted for.

3.1 Radiological samples

For each subsample, between 500 and 1000 ml of sediment should be placed into 500 ml plastic container(s) using a clean plastic scoop. Radiological subsamples over 500 ml would be stored in two containers: this is standard practise for radiological samples and would not influence analytical results. Clearly labelled sample containers should be filled, and any excess water discarded to leave a small air gap at the top of the container. The top should be screwed or pushed on firmly and the container wiped clean before being placed in a clean plastic bag and sealed with tape.

Two sub-samples should be taken at each depth at each station as a full set of replicate subsamples will be collected. Additional cores per station may be required to provide a sufficient volume of material.

Samples should be clearly labelled and carefully packed to minimise risk of damage during transport. Samples should be stored either at room temperature (out of direct sunlight) or refrigerated but not frozen and sent to the analysing laboratory as soon as possible (e.g. by overnight courier). A specific period within which samples must be received by the laboratory is not defined, however fast transport is preferable as it reduces the possibility of algal growth, which may take up radionuclides following sample collection.

3.2 Chemical and PSA samples

For each subsample, one contaminant-free 500 ml glass jar should be ¾ filled with sediment using a clean stainless-steel scoop, in accordance with MMO Chemical Determinants Guidance (MMO, 2018). Contaminant-free foil should be placed over the top of the jar and the lid replaced firmly.

If the sample contains coarse gravelly material, a second container should be subsampled according to the same methodology. A plastic container can be used for the additional subsample, as analysis of this subsample would be for PSA only, and therefore contamination from the plastic material is not a concern. A conservative approach to determining whether a second jar is required should be employed, based on visual inspection of the core by an experienced geotechnical technician.

Two sub-samples should be taken at each depth at each station, as a full set of replicate subsamples will be collected. If the subsample consists of coarse gravelly material, a total of four sub-samples would be required at each depth. Additional cores per station may be required to provide a sufficient volume of material.

The jars and containers should be clearly labelled and carefully packed to minimise the risk of breakage. The samples should be frozen and then sent to the analysing laboratory as soon as practical in insulated cool boxes with frozen ice-packs or in an environment controlled vehicle.

4 Sample analysis

The acquired samples will be analysed for radionuclides and chemical contaminants as recommended in OSPAR (2014) and are the same as used in 2017 sampling ahead of the previous 2018 dredging campaign. All analyses will be performed at an MMO validated and UKAS accredited laboratory and are described below.

In all cases, all chemical analysis will be undertaken on samples from the same container. Chemical and PSA analysis will be undertaken on material from the same subsample container, except where sediment is coarse, in which case PSA would be undertaken on a second sub-sample, since a larger sample volume is required for PSA of coarse sediment. Radiological analysis must be undertaken on material stored in separate containers to chemical and PSA subsamples, as sample handling and storage requirements differ, as described in sections 3.1 and 3.2. Specifically, radiological analysis cannot be completed on samples which have been frozen, and conversely chemical analyses cannot be completed on samples which are older than one week, unless the sample is frozen (MMO, 2018). Therefore, for logistical reasons, all analyses cannot be undertaken on subsamples from the same container.

In some cases, different subsamples at a certain depth at a sample station would be taken from different cores collected at the sample station. Multiple cores at one sample station would be required in the following scenarios:

- Where a single core does not contain a sufficient volume of sediment for a full set of subsamples and replicates at a specific depth. This would be more likely for coarse sediment, as additional PSA subsamples would be required, requiring a greater total volume of material.
- If a vibrocore could not sample to the required depth due to operational restrictions, a rotary core would be required to obtain a sample of deeper sediments. Rotary coring can disturb the surficial sediment, potentially mixing the upper layers of the core. Therefore, a vibrocore would also be collected at the sample station to obtain shallow depth subsamples, to ensure the subsamples near to the surface were as undisturbed as possible, and that layering of material was preserved. Therefore, shallow samples would come from the vibrocore, whilst deep samples would come from the rotary core.
- If an incomplete core sample was obtained, in which case further cores would be collected to obtain sufficient sediment for all subsamples.
- Replicate subsamples will be collected for contingency, in the event that samples were lost or damaged in transit. To obtain sufficient material, it is likely that replicates would come from different cores. As far as possible, each set of replicates would be taken from the same core (e.g. all replicate A subsamples (chemical, PSA and radiological) would be from core 1, and all replicate B subsamples from core 2).

As a result, subsamples being analysed may come from different cores collected at the same sample station (maximum 15 m spacing proposed). Replicates from different cores at the same sample station may exhibit minor differences, however minor spatial variability is an unavoidable factor in any sampling campaign. The purpose of sampling at multiple sample stations within each dredge location is to characterise such localised variability. The sample material would still be representative of the proposed dredge material where multiple cores are used at one station.

All samples will be retained and stored appropriately to avoid degradation once analysis is completed, in case further analysis of additional determinants is required.

4.1 Radiological analyses

4.1.1 Analysis for de minimis assessment

Radionuclide analysis will be conducted using gamma spectroscopy by γ counting samples on a high purity Ge detector to detect any activity within the energy range 60 keV to 2 MeV, including the detection of ^{60}Co, ^{137}Cs, ^{226}Ra (via ^{214}Pb), ^{232}Th (via ^{228}Ac), ^{238}U (via ^{234}Th), and ^{241}Am. The analysis technique uses high-resolution gamma-ray spectroscopy, which due to its resolution, allows the identification of a wide range of alpha, beta and gamma emitting radionuclides, and thorough assessment of any radioactivity in the sediment.

Assessment will be undertaken in line with the guidance for the dose assessment methodology for dredge operators and the public as detailed in IAEA (2003) and (2015) and in accordance with the current UK accepted methodology, described in RL05/06 (McCubbin & Vivian, 2006). Results will be compared against internationally accepted limits recommended by the IAEA (2003; 2004).

If evidence of enhanced activity was observed in the initial screening of the sediment cores or if enhanced activity of americium-241 was observed in any core, then a more refined radiological assessment on the existing cores taken might be required, as per the IAEA de minimis levels stepwise evaluation procedure. This procedure is described in IAEA (2003) and (2015) and the current UK accepted methodology, described in RL05/06 (McCubbin & Vivian, 2006).

4.1.2 Reassurance monitoring

Additional reassurance monitoring will also be undertaken at two core sample stations, one core at the outfall locations and one core from the intake locations, as these are the locations where the bulk of the dredge will take place (proposed sample stations are detailed in Appendix A). Analysis will be undertaken on subsamples from cores which are also analysed using the gamma spectroscopy (at the depths defined in Table 3), to enable direct comparison of results from each analysis.

Alpha spectroscopy will be used to determine the presence of plutonium (Pu-239+240) and americium (Am-241) isotopes within subsamples from the two cores, in line with ISO 18589. Though not required according to standard radiological assessment procedure, this additional reassurance monitoring will be undertaken to directly determine the presence of pure alpha emitting radionuclides.

The methodology proposed in section 4.1.1 uses gamma spectroscopy for the detection of a wide range of radionuclides. Most Alpha and Beta emissions are accompanied by a Gamma Ray, and as such gamma spectroscopy will directly measure most Alpha or Beta emitters. Based on the presence of the radionuclides detected using gamma spectroscopy, the presence of any pure Alpha or Beta emitters (which do not emit a gamma ray) are also inferred according to the standard assessment procedure. The additional Alpha spectroscopy will directly detect any Alpha emitters, regardless of whether they emit a Gamma Ray, to provide reassurance that the values determined by the gamma spectroscopy are fit for purpose.

Therefore, the purpose of this element of the reassurance monitoring will be to reaffirm the suitability of the gamma spectroscopy method, therefore providing a thorough assessment of any radioactivity in the sediment. As the alpha spectroscopy analysis is for reassurance purposes, it is not required to be undertaken at all locations.

Further analysis of Tritium and Organically Bound Tritium (OBT) in line with ISO 18589 will also be undertaken on the same subsamples used for the additional alpha analysis. The primary source of OBT in the Severn Estuary is historical discharges at Cardiff. Research conducted by the Food Standards Agency on the impact of these discharges on the Severn Estuary has shown that levels of OBT are highest closest to the source of the original discharge and decrease with distance due to sediment transport through the estuary (Croudace et al. 2002). Although no specific sampling of OBT is deemed necessary due to the location of the sediment being dredged, this analysis will be undertaken for additional reassurance monitoring to determine the specific presence of OBT.

4.2 Chemical analyses

Samples will be analysed to determine the concentrations of metals, organotins, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) and the results compared with Cefas Action Levels (MMO, 2015). Results should not be normalised for determination of action levels, as Cefas Action Levels were designed for use with non-normalised contaminant concentrations.

PAHs

Analysis for PAHs listed in Table 5 will be achieved using gas chromatography-mass spectrometry (GC-MS). Additionally, a total hydrocarbon (THC) measurement will be performed using UV fluorescence spectrophotometry calibrated with a Forties oil standard.

Metals (partial digestion)
The metals listed in Table 5 will be analysed using microwave digestion with nitric acid and subsequent analysis by inductively coupled plasma mass spectroscopy (ICP-MS) and inductively coupled plasma optical emission spectroscopy (ICP-OES).

Organotins
The organotins listed in Table 5 will be extracted from the sediment sample, converted into their hydrides using sodium borohydride and analysed by gas chromatography – flame photometric detection (GC-FPD).

PCBs
For the analysis of the PCBs listed in Table 5, the sediment samples will be dried and sieved to a less than 2 mm fraction. The dried sediment will be extracted by soxhlet, and the extracts cleaned and analysed by gas chromatography with electron capture detection (GC-ECD).

The limits of detection and quantification of the analyses to be conducted are shown in Table 5.

Table 5. Analytical method detection limits for metals, organotins and PAHs and limits of quantification for PCBs.

Determinant	Limit of detection (dry weight basis)
Metals (Partial Digestion)	
Arsenic (As)	0.01 mg/kg
Cadmium (Cd)	0.01 mg/kg
Chromium (Cr)	0.01 mg/kg
Copper (Cu)	0.01 mg/kg
Lead (Pb)	0.01 mg/kg
Mercury (Hg)	0.006 mg/kg
Nickel (Ni)	0.01 mg/kg
Zinc (Zn)	0.20 mg/kg
Organotins	
Tribultyltin (TBT)	2 µg/kg
Dibutyltin (DBT)	2 µg/kg
Polyaromatic Hydrocarbons (PAHs):	
Acenaphthene	0.1 µg/kg
Acenaphthylene	0.1 µg/kg
Anthracene	0.1 µg/kg
Benzo[a]anthracene	0.1 µg/kg
Benzo[a]pyrene	0.1 µg/kg
Benzo[b]fluoranthene	0.1 µg/kg
Benzo[e]pyrene	0.1 µg/kg
Benzo[ghi]perylene	0.1 µg/kg
Benzo[k]fluoranthene	0.1 µg/kg
Methyl Naphthalenes (C1-Naphthalenes)	0.1 µg/kg
Methyl Phenanthrenes / Anthracenes (C1-Phenanthrenes)	0.1 µg/kg
Dimethyl Naphthalenes (C2-Naphthalenes)	0.1 µg/kg
Trimethyl Naphthalenes (C3-Naphthalenes)	0.1 µg/kg

<table>
<tr><td>Chrysene</td><td>0.1 µg/kg</td></tr>
<tr><td>Fluoranthene</td><td>0.1 µg/kg</td></tr>
<tr><td>Fluorene</td><td>0.1 µg/kg</td></tr>
<tr><td>Indeno[1,2,3-cd]pyrene (Indeno[123-cd]P)</td><td>0.1 µg/kg</td></tr>
<tr><td>Naphthalene</td><td>0.1 µg/kg</td></tr>
<tr><td>Perylene</td><td>0.1 µg/kg</td></tr>
<tr><td>Phenanthrene</td><td>0.1 µg/kg</td></tr>
<tr><td>Pyrene</td><td>0.1 µg/kg</td></tr>
<tr><td>Dibenz(a,h)anthracene</td><td>0.1 µg/kg</td></tr>
<tr><td>Total Hydrocarbon Content (THC)</td><td>0.1 mg/kg</td></tr>
<tr><td colspan="2">25 Polychlorinated Biphenyls (PCBs) congeners (as per International Union of Pure and Applied Chemistry (IUPAC) nomenclature):</td></tr>
<tr><td rowspan="2">CB 18, CB 28[a], CB 31, CB 44, CB 47, CB 49,
CB 52, CB 66, CB101[a], CB 105, CB 110,
CB 118[a], CB 128, CB 138[a], CB141, CB149,
CB 151, CB 153[a], CB 156, CB 158, CB 170,
CB 180[a], CB 183, CB 187, CB 194</td><td>Limit of quantification</td></tr>
<tr><td>Per congener = 0.2 µg/kg
Sum of ICES7 = 1.4 µg/kg
Sum of 25 congeners = 5.0 µg/kg

Key = [a] ICES7 congener</td></tr>
</table>

Chemical analysis will be completed for all Tier II determinants in the primary list defined in Technical Annex I of the OSPAR guidelines (OSPAR, 2014). For secondary determinants where Cefas Action Levels are defined, and where deemed appropriate, further analysis will be completed, e.g. for additional PAHs and PCBs. Further secondary list determinants are deemed to be low risk given the open coastal nature of the site, high tidal flushing, lack of heavy industry at the site, and therefore a lack of identified pathways for these contaminants. DDT and dieldrin (organochlorine pesticides) are generally found in enclosed waterways with high levels of agricultural activity. However, the risk of their presence is low given the open coastal setting and high tidal flushing at the site. There is no historical heavy industry in the locality i.e. no local ports or shipyards, and therefore the risk for anti-fouling agents is also low.

4.3 Particle size analysis

Particle size analysis (PSA) will be carried out in accordance with NE Atlantic Marine Biological Analytical Quality Control Scheme (NMBAQC) best practice guidance (Mason, 2016).

If frozen, samples will be defrosted prior to analysis and a representative subsample taken. Laser diffraction will be carried out on the <2 mm sediment using a Beckman Coulter LS13320 laser sizer (or similar). The remainder of the subsample will be wet sieved using a 1 mm sieve. The >1 mm sediment fraction will be oven dried and then dry sieved at half phi intervals. The <1 mm sediment fraction will be oven dried and the weight recorded. The sieve and laser data will be merged to produce a full Particle Size Distribution (PSD) at half phi intervals.

Analysis of further physical determinants is described within OSPAR guidance Technical Annex I (OSPAR 2014), namely percent solids, density/specific gravity, and organic matter (Total Organic Carbon (TOC)). These determinants are not routinely analysed for dredge disposal applications in England and Wales where chemical analysis is also performed, and their analysis is not proposed for this sampling campaign; the justification for each case is set out below.

Percent solids: Where chemical analysis is not completed, percent solids can be used to indicate contaminant accumulation potential. As contaminants will be explicitly determined by chemical analysis, determination of percent solids is not deemed necessary. However, percent solids are determined as part of the process for metals analysis and will be reported alongside metals results, noting that these results would not directly inform the decision regarding whether material is suitable for disposal to sea, as chemical analysis results would supersede results from this indicator.

Total Organic Carbon (TOC): TOC can be used as an indicator of potential hydrocarbon content when full PAH analysis is not completed. However, as full PAH analysis will be conducted on all subsamples and compared to action levels, TOC is not required. TOC has no associated Cefas Action Level for comparison. TOC can also theoretically be used for normalisation, however, Cefas Action Levels are not set for normalised results, therefore normalisation using TOC would result in erroneous categorisation of results.

Density (or specific gravity) can be determined to a reasonable level of accuracy using PSA results if required and therefore will not be explicitly determined through laboratory analysis.

5 Reporting

Following analysis of the sediment samples, the results of the analyses undertaken will be reported to the appropriate regulatory body together with an assessment of whether the analysis results indicate that the sampled sediments are suitable for disposal to sea. The results and assessment will be submitted to the appropriate regulatory body for approval prior to dredging works commencing.

References

Croudace, I.W., Warwick, P.E., Morris, J.E., Dyer, F. M., Howard, A.G., and Cundy, A.B. (2002). Organically-bound tritium (OBT) dispersion and accumulation in Severn Estuary sediments. Contract RP01034: report to the Food Standards Agency.

IAEA (2003). Determining the suitability of materials for disposal at sea under the London Convention 1972: A radiological assessment procedure. IAEA-TECDOC-1375, IAEA, Vienna.

IAEA (2004). Sediment distribution coefficients and concentration factors for biota in the marine environment. Tech. Rep. Ser. No. 422, IAEA, Vienna.

IAEA (2015). Determining the Suitability of Materials for Disposal at Sea under the London Convention 1972 and London Protocol 1996: A Radiological Assessment Procedure, IAEA-TECDOC-1759, IAEA, Vienna.

Mason, C. (2016). NMBAQC's best practice guidance. Particle Size Analysis (PSA) for Supporting Biological Analysis. National Marine Biological AQC Coordinating Committee.

McCubbin, D. and Vivian, C. (2006). Dose assessments in relation to disposal at sea under the London Convention 1972: judging de minimis radioactivity, Cefas Environment Report RL05/06.

MMO (2015). High Level Review of Current UK Action Level Guidance. A report produced for the Marine Management Organisation, pp 73. MMO Project No: 1053. ISBN: 978-1-909452-35-0.

MMO (2018) Guidance Chemical determinands Updated 18 January 2018. https://www.gov.uk/government/publications/marine-licensing-physical-and-chemical-determinands-for-sediment-sampling/chemical-determinands [accessed 16 July 2019].

Natural Resources Wales (2014). Marine and Coastal Access Act 2009: Part 4 – Marine Licencing, Marine Licence: 12/45/ML.

OSPAR (2014). OSPAR Guidelines for the Management of Dredged Material at Sea. OSPAR Commission Agreement 2014-06.

Appendix A Indicative sample station locations

Table 6 provides indicative locations of sample stations. Final locations are subject to review and assessment of jack up location feasibility, however it is envisaged that any correction to the location will be insignificant.

Two core sample stations will have additional radiological analysis on subsamples: one at the outfalls and one at the intakes. The final sample stations selected for additional analysis will be determined during the sampling campaign from the green shaded stations in Table 6, to enable the selection of stations where the greatest volume of sediment is available for subsampling. This will provide additional reassurance that the minimum volume requirement for radiological sampling (500 ml) can be provided at these stations, as a smaller volume would not be sufficient to enable the full suite of analyses to be completed.

Table 6: Target sediment sampling stations. Green shaded stations indicate those which can be selected for additional OBT/Tritium/Alpha spec radiological analysis (one station at the intakes and one the outfalls). Co-ordinates provided in British National Grid.

Dredge area	Point ID	Sample type	Easting (mE BNG)	Northing (mN BNG)
Intake O/S 11	OS11	Grab	318590.91	148843.25
	OS11-A	Core	318631.52	148868.31
	OS11-B	Core	318642.26	148827.96
	OS11-C	Core	318548.59	148816.78
Intake O/S 13	OS13	Grab	318476.21	149007.47
	OS13-A	Core	318423.01	149025.45
	OS13-B	Core	318430.59	148984.44
	OS13-C	Core	318527.55	148992.18
Intake O/S 21	OS21	Grab	318136.60	148696.10
	OS21-A	Core	318089.53	148709.89
	OS21-B	Core	318097.10	148668.88
	OS21-C	Core	318188.39	148681.10
Intake O/S 23	OS23	Grab	318021.70	148854.10
	OS23-A	Core	318062.34	148837.29
	OS23-B	Core	318054.50	148879.29
	OS23-C	Core	317974.67	148826.41
Outfall O/S 01	OS01-A	Grab	319128.54	147578.51
	OS01-B	Core	319190.78	147577.23
Outfall O/S 02	OS02-A	Grab	319176.80	147521.11
	OS02-B	Core	319132.91	147513.68
Outfall Flotation	OF-A	Core	319111.78	147466.53
	OF-B	Core	319190.62	147459.36
	OF-C	Core	319159.03	147410.61
	OF-D	Core	319199.30	147375.24
	OF-E	Core	319161.20	147339.50
	OF-F	Core	319153.89	147630.23
Fish Return System	FRS-A	Core	320208.91	146712.62
	FRS-B	Core	320242.90	146711.87
	FRS-C	Core	320247.15	146687.88
Jetty	JTY-A	Core	319153.98	146540.51

Dredge area	Point ID	Sample type	Easting (mE BNG)	Northing (mN BNG)
	JTY-B	Core	319199.83	146548.81
	JTY-C	Core	319245.69	146557.10
	JTY-D	Core	319291.54	146565.39
	JTY-E	Core	319337.40	146573.69
	JTY-F	Core	319384.00	146582.12

Appendix B Licence areas

Table 7 contains the proposed dredge licence areas.

Table 7: Vertices of proposed dredging and licence areas as denoted in Figure 1. Co-ordinates provided in British National Grid.

Area descriptor	Infrastructure identifier	Eastings BNG	Northings BNG
2018 intake and outfall dredging areas	Intake OS11	318621.25	148876.66
		318550.97	148864.26
		318560.57	148809.84
		318630.84	148822.23
	Intake OS13	318435.98	149028.69
		318506.76	149041.17
		318445.66	148973.77
		318516.44	148986.25
	Intake OS23	317973.94	148875.00
		318043.93	148887.34
		317983.49	148820.87
		318053.47	148833.21
	Intake OS21	318097.29	148716.68
		318166.50	148728.88
		318175.91	148675.52
		318106.70	148663.32
	Outfall OS01	319098.79	147608.26
		319158.28	147608.26
		319158.28	147548.76
		319098.79	147548.76
	Outfall O/S 02	319146.44	147551.47
		319207.17	147551.47
		319207.17	147490.74
		319146.44	147490.74
2021 FRR dredging area	FRS outfall head	320194.00	146722.00
		320266.00	146722.00
		320266.00	146650.00
		320194.00	146722.00

Area descriptor	Infrastructure identifier	Eastings BNG	Northings BNG
2021 FRR licence area (20m buffer)	FRS outfall head	320173.99	146630.01
		320173.99	146741.99
		320285.98	146742.03
		320286.02	146630.01
2021 intake and outfall dredging area	Intake OS13	318566.00	148961.00
		318407.00	148933.00
		318386.00	149054.00
		318545.00	149082.00
	Intake OS11	318501.00	148890.00
		318660.00	148918.00
		318681.00	148797.00
		318522.00	148769.00
	Intake OS23	318104.00	148808.00
		317945.00	148780.00
		317923.00	148900.00
		318083.00	148929.00
	Intake OS21	318226.00	148650.00
		318068.00	148622.00
		318047.00	148742.00
		318205.00	148770.00
	Outfalls and floatation pocket	319047.00	147668.00
		319258.00	147668.00
		319258.00	147280.00
		319103.00	147280.00
		319103.00	147408.00
		319047.00	147408.00

Area descriptor	Infrastructure identifier	Eastings BNG	Northings BNG
2021 intake and outfall licence area (20m buffer)	Intake OS13	318543.15	148977.38
		318423.59	148956.29
		318409.26	149037.55
		318528.82	149058.63
	Intake OS11	318523.97	148873.33
		318643.52	148894.41
		318657.85	148813.16
		318538.29	148792.08
	Intake OS23	318080.86	148823.96
		317960.89	148802.81
		317946.53	148884.23
		318066.50	148905.38
	Intake OS21	318203.02	148666.13
		318084.43	148645.22
		318070.17	148726.06
		318188.76	148746.97
	Outfalls and floatation pocket	319067.32	147647.71
		319238.00	147647.71
		319238.00	147300.25
		319122.56	147300.25
		319122.56	147427.66
		319067.32	147427.66
2021 jetty licence area	Jetty	319441.36	146522.95
		319143.39	146469.05
		319116.38	146618.31
		319414.36	146672.21