Port of Waterford
Benthic Ecology Survey

Produced by

AQUAFACT International Services Ltd (APEM Group)

On behalf of

Port of Waterford

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AQUAFACT APEM Group

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1. Introduction

AQUAFACT International Services Ltd. (APEM Group) was commissioned by Malone O' Regan on behalf of the Port of Waterford (PoW) to carry out a subtidal benthic ecology survey within the Port of Waterford and the wider Barrow, Nore and Suir Estuaries in respect of 2026-2033 Navigation Maintenance Dredging application.

The Waterford Estuary, located in southeast Ireland, is a semi-enclosed coastal water body open to sea through an entrance ca. 4.25km wide between Hook Head and Dunmore East. Just north of the mouth of the estuary is Creadan Head, in which a series of beaches and tidal flats are located and extend north to Passage East. The water surface area covers approximately 80km², being for the most part relatively shallow riverine sections, however, a series of deep pockets occur within Waterford Harbour. Two major rivers join into the Waterford Estuary, the River Suir and the River Barrow. These rivers are both influenced by the tidal cycle within the estuary. The River Suir is tidal ca. 60km upstream from the entrance at Hook Head. The River Barrow and the River Nore, which is linked to the River Barrow, are both tidal for ca. 55km to St. Mullins on the River Barrow and to Inistioge on the River Nore.

The Port of Waterford's authority limits extends 6.5 km south of a line between Hook Head and Falskirt Rock, encompassing the majority of the estuary. The Port's waterway consists of a primary navigational channel, to the main terminal at Belview, for the safe transit of trade vessel.

The estuary is extremely complex and dynamic in its sediment movement and because of this sedimentation is highly variable. Sedimentation in the upper estuary is dominated by the tides, with greater sedimentation during a spring tide, due to the greater amount of energy present. Flood tides transport sediment up the estuary in the water column or as bed load. However, the majority of the ebb tide flows are not strong enough to keep the material in suspension and push the sediment back down the estuary. Therefore, the sediment accumulates in the areas of lowest velocity. The outer estuary sedimentation is primarily storm driven and thus highly variable.

The navigation channel into Port of Waterford has, for the most part, good water depths but there are sand bars at Duncannon and Cheekpoint that restrict navigation into the Port. These, in conjunction with the berths at Belview, are the primary dredging areas and require dredging at least twice a year. Maintenance of the navigation channel through these bars is essential to ensure the channel remains fit for purpose and safe to use.

Figure 1.1: Location of study area.

2. Materials & Methods

2.1. Sampling Procedure

To carry out the subtidal benthic assessment of the Port of Waterford survey area, AQUAFACT surveyed a total of 27 stations. Sampling took place on the 23rd and 24th May 2023 from the Keltoi Warrior. Figure 2.1 shows the location of the grab stations sampled and Table 2.1 shows the station coordinates. Survey areas include Port of Waterford (W1-6), Little Island (LI1-2), Cheekpoint (CP1-10), Passage East (PE1-3) and Dollar Bay, Duncannon (DB1-6). Of the 27 planned stations, 11 were not successfully sampled as the substrate was hard ground or cobbles. Additionally, a successful replicate faunal grab could not be collected at 6 stations (CP7, W2, W3, W6, LI2, and DB5). This was likely as a result of patchy distribution of suitable soft sediment and surrounding hard ground or cobbles. One successful faunal grab was returned but after a minimum of three further attempts at the same coordinates, no replicate faunal grab could be collected and the station needed to be abandoned to keep within survey time constraints.

Figure 2.1: Location of the grab stations sampled on the 23rd and 24th May 2023.

Table 2.1: Station coordinates of the grab stations.

Station	Latitude	Longitude	Successful Grab?	Reason
W 1	52.2650	-7.1166	NO	Hard ground
W 2	52.2644	-7.1166	NO	Hard ground
W 3	52.2643	-7.1137	NO	Hard ground
W 4	52.2638	-7.1136	NO	Hard ground
W 5	52.2639	-7.1098	NO	Hard ground
W 6	52.2631	-7.1096	YES	
LI 1	52.2567	-7.0575	NO	Hard ground
LI 2	52.2555	-7.0463	YES	
CP 1	52.2767	-7.0081	YES	
CP2	52.2762	-7.0029	YES	
CP3	52.2750	-7.0096	YES	
CP4	52.2747	-7.0058	YES	
CP5	52.2748	-7.0021	YES	
CP6	52.2733	-7.0046	YES	

Station	Latitude	Longitude	Successful Grab?	Reason
CP7	52.2736	-6.9996	NO	Hard ground
CP 8	52.2742	-6.9957	NO	Hard ground
CP 9	52.2728	-7.0013	YES	
CP 10	52.2731	-6.9967	YES	
PE 1	52.2436	-6.9746	NO	Hard ground
PE 2	52.2417	-6.9699	NO	Hard ground
PE 3	52.2395	-6.9650	YES	
DB 1	52.1898	-6.9417	YES	
DB 2	52.1898	-6.9319	YES	
DB 3	52.1938	-6.9417	YES	
DB 4	52.1938	-6.9319	YES	
DB 5	52.1878	-6.9417	NO	Hard ground
DB 6	52.1878	-6.9319	YES	

AQUAFACT has in-house standard operational procedures for benthic intertidal sampling and these were followed for this project. Additionally, the NMBAQC report "Guidelines for processing marine macrobenthic invertebrate samples: a processing requirements protocols" (Worsfold & Hall, 2010) was adhered to.

A 0.025m^2 van Veen grab was used to sample the grab sites. On arrival at each sampling station, the vessel location was recorded using DGPS (latitude/longitude). Additional information such as date, time, site name, sample code and depth were recorded in a data sheet.

Two replicate grab samples were attempted at each of the 27 stations for faunal analysis and a third sample was collected for sediment grain size and organic carbon analysis. The grab deployment and recovery rates did not exceed 1 metre/sec. This was to ensure minimal interference with the sediment surface as the grab descended. Upon retrieval of the grab a description of the sediment type was noted in the sample data sheet. Notes were also made on colour, texture, smell, and presence of animals.

The grab sampler was cleaned between stations to prevent cross contamination.

The samples collected for faunal analysis were carefully and gently sieved on a 1mm mesh sieve as a sediment water suspension for the retention of fauna. Great care was taken during the sieving process in order to minimise damage to taxa such as spionids, scale worms, phyllodocids, and amphipods. The sample residue was carefully flushed into a pre-labelled (internally and externally) container from below. Each label contained the sample code and date. The samples were stained with Eosin Briebrich scarlet and fixed in 4% w/v buffered formaldehyde solution upon returning to the laboratory. These samples were ultimately preserved in 70% alcohol prior to processing.

2.2. Sample Processing

All faunal samples were placed in an illuminated shallow white tray and sorted first by eye to remove large specimens and then sorted under a stereo microscope (x 10 magnification). Following the removal of larger specimens, the samples were placed into Petri dishes, approximately one half teaspoon at a time and sorted using a binocular microscope at x25 magnification.

The fauna was sorted into four main groups: Polychaeta, Mollusca, Crustacea, and others. The 'others' group consisted of echinoderms, nematodes, nemerteans, cnidarians, and other lesser phyla. The fauna were maintained in stabilised 70% industrial methylated spirit (IMS) following retrieval and identified to species level where practical using a binocular microscope, a compound microscope, and all relevant taxonomic keys. After identification and enumeration, specimens were separated and stored to species level.

The sediment granulometric analysis was carried out by AQUAFACT using the traditional granulometric approach. Traditional analysis involved the dry sieving of approximately 100g of sediment using a series of Wentworth graded sieves. The process involved the separation of the sediment fractions by passing them through a series of sieves. Each sieve retained a fraction of the sediment, which were later weighed, and a percentage of the total was calculated. Table 2.2 shows the classification of sediment particle size ranges into size classes. Sieves, which corresponded to the range of particle sizes, were used in the analysis. Appendix 1 provides the detailed granulometric methodology.

Table 2.2: The classification of sediment particle size ranges into size.

Range of Particle Size	Classification	Phi Unit
<63µm	Silt/Clay	>4 Ø
63-125 µm	Very Fine Sand	4 Ø, 3.5 Ø
125-250 µm	Fine Sand	3 Ø, 2.5 Ø
250-500 µm	Medium Sand	2 Ø, 1.5 Ø
500-1000 µm	Coarse Sand	1 Ø, 1.5 Ø
1000-2000 µm (1 – 2mm)	Very Coarse Sand	0 Ø, -0.5 Ø
2000 – 4000 µm (2 – 4mm)	Very Fine Gravel	-1 Ø, -1.5 Ø
4000 -8000 µm (4 – 8mm)	Fine Gravel	-2 Ø, -2.5 Ø
8 -64 mm	Medium, Coarse & Very Coarse Gravel	-3 Ø to -5.5 Ø
64 – 256 mm	Cobble	-6 Ø to -7.5 Ø
>256 mm	Boulder	< -8 Ø

The additional sediment samples collected from the faunal stations had their organic carbon analysis performed by ALS Laboratories in Loughrea using the Loss on Ignition method. Appendix 1 provides the methodology.

2.3. Data Analysis

Uni- and multi-variate statistical analysis of the faunal data was undertaken using PRIMER v.6 (Plymouth Routines in Ecological Research).

2.3.1. Univariate Indices

Using PRIMER the faunal data was used to produce a range of univariate indices. Univariate indices are designed to condense species data in a sample into a single coefficient that provides quantitative estimates of biological variability (Heip *et al.*, 1998; Clarke and Warwick, 2001). Univariate indices can be categorised as primary or derived indices.

Primary biological indices used in the current study include:

number of taxa (S) in the samples and

number of individuals (N) in the samples.

Derived biological indices, which are calculated based on the relative abundance of species in samples, used in the study include:

- Margalef's species richness index (d) (Margalef, 1958),

$$D = \frac{S - 1}{\log_2 N}$$

where: N is the number of individuals and S is the number of species

Margalef's species richness is a measure of the total number of species present for a given number of individuals.

- Pielou's Evenness index (J) (Pielou, 1977)

$$J = \frac{H^{'}\text{(observed)}}{H^{'}_{max}}$$

where: $H^{'}_{max}$ is the maximum possible diversity, which could be achieved if all species were equally abundant (= $\log_2 S$)

Pielou's evenness is a measure of how evenly the individuals are distributed among different species.

- Shannon-Wiener diversity index (H') (Pielou, 1977)

$$H^{'} = -\sum_{i=1}^{S} p_i(\log_2 p_i)$$

where: p_I is the proportion of the total count accounted for by the i^{th} taxa

Shannon-Wiener diversity index takes both species abundance and species richness into account quantify diversity (Shannon & Wiener, 1949).

- The Shannon-Wiener based Effective Number of Species (ENS) (Hill, 1973; Jost, 2006)

$$H = \exp(H')$$

where H' is the Shannon-Wiener diversity index.

The Shannon-Wiener index diversity index is converted to ENS to reflect 'true diversities' (Hill, 1973, Jost, 2006) that can then be compared across communities (MacArthur, 1965; Jost, 2006). The ENS is equivalent to the number of equally abundant species that would be needed in each sample to give the same value of a diversity index, *i.e.,* Shannon-Wiener Diversity index. The ENS behaves as one would intuitively expect when diversity is doubled or halved, while other standard indices of diversity do not (Jost, 2006). If the ENS of one community is twice that of another then it can be said that the community is twice as diverse as the other.

2.3.2. Multivariate Analysis

The PRIMER programme (Clarke & Warwick, 2001) was used to carry out multivariate analyses on the station-by-station faunal data. All species abundance data from the grab surveys was square root transformed and used to prepare a Bray-Curtis similarity matrix in PRIMER. The square root transformation allows some of the less abundant species to play a part in the similarity calculation. Various ordination and clustering techniques can then be applied to the similarity matrix to determine the relationship between the samples.

Multidimensional scaling (MDS) is a technique that ordinates samples as points in 2D or 3D space based on similarity in species distribution data. MDS performed on the Bray-Curtis similarity matrix produce ordination maps whereby the placement of samples reflects the similarity of their biological communities, rather than their simple geographical location (Clarke & Warwick, 2001).

An indication of how well the similarity matrix is represented by the ordination is given by stress values calculated by comparing the interpoint distances in the similarity matrix with the corresponding interpoint distances on the ordinations. Perfect or near perfect matches are rare in field data, especially in the absence of a single overriding forcing factor such as an organic enrichment gradient. Stress values increase, not only with the reducing dimensionality (lack of clear forcing structure), but also with increasing quantity of data (it is a sum of the squares type regression coefficient). Clarke & Warwick (2001) have provided a classification of the reliability of MDS plots based on stress values, having compiled simulation studies of stress value behaviour and archived empirical data. This classification generally holds well for ordinations of the type used in this study. Their classification is given below:

- Stress value < 0.05: Excellent representation of the data with no prospect of misinterpretation.
- Stress value < 0.10: Good representation, no real prospect of misinterpretation of overall structure, but very fine detail may be misleading in compact subgroups.
- Stress value < 0.20: This provides a useful picture, but detail may be misinterpreted particularly nearing 0.20.
- Stress value 0.20 to 0.30: This should be viewed with scepticism, particularly in the upper part of the range, and discarded for a small to moderate number of points such as < 50.

- Stress values > 0.30: The data points are close to being randomly distributed in the ordination and not representative of the underlying similarity matrix.

Each stress value must be interpreted both in terms of its absolute value and the number of data points. In the case of this study, the moderate number of data points indicates that the stress value can be interpreted more or less directly. While the above classification is arbitrary, it does provide a framework that has proved effective in this type of analysis.

Hierarchical Agglomerative Clustering (HAC) is used to cluster samples based on between-sample similarities into groups in dendrograms. Similarity Profiling (SIMPROF) is used to test if differences between HAC derived similarity-based clusters are significant. Similarity Percentages (SIMPER) analysis can be used to determine the characterising species of each cluster of stations identified either arbitrarily (by eye) from HAC dendrograms or statistically using SIMPROF testing (Clarke and Warwick, 2001; Clarke and Gorley, 2006).

The species, which are responsible for the grouping of samples in CLUSTER analyses, were identified using the PRIMER programme SIMPER (Clarke & Warwick, 1994). This programme determined the percentage contribution of each species to the dissimilarity/similarity within and between each sample group.

3. Results

3.1. Fauna

The taxonomic identification of the benthic infauna across all 19 sampled faunal subtidal stations surveyed yielded a total count of 44 taxa ascribed to 6 phyla and comprising 339 individuals. Of the 44 taxa identified, 26 were identified to species level. The remaining 18 could not be identified to species level due to the fact that they were juveniles, damaged or indeterminate. The full faunal abundance species list can be seen in Appendix 2.

Of the 44 taxa recorded, 1 was a nemertean (ribbon worm), 16 were annelids (segmented worms), 10 were arthropods (crabs, shrimps, insects *etc*.), 13 were molluscs (mussels, cockles, snails *etc*.), 2 were bryozoans (moss animals) and 2 were echinoderms (brittlestars).

3.1.1. Univariate Analysis

In order to carry out the univariate analyses all replicate data were combined to give a total for each station prior to statistical analysis. Epifaunal and colonial species were removed. Additionally, stations where a replicate faunal sample could not be collected were removed from the analysis. These included stations CP7, W2, W3, W6, L12, and DB5. Univariate statistical analyses were carried out on the reduced station-by-station faunal data. The following parameters were calculated and can be seen in Table 3.1; species numbers, number of individuals, richness, evenness, Shannon-Wiener diversity, and Effective Species Number (ENS). Species numbers ranged from 1 (PE3) to 17 (DB4). Number of individuals ranged from 2 (PE3) to 78 (CP1). Richness ranged from 0 (PE3) to 4.23 (DB4). Evenness ranged from 0.61 (CP1) to 1.00 (CP4 & CP9). Shannon-Wiener diversity ranged from 0 (PE3) to 2.5 (DB4). Effective number of species ranged from 1(PE3) to 12.14 (DB4) indicating that station DB4 is over 12 times more diverse than PE3. Figure 3.1 shows these community indices in graphical form.

Table 3.1: Univariate measures of community structure.

Station	No. Taxa	No. Individuals	Richness	Evenness	Shannon-Wiener Diversity	Effective Number of Species
	S	N	d	J'	H'(loge)	EXP(H')
CP1	7	78	1.38	0.61	1.19	3.30
CP2	7	7	3.08	1.00	1.95	7.00
CP3	7	42	1.61	0.74	1.44	4.22
CP4	2	2	1.44	1.00	0.69	2.00
CP5	3	4	1.44	0.95	1.04	2.83
CP6	2	4	0.72	0.81	0.56	1.75
CP9	4	4	2.16	1.00	1.39	4.00
CP10	2	3	0.91	0.92	0.64	1.89
PE3	1	2	0.00	-	0.00	1.00
DB1	8	22	2.26	0.78	1.62	5.03
DB2	10	36	2.51	0.85	1.97	7.15
DB3	11	33	2.86	0.81	1.94	6.98
DB4	17	39	4.37	0.88	2.50	12.14
DB6	12	32	3.17	0.88	2.20	9.01

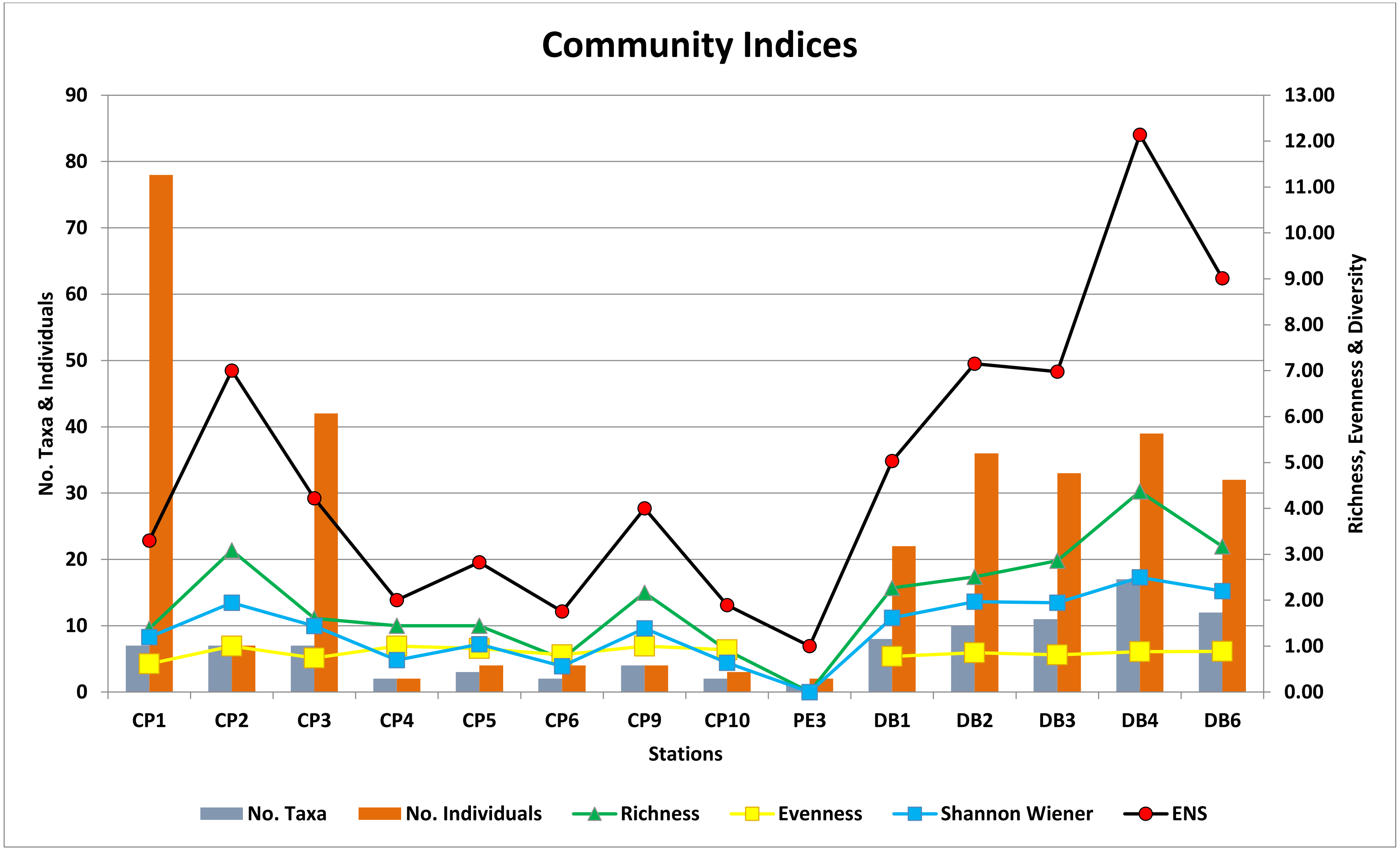


Figure 3.1: Subtidal community diversity indices. Diversity is expressed in Effective Number of Species (ENS) and Shannon-Wiener Diversity.

3.1.2. Multivariate Analysis

The same data set used above for the univariate analyses was also used for the multivariate analyses. The dendrogram and the MDS plot can be seen in Figures 3.2 and 3.3, respectively. SIMPROF analysis revealed 4 statistically significant groupings between the 13 stations (the samples connected by red lines cannot be significantly differentiated). The stress level on the MDS plot indicates This provides a good representation of the data, with no real prospect of misinterpretation of overall structure, but very fine detail may be misleading in compact subgroups.

A clear divide (94.72% dissimilarity) can be seen between **Group a** and all other groups. A similarly clear divide (91.05% dissimilarity) can be seen between **Group b** and **Groups c** and **d**, and another between **Group c** and **Group d** (87.14% dissimilarity).

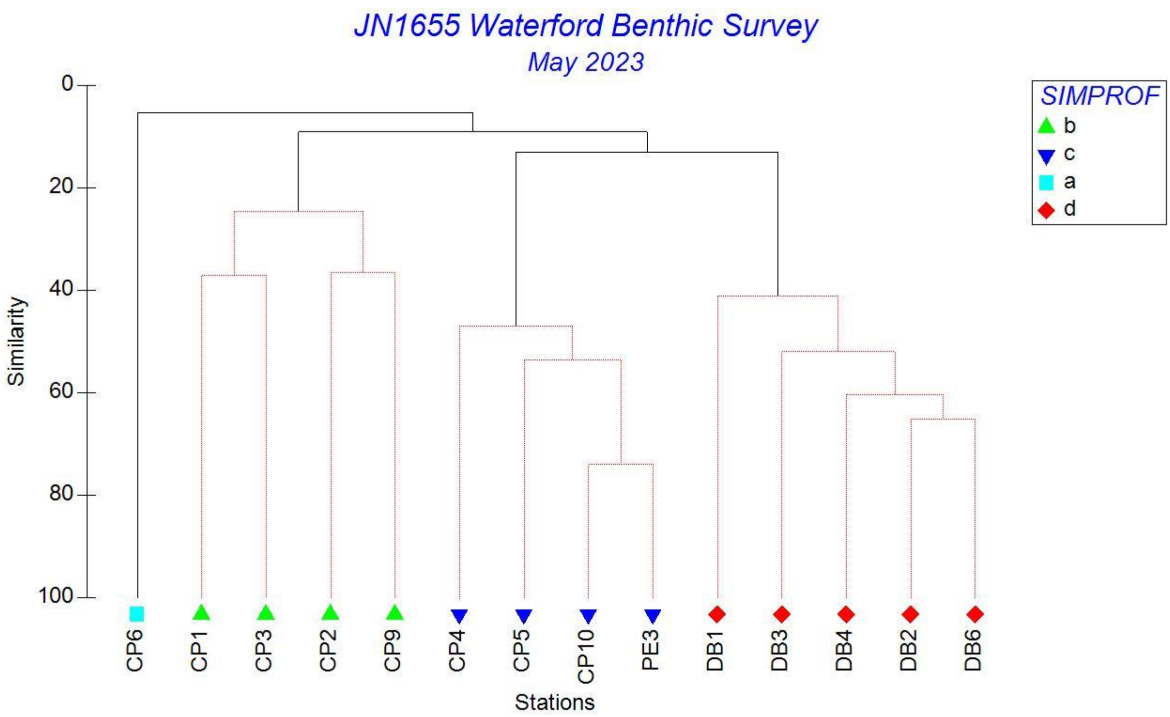


Figure 3.2: Dendrogram produced from Cluster analysis.

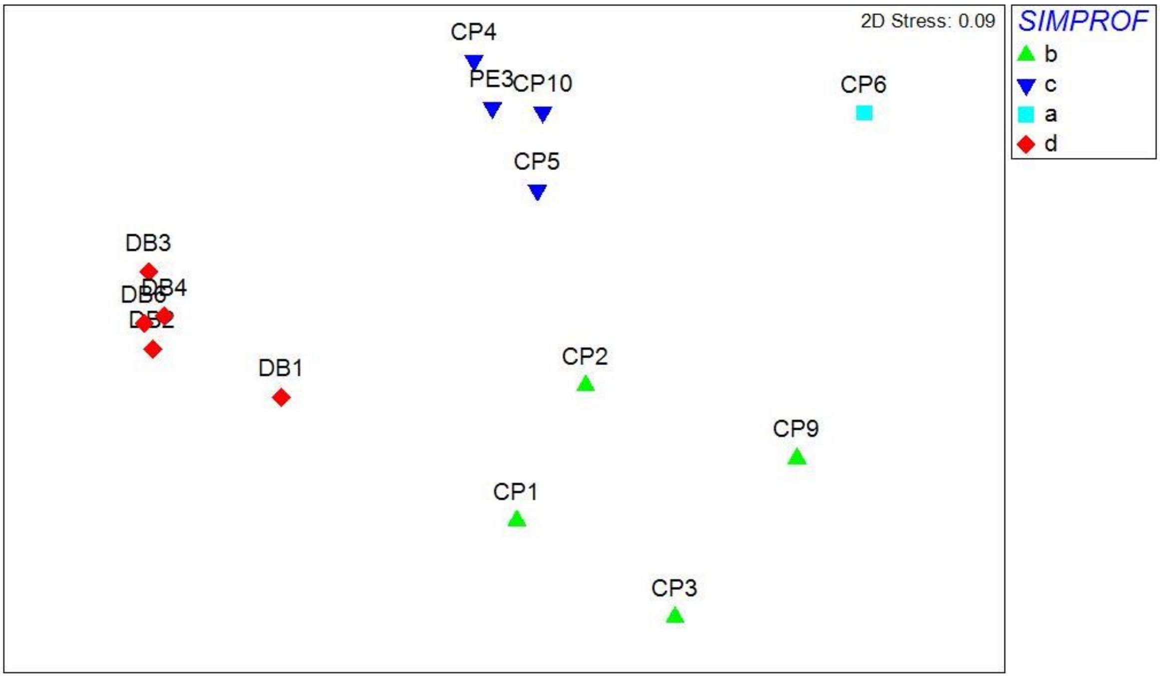


Figure 3.3: MDS plot.

Group a consisted of station CP6. This group separated from all other groups at a 94.72% dissimilarity level. Group a contained only 2 taxa comprising 4 individuals. SIMPER analysis could not be carried out on this group as it only contained one station. One taxon, the bivalve Mytilidae (juv.) has 3 individuals and the gastropod *Peringia ulvae* had 1 individual present. Mytilidae (juv). and *Peringia ulvae* are tolerant of disturbance, occurring under normal conditions, but their populations are stimulated by organic enrichment.

Group b consisted of stations CP1, CP2, CP3, and CP9. This group separated from Groups c and d at a 91.05% dissimilarity level and had a within group similarity of 28.59%. Group b contained 13 taxa comprising 131 individuals. Of the 13 taxa, 4 were present twice or less. Four taxa accounted for almost 81% of the faunal abundance: the polychaetes *Tharyx killariensis* (53 individuals, 40.46% abundance) and *Pygospio elegans* (14 individuals, 10.69% abundance), the amphipod *Corophium volutator* (25 individuals, 19.08% abundance), and the gastropod *Peringia ulvae* (14 individuals, 10.69% abundance). SIMPER analysis further revealed *Macoma balthica* as a characterising species of this group. *Corophium volutator, Pygospio elegans* and *Peringia ulvae* are tolerant of disturbance, occurring under normal conditions, but their populations are stimulated by organic enrichment. *Tharyx killariensis* is a second order opportunistic species present in slight to pronounced unbalanced conditions.

Group c consisted of stations CP4, C5, C10, and PE3. This group separated from Group d at an 87.14% dissimilarity level. This group had a within-group similarity level of 53.64%. Group c contained 5 taxa comprising 11 individuals. Of the 5 taxa, 4 were present twice or less. Only one species was present across all stations, the polychaete *Nephtys hombergii* (7 individuals, 63.64% abundance). *Nephtys hombergii* is indifferent to enrichment and are typically present in low densities with non-significant variations over time.

Group d consisted of stations DB1, DB2, DB3, DB4, and DB6. This group separated from Group c at an 87.14% dissimilarity level and had a within group similarity of 50.5%. Group d contained 27 taxa comprising 162 individuals. Of the 27 taxa, 16 were present twice or less. Five taxa accounted for over 64% of the faunal abundance: the bivalves Tellinidae (juv.) (35 individuals, 21.6% abundance) and *Fabulina fabula* (22 individuals, 13.58% abundance), the polychaetes *Magelona filiformis* (20 individuals, 12.35% abundance) and *Nephtys hombergii* (13 individuals, 8.09% abundance), and the amphipod *Bathyporeia* sp. (14 individuals, 8.64% abundance). SIMPER analysis further revealed *Mactra stultorum* as a characterising species of this group. Tellinidae (juv.), *Fabulina fabula, Magelona filiformis,* and *Bathyporeia* sp. are very sensitive to organic enrichment and are present in unpolluted conditions. *Nephtys hombergii* is indifferent to enrichment and are typically present in low densities with non-significant variations over time.

Groups a and b can be described as belonging to the JNCC biotope SS.SMu.SMuVS.PolCvol *Polydora ciliata* and *Corophium volutator* in variable salinity infralittoral firm mud or clay (EUNIS code A5.321). SS.SMu.SMuVS.PolCvol is a sublittoral biotope occurring in sheltered, very sheltered and extremely sheltered areas with weak tidal streams. The biotope occurs in variable salinity and exclusively in clay and very firm mud and is characterized by a turf of the polychaete *Polydora* along with the amphipod *Corophium volutator.* The resilience and resistance of the biotope to impacts is considered high (De-Bastos & Hill, 2016).

Additionally, these stations can be classified as belonging to one of the four common benthic community habitat types occurring in the River Barrow and River Nore SAC (Figure 3.4) (NPWS, 2011) namely the habitat 'Muddy estuarine community complex'. This community is present intertidally and subtidally from Cheek Point and Great Island northward to New Ross. The substrate of this community complex is predominantly of fine material. The distinguishing species for this group are the bivalve *Scrobicularia plana* and *Macoma balthica,* the amphipod *Corophium* *volutator,* the polychaete *Streblospio shrubsolii,* and the oligochaetes *Tubificoides pseudogaster* and *Tubificoides benedii.* These species are indicative of variable salinity community (NPWS, 2011). This biotope community was also previously recorded in the Belview Port area.

Group c can be said to be belong to the JNCC biotope SS.SMu.SMuVS.MoMu – Infralittoral fluid mobile mud (EUNIS code: A5.324). Fluid mobile mud is suspended and deposited on each tide. In areas with high quantities of suspended particulate material in the water column, it may become deposited around slack water when currents fall and can form fluid mud layers up to several metres thick becoming a transient habitat. Species present within this biotope will be those washed in from other communities such as *Nephtys hombergii* or oligochaetes. In his benthic biotope classification of the subtidal sedimentary habitats in the Lower River Suir SAC and the River Nore and River Barrow SAC, Kennedy (2008) recorded this biotope at this location near Cheekpoint as well as the JNCC biotope SS.SMu.ISaMu.NhomMac – *Nephtys hombergii* and *Macoma balthica* in infralittoral sandy mud in adjacent waters.

Group d can be said to exhibit elements of the JNCC biotope SS.SSa.IMuSa.FfabMag – *Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand (EUNIS code A5.242). Additionally, this group can be classified as belonging to another of the four common benthic community habitat types occurring in the River Barrow and River Nore SAC (Figure 3.4) (NPWS, 2011) namely Fine Sand with *Fabulina fabula* community, within the Qualifying Interest Estuaries [1130]. This subtidal community is confined to the southern margin of this site at the mouth of Waterford Harbour. Its northern limit is broadly delineated by a line extending from Crooke on the western side to Balinphile on the eastern side of the Waterford Harbour. The sediment is that of fine sand ranging from 43-59% to very fine sand ranging from 24-45%. The biological community is distinguished by the co-occurrence of moderately large numbers of the bivalve *Fabulina fabula* and the polychaete *Nephtys hombergii*. Also frequently present are the polychaetes *Owenia* and *Magelona filiformis* and the bivalve *Mactra stultorum.*

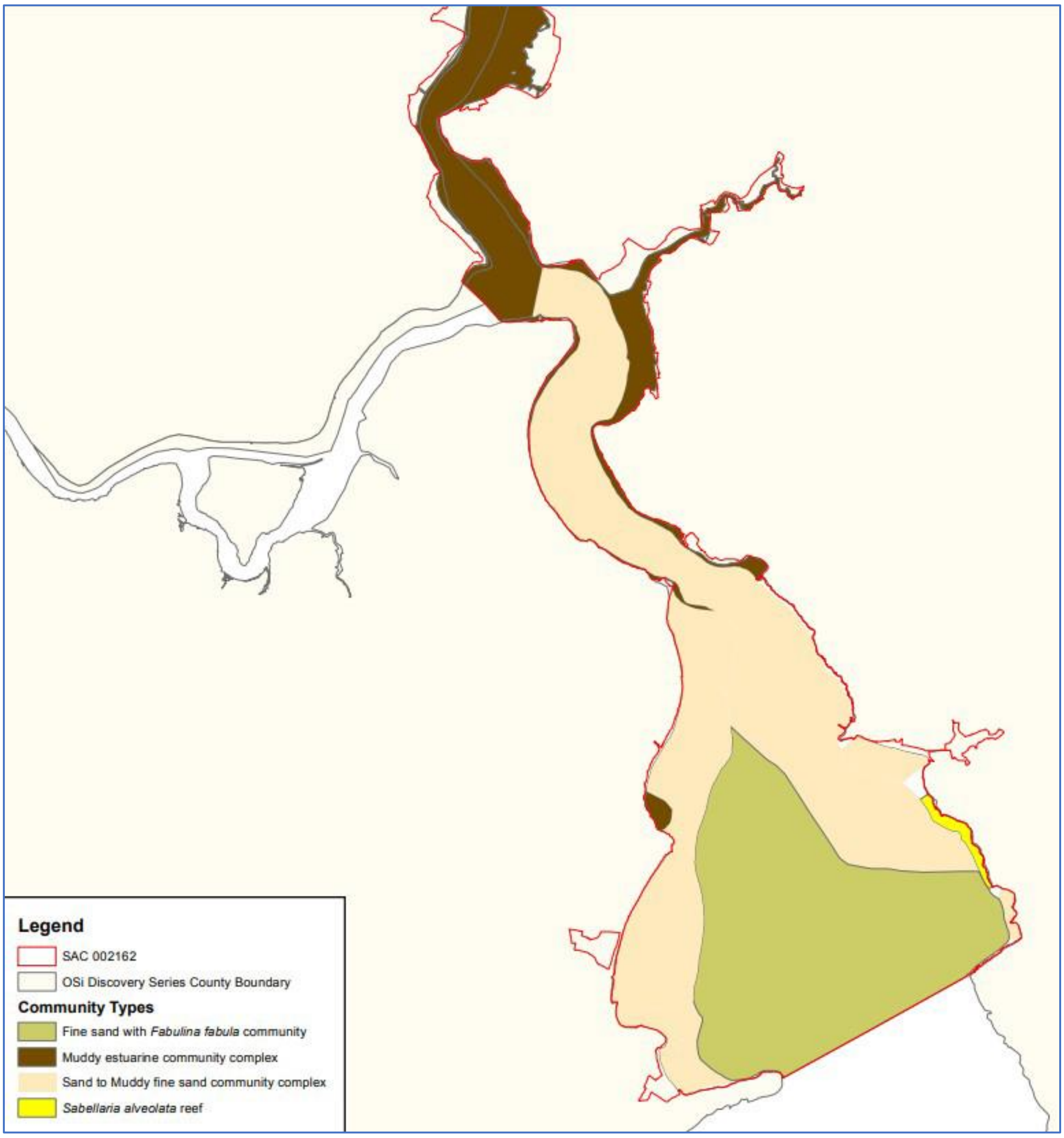


Figure 3.4: River Barrow and River Nore conservation objectives marine community types (NPWS, 2011).

3.2. Sediment

Table 3.2 shows the sediment characteristics of the subtidal and intertidal stations surveyed including the granulometry and the percentage organic carbon.

The sediment sampled within the study area was classified as slightly gravelly muddy sand (CP1, CP2, CP3, and CP10), gravelly muddy sand (CP4 and PE3), sand (DB1, DB2, DB3, DB4, and DB6), muddy sand (CP5, CP6, and CP9) and gravelly sand (DB5) according to Folk (1954). No medium gravel-boulders were recorded. Highest levels of fine gravel and fine sand were recorded at DB6 (22.7% and 39.6% respectively). Highest levels of very fine gravel, very coarse sand, and silt/clay were recorded at PE3 (6.6%, 12.5%, and 26.6% respectively). Highest levels of coarse sand were recorded at CP10 (10.6%). Highest levels of medium sand were recorded at DB5 (33.8%). Highest levels of very fine sand were found at CP5 (62.8%). Figure 3.5 illustrates the sediment type according to Folk (1954). Figures 3.6 and 3.7 illustrate the sediment fractions of stations CP1-10 and stations DB1-6 and PE3 respectively. Organic matter values ranged from 1.97% (DB1) to 9.33% (PE3).

Figure 3.5: Sediment type at each stations according to Folk (1954).

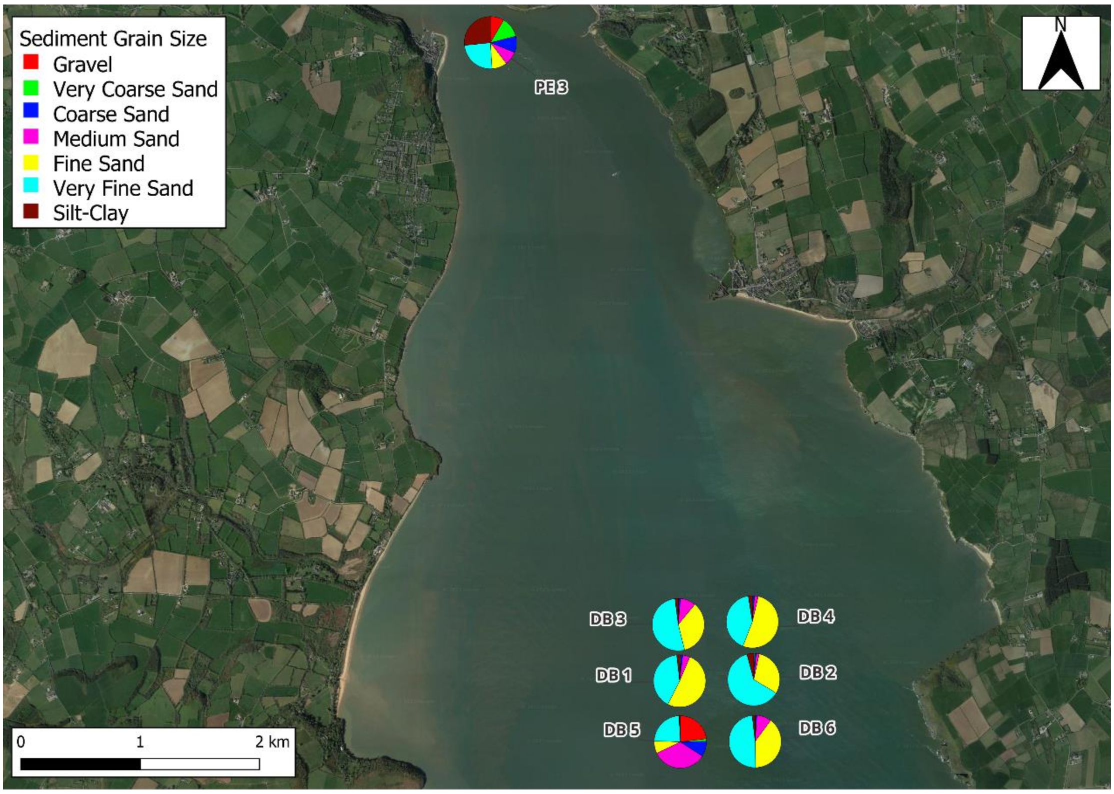


Figure 3.6: Sediment fractions of stations DB1 t0 DB6 and PE3.

Figure 3.7: Sediment fractions of CP1 to CP10.

Table 3.2: Sediment characteristics of the benthic faunal stations sampled. LOI refers to the % organic carbon loss on ignition.

Station	>8mm	Fine Gravel (4-8mm)	Very Fine Gravel (2-4mm)	Very Coarse Sand (1-2mm)	Coarse Sand (0.5-1mm)	Medium Sand (0.25-0.5mm)	Fine Sand (125-250mm)	Very Fine Sand (62.5-125mm)	Silt-Clay (<63mm)	Folk (1954)	LOI (%)
CP1	0	0.1	1.1	3.3	4.4	3.1	21.6	55.1	11.2	Slightly Gravelly Muddy Sand	5.56
CP2	0	0.1	1.4	6.4	9.5	7.7	15.8	39.1	20	Slightly Gravelly Muddy Sand	6.4
CP3	0	0.3	1.8	4.5	5	4	15	51.2	18.1	Slightly Gravelly Muddy Sand	5.54
CP4	0	15.9	3.7	3.8	4.3	5.7	17.8	38	10.8	Gravelly Muddy Sand	5.13
CP5	0	0	0.7	1	2.8	2.4	15.3	62.8	15.1	Muddy Sand	4.66
CP6	0	0.2	1.5	6.8	10.1	7	12.6	42.1	19.6	Muddy Sand	6.73
CP9	0	0	0.4	3.1	4.9	4.2	15.3	59	13	Muddy Sand	4.49
CP10	0	0.9	2.2	8.9	10.6	8.4	15.3	34.7	19.1	Slightly Gravelly Muddy Sand	7.42
DB1	0	0.1	0.2	0.4	1.3	4.4	51	40.7	1.8	Sand	1.97
DB2	0	0	0.1	0.5	0.9	1.9	30.2	62.2	4.2	Sand	2.69
DB3	0	0	0.1	0.2	1	9.7	35.1	51.9	2	Sand	2.01
DB4	0	0	0.1	0.4	0.9	2.3	52.2	41.6	2.5	Sand	3.42
DB5	0	22.7	0.4	1.5	9.6	33.8	7.7	23.6	0.8	Gravelly Sand	2.38
DB6	0	0	0.1	0.2	0.8	9.1	39.6	48.4	1.8	Sand	2.24
PE3	0	1.9	6.6	12.5	10.1	8.5	9.4	24.3	26.6	Gravelly Muddy Sand	9.33

4. Discussion

4.1. Navigation Maintenance Dredging 2026-2033

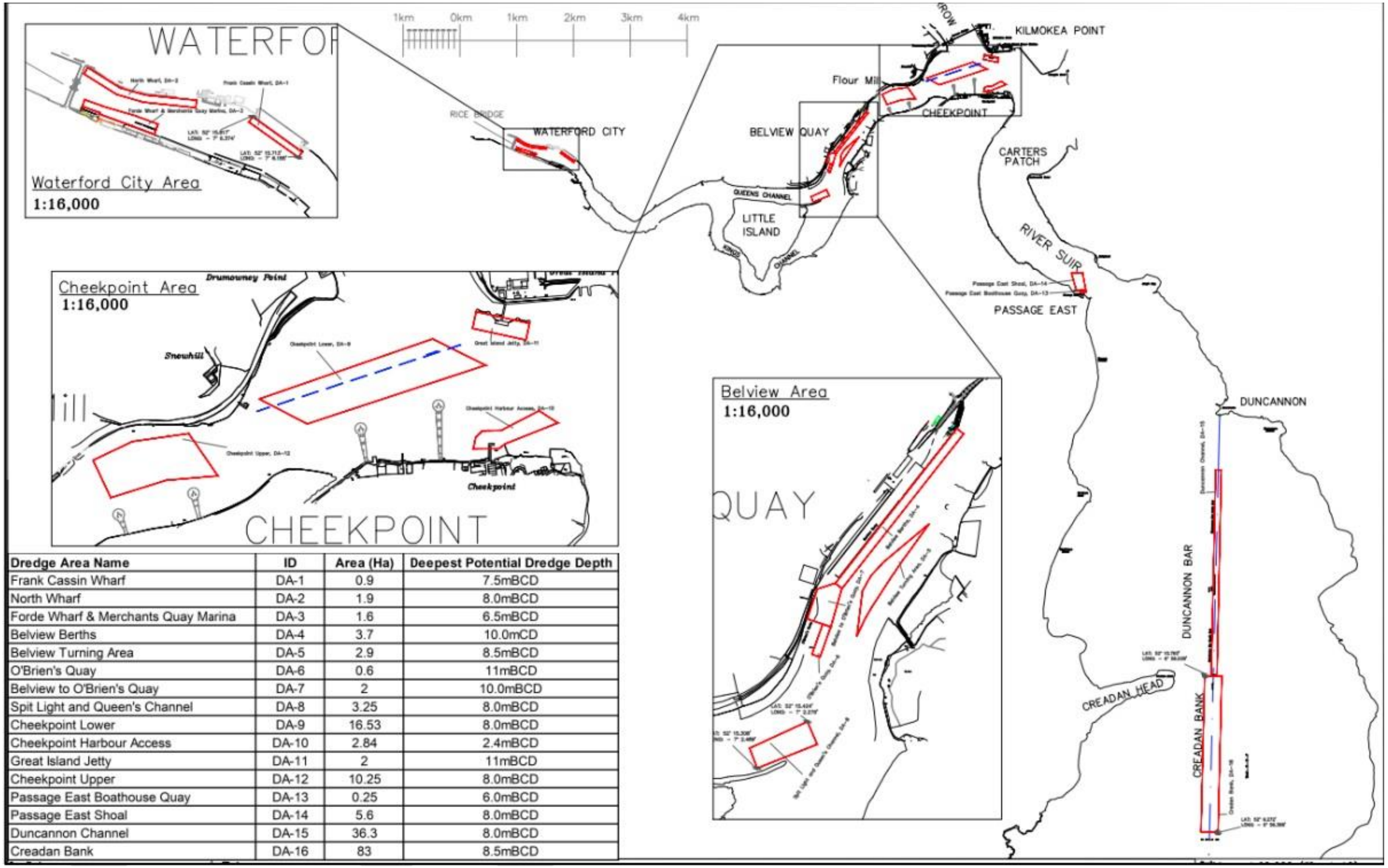
Waterford estuary is extremely complex and dynamic in its sedimentation movement and because of this sedimentation is highly variable. Sedimentation in the upper estuary is dominated by the tides, with greater sedimentation during spring tides, due to the greater amount of energy present. Flood tides transport sediment up the estuary in the water column or as bed load. However, the majority of the ebb tide flows are not strong enough to keep the material in suspension and push the sediment back down the estuary. As a result of this, the sediment accumulates in the areas of lowest velocity. In the outer estuary sedimentation is primarily storm driven and thus highly variable.

The navigation channel into Port of Waterford has, for the most part, good water depths but there are sand bars at Duncannon and Cheekpoint that restrict navigation into the port. These, in conjunction with the berths at Belview, are the primary dredging areas and require dredging at least twice a year. Maintenance of the navigation channel through these sand bars is essential to ensure the channel remains fit for purpose and safe to use (Malone O'Regan, 2023).

The current licence (S0012-03) expires on the 31st of December 2025 and therefore the Port of Waterford is seeking an 8-year duration Dumping at Sea Permit and Foreshore Licence to run inclusively from 2026 to 2033. It is requested that the maintenance dredging required be allowed to be undertaken at any time during this period as identified by regular hydrographic survey. Any maintenance operations will be dictated by the extent of sedimentation that has occurred in each area of the harbour. These rates can fluctuate significantly, based on inclement weather resulting in storm conditions and high rainfall. Severe sedimentation has occurred in the past after a storm event and this contingency is included to ensure that the port can act immediately to reduce the build-up and allow trade to continue. The existing dumping at sea permit does not allow ploughing to occur between the start of March and the end of June, with the exception of those sites at Cheekpoint where ploughing is restricted to spring tides periods only. Bed levelling is permitted to be undertaken at all times of the year. No change to this is proposed. Similar to the current permit, it is requested that 823,513 wet tonnes are permitted to be placed at the offshore site from 2026 to 2033 inclusive. There has been no increase in the permitted quantity of sediment disposed of at the offshore site since the previous permit.

Sedimentation rates can vary considerably depending on the severity of weather conditions, river flow and prevailing wind direction. Severe sedimentation has occurred in the past after a storm event and this contingency is included to ensure that the Port of Waterford can act immediately to reduce the build-up and allow trade to continue. Therefore, further to this regular disposal activity, it is also requested that an annual contingency tonnage of 175,000 dry tonnes be allocated to this disposal site should extreme weather events cause an inundation of sediment. This increased allowance is requested due to the inclusion of Creadan Bank on this application, which is located in an extremely dynamic area and represents a significant risk in extreme events. As per previous permits this allocation would only be deposited if the dredging of this material is required to maintain navigable depths, as evidenced by pre-dredge and post dredge bathymetric surveys. The use of the contingency allowance would be subject to the prior written agreement of the Agency. This contingency allowance is not requested as part of the regular annual tonnage as it is likely it will not be needed, and it would unnecessarily increase the annual permitted dumping tonnage. However, failure to include an allowance for inundation events would be irresponsible of the port, considering the estuary's history of such events. The inclusion of the contingency figure means that an emergency application to the EPA would not being required for an extreme weather/inundation event when a quick response to the conditions may be required. Under its current permit/licence, the port is permitted to plough dredge a maximum of 159,165 wet tonnes annually. No change to this tonnage is proposed (Malone O'Regan, 2023).

The proposed dredging areas to be maintained by Port of Waterford are illustrated in Figure 4.1. The location of the disposal site to the west of Hook Head is illustrated in Figure 4.2.



Dredge Area Name	ID	Area (Ha)	Deepest Potential Dredge Depth
Frank Cassin Wharf	DA-1	0.9	7.5mBCD
North Wharf	DA-2	1.9	8.0mBCD
Forde Wharf & Merchants Quay Marina	DA-3	1.6	6.5mBCD
Belview Berths	DA-4	3.7	10.0mCD
Belview Turning Area	DA-5	2.9	8.5mBCD
O'Brien's Quay	DA-6	0.6	11mBCD
Belview to O'Brien's Quay	DA-7	2	10.0mBCD
Spit Light and Queen's Channel	DA-8	3.25	8.0mBCD
Cheekpoint Lower	DA-9	16.53	8.0mBCD
Cheekpoint Harbour Access	DA-10	2.84	2.4mBCD
Great Island Jetty	DA-11	2	11mBCD
Cheekpoint Upper	DA-12	10.25	8.0mBCD
Passage East Boathouse Quay	DA-13	0.25	6.0mBCD
Passage East Shoal	DA-14	5.6	8.0mBCD
Duncannon Channel	DA-15	36.3	8.0mBCD
Creadan Bank	DA-16	83	8.5mBCD

Figure 4.1: Proposed Dredging Areas to be Maintained by Port of Waterford (Malone O'Regan, 2023).

4.1.1. Trailing Suction Hopper Dredger

Due to the specific characteristics of the Port of Waterford the Trailing Suction Hopper Dredger (TSHD) is the primary dredging method used to maintain the design depth of the navigational channels, and the other accessible areas of the Port's berths. The areas to be dredged will be identified regularly by hydrographic survey.

To start the dredging operations, the TSHD will sail to the area to be dredged. Once in the vicinity of its dredging area, the TSHD will lower the draghead(s) to the seabed and dredging can commence. The centrifugal dredge pump, installed inside the dredger, takes up a mixture of water and soil through the draghead and suction pipe, and pumps the mixture into its integral hopper. The sediment will settle in the hopper and, if advantageous, only the water is discharged through an adjustable overflow system. When the draught of the vessel reaches the dredging loading mark or when circumstances do not allow for further loading, dredging will cease, and the suction pipe hoisted on deck. The dredger will fill its hopper in each of the identified dredging areas as efficiently as possible.

Upon filling its hopper, the dredger will sail to the licensed disposal site and slows to approximately one to two knots. The dredger will then open bottom doors, or split along its hull, to allow the release of its contents over several minutes. During the disposal operation the dredger is travelling at between one to two knots within the disposal area. Due to this, the material is spread over the disposal site and ensures against accumulation of material within an isolated area (*i.e.,* the centre of the disposal site). This process is repeated for each disposal operation, with the master of the vessel referring to the previous disposal locations used within the on-board tracking system and selecting a new disposal location within the licensed area. By using as much of the disposal site as possible any impacts of excessive accumulation in one location from the disposal activity will be minimised.

This process will be continued until interim hydrographic surveys show that the required safe navigation depths required have been achieved and dredging can cease.

4.1.2. Plough Dredging

A plough vessel generally uses, if available, a bulldozer type plough to relocate material, although a standard open box plough can suffice on occasion. Sediment movement is achieved by towing a bottomless rectangular box-shaped fabricated steel implement behind a powered vessel, usually a small workboat or tug. When used correctly, the plough is suspended at a controlled height from an A-frame mounted over the stern of the towing vessel. Height, or depth of submergence, is controlled by a deck mounted hoist winch. The cutting blade at the leading edge of the plough slices the surface sediment which is then contained within the sides and rear of the following plough until reaching an area where the bed level is lower than the suspended level of the plough, whereupon the contained sediment falls from the open bottom of the plough. The plough is then raised above the general seabed level and the towing vessel returns to the area from which sediment is to be moved and repeats the cycle.

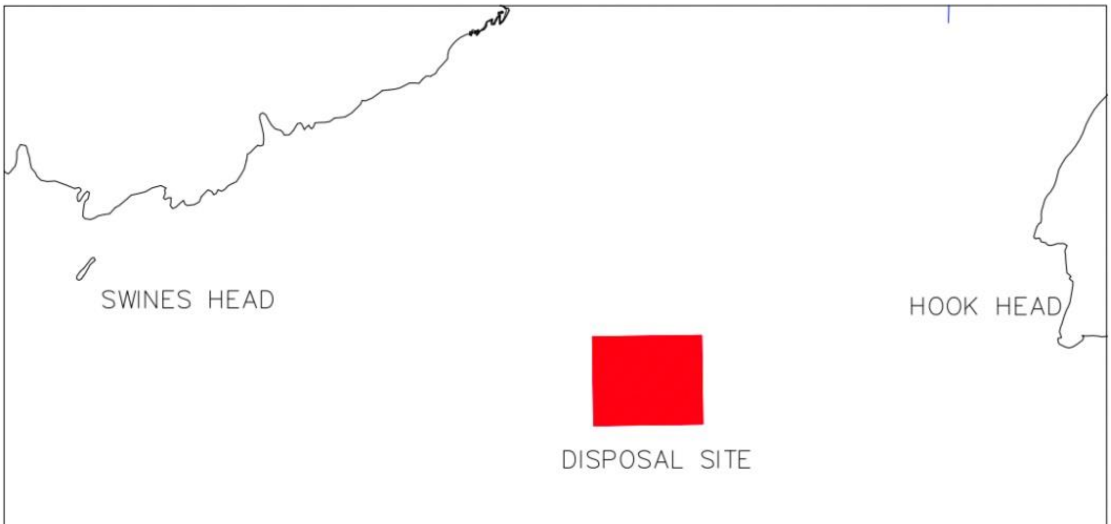
Ploughing is also undertaken regularly at Cheekpoint Lower Bar. The Port of Waterford has invested considerable time and effort over the last number of years to study the sedimentation regime that occurs at Cheekpoint Lower Bar. This is because it is the primary dredging cost for the Port annually. From a variety of studies and observations, the Port have ascertained with confidence that sedimentation is significantly greater over spring tide periods. Sedimentation rates on the spring tide can commonly be 2 to 3 times greater than the neaps, and on occasion considerably more. Turbidity monitors in and around Cheekpoint have reflected this assertion as the spring tide energy mobilises significant amounts of sediment around the estuary generally. A hydrodynamic model developed by the Port has corroborated this hypothesis. Therefore, the decision was taken to undertake ploughing during spring tide periods to minimise the amount of sediment settling in the area while it was still fluid and unconsolidated. The premise of these operations is prevention rather than cure. Also, environmentally, ploughing on spring tides is also more attractive due to the naturally elevated background levels of suspended sediment that are present. The port has used this preventative technique over the past number of years in compliance with its current licence/permit. Furthermore, the Port is currently looking at long term solutions to try and minimise or negate the sedimentation and associated dredging requirement at Cheekpoint Lower Bar and is seeking to progress these options.

4.1.3. Mechanical Dredging

There is also the potential for utilisation of a mechanical dredger in some areas. These dredgers use a bucket lowered to the seabed to excavate the targeted sediment material which is then raised to the surface. However, these dredgers do not have any means of transporting the dredged sediment so 'hopper barges' are required to be filled and transit to the licensed disposal site. The areas that may require the use of a mechanical dredger are limited to quay walls and berths where material has been compressed and has consolidated to a degree that it cannot be removed by other methods of dredging. This option is not favoured by the Port as it is significantly more expensive that the use of a TSHD/plough and it is only utilised as a last resort when conditions dictate the standard processes are technically unfeasible.

4.1.4. Disposal Site

The offshore disposal site (Figure 4.2) proposed for this application has been in use for the Proposed Development since 1996. The dredging methodology, volume and local site characteristics have not changed in the intervening period so all historical studies undertaken with respect to the dump site and its impacts are deemed to be relevant (Malone O'Regan, 2023).



	WGS84 Coordinates		Area (Ha)
	Latitude	Longitude	
Disposal Site	52° 07.45' N	06° 58.80' W	52 Hectares
	52° 07.10' N	06° 58.80' W	
	52° 07.10' N	06° 58.10' W	
	52° 07.45' N	06° 58.10' W	

Figure 4.2: Offshore Disposal Site.

4.2. Suspended Solid Concentration and Sedimentation

Naturally occurring tidally generated suspended solid concentrations were modelled by Delft Hydraulics (Eysink *et al*., 2000) and vary between 50 and 500mg/l at both Belview Point in the River Suir and at Garraunbaun Rock near Ferry Point in the White Horse Reach of the River Barrow. In contrast, at Cheekpoint, the confluence of the River Barrow and the River Suir, the tidally generated suspended solids concentrations were typically less than 150mg/l. Downstream in the River Suir, between Passage East and Buttermilk Point, naturally occurring, tidally generated suspended solids exceeded 1,000mg/l. Tidally generated suspended solids at Duncannon Bar within the Suir Estuary were above 100mg/l at bed and mid-water on spring tides. Background suspended sediment concentrations (SSC) (of the fraction) in the Cheek Point area vary dynamically during the tidal cycle, with maximum concentrations at 0 to 2 hours after maximum ebb and flood currents and minimum concentrations at 0 to 2 hours following slack water (Rijn, 1990).

ABP Marine Environmental Research Ltd. (ABPmer) modelled the impact of plough dredging at Cheek Point Lower (ABPmer, 2017). The modelling showed that the dispersed sediment would move throughout the estuary, with the vast majority moving up-estuary, but would generally be confined to the area between Buttermilk Point and Little Island. The greatest effects were seen throughout the estuary at the end of the plough disturbance scenario (8 days with ploughing ceasing on Day 4). These effects decay to background levels within about four days following cessation of ploughing on falling spring tides. Most material would be moved (transported and eroded) on the flood tide and during spring tides whereas neap tides would predominantly be accretional. The modelling identified locations of temporary sediment storage (later eroded) as well as sediment 'sinks', where accretion would be more permanent, notably the southern edge of the Cheekpoint section, adjacent to the maintained channel. Maximum SSC (suspended sediment concentrations) (above background) at the point of disturbance were around 2,500 mg/l near-bed at the time of peak flows and 1,500 mg/l during slack flows. One day following completion of plough disturbance, peak SSC would reduce by over an order of magnitude at the disturbance site. Maximum concentrations away from the disturbance location, for the most part, would occur on peak flood flows as 'pulses' that rarely last for longer than 30 minutes per tide. Individual spikes can reach 1,000 mg/l at some locations. Elevated SSC that last for several hours are generally in the range 150-250 mg/l, depending on location, on spring flood tides, and lower on ebb tides. Average elevated concentrations are rarely above 50 mg/l. These values compare against the measured background SSC level, which were recorded between 350 and 600 mg/l between Carters Patch and the River Barrow, on a typical spring tide, increasing to up to 1,000 mg/l during an observed storm event. Sedimentation as a result of the plough disturbance is for the most part temporary, accumulating during periods of slack water, or in areas of eddy circulation. With the exception of identified 'sink' areas, accumulations are small, a few millimetres to 1 to 2 centimetres. Most accumulations are re-eroded on the following peak flows (predominantly on the flood). In the areas around Carters Patch, sedimentation of up to 1.5 cm was present for a maximum period of 6 hours before being re-eroded and in all cases, sedimentation rates and SSC levels increase after *c*. 2 days of ploughing. This indicates that this is the timescale for disturbed material (probably the coarser fraction) to move up- and down-estuary, before returning through the Cheekpoint area (AQUAFACT, 2017).

Figures 4.3 and 4.4 shows the difference in SSC immediately at the end of ploughing (Plough +0 days) and 4 days following cessation of ploughing (Plough +4 days) at ebb and flood tide respectively. Figures 4.5 and 4.6 show the difference in sedimentation immediately at the end of ploughing and 4 days following cessation of ploughing at high water and low water respectively.

Delft Hydraulics modelled the impacts of trailer-suction hopper dredging activities at the Duncannon Bar on the spreading of suspended sediment in the estuary of the River Suir (Eysink *et al.,* 2000). Environmental Tracing Systems (ETS) undertook a fluorescent particle tracing study in order to determine the fate of dredged material from Cheek Point Harbour (ETS, 1998). The turbidity generated by the dredging activity must be weighed against the turbidity which results from natural processes (*e.g.,* storm surges) and the background turbidity (*e.g.,* navigation) that occurs in the dredging areas before, during and after the dredging activity. The majority of suspended sediment generated due to dredging activities is at depth (*i.e.,* close to the seafloor). In its initial deliberations, Delft Hydraulics (Eysink *et al.,* 2000) considered that the additional turbidity above background levels 50m around the dredging Trailing Suction Hopper Dredge would be of the order of *c*. 250-300mg/l of suspended solids. However, the modelling concluded that the increase in suspended sediment concentrations above background would be of the order of 100mg/l within 50m of the dredger. Assuming suspended solids in the channel are at the upper end of this observed range *i.e.,* 100mg/l, the suspended solids concentrations local to the dredger are likely to increase to the order of 250mg/l at Cheekpoint and 200mg/l at Duncannon Bar.

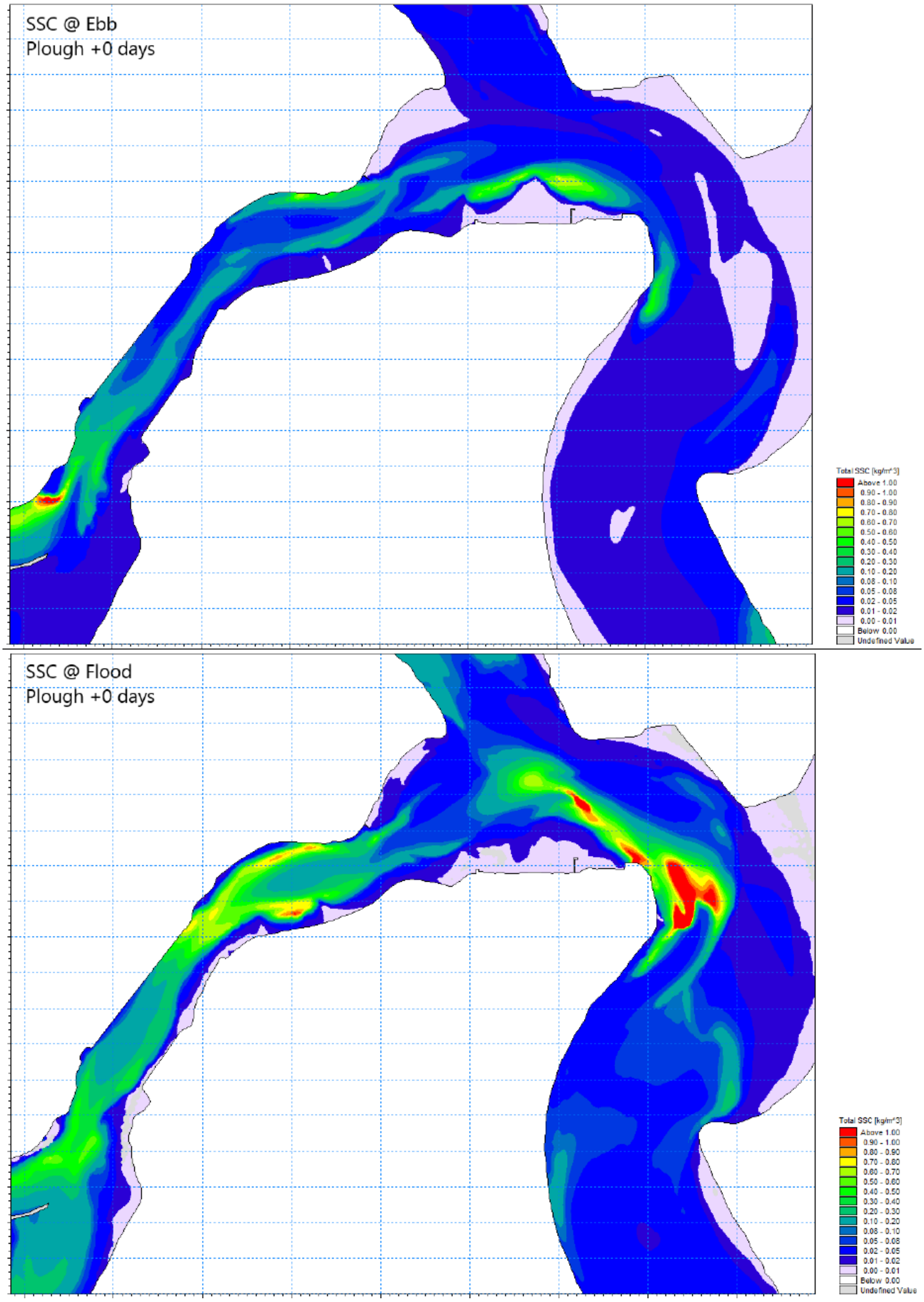


Figure 4.3: SSC at ebb and flood tide immediately at the end of ploughing.

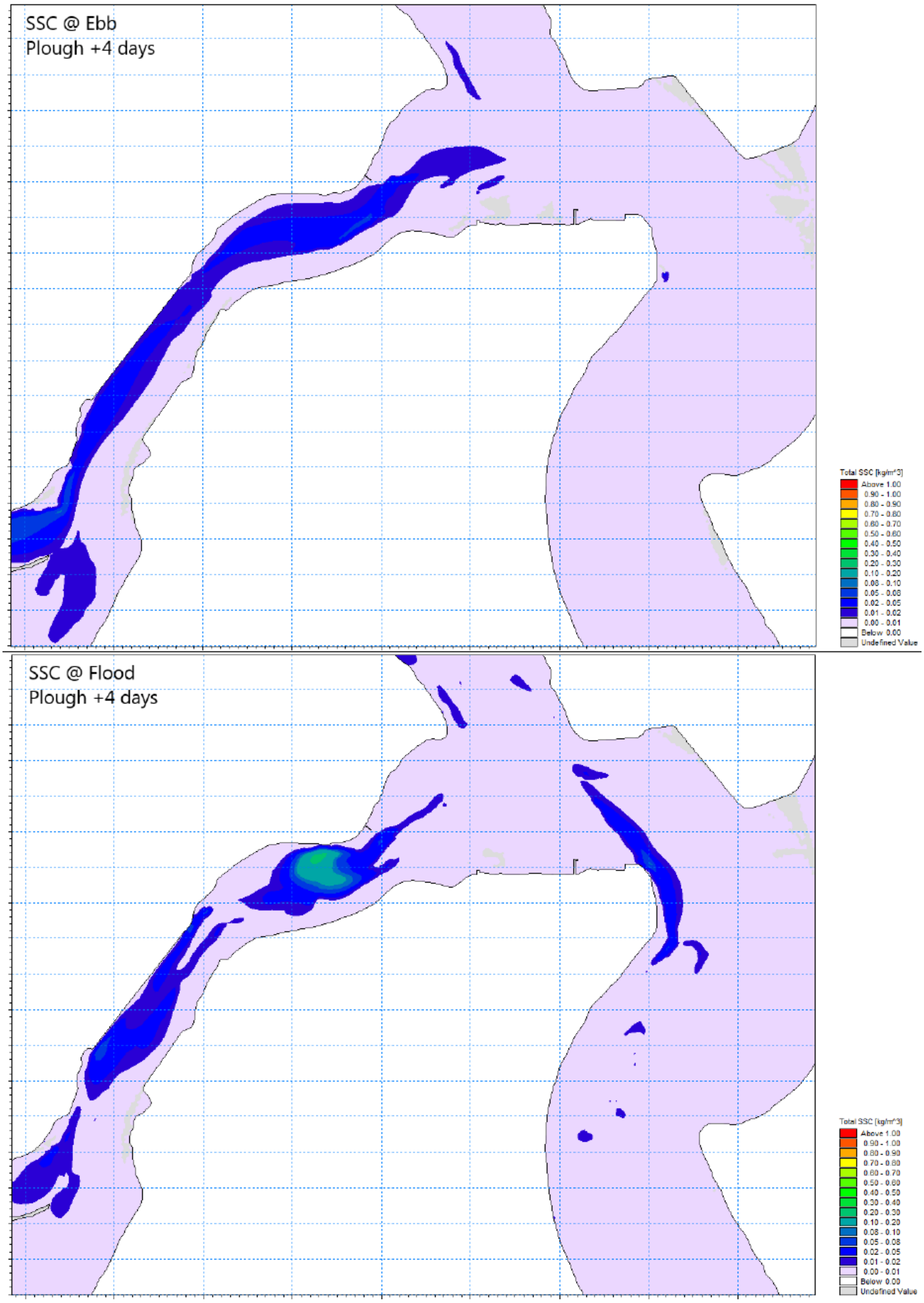


Figure 4.4: SSC at ebb and flood tide 4 days following cessation of ploughing.

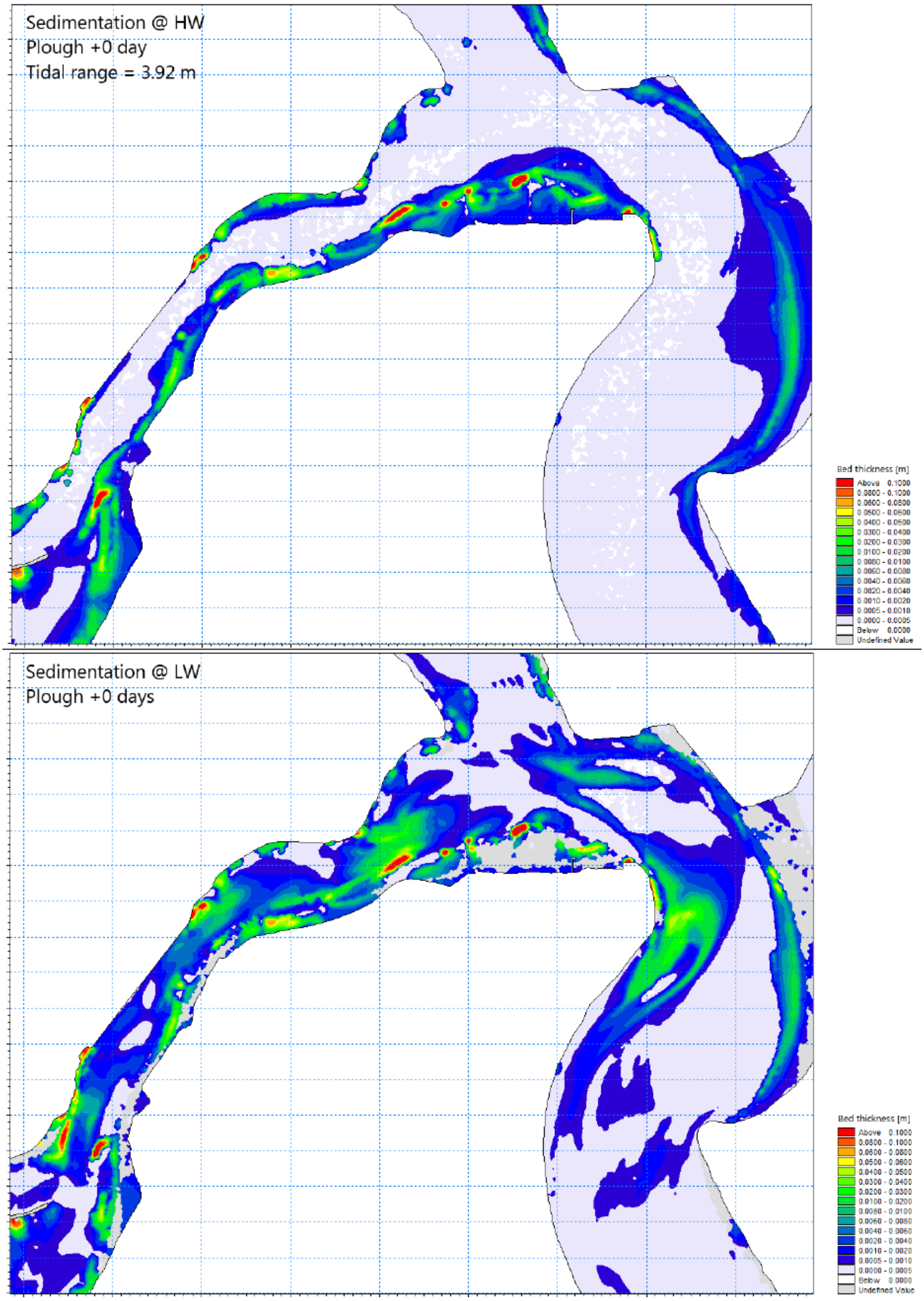


Figure 4.5: Sedimentation at high and low water immediately at the end of ploughing.

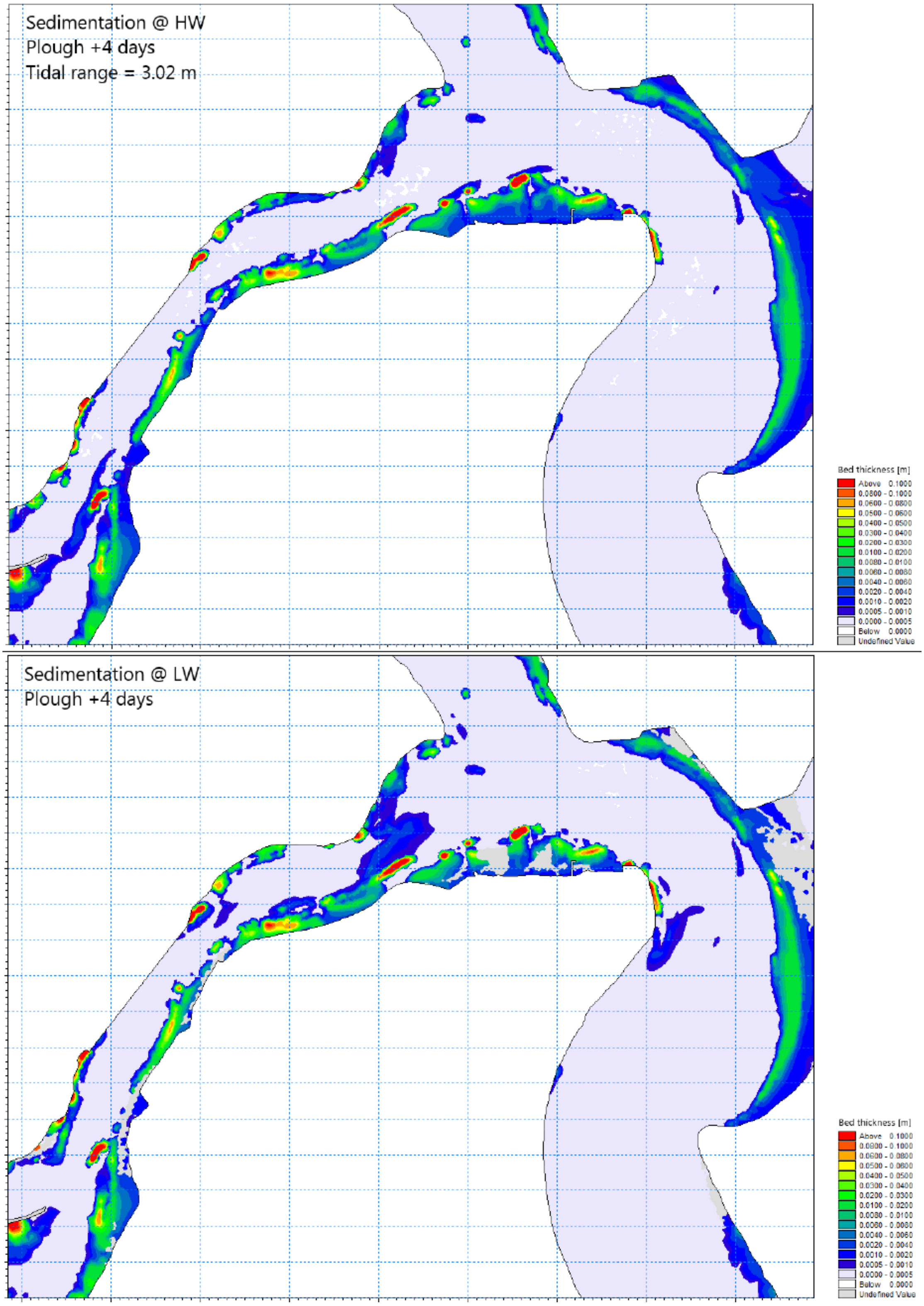


Figure 4.6: Sedimentation at high and low water 4 days following cessation of ploughing.

4.3. Benthic Ecology

4.3.1. Natura Impact Assessment

AQUAFACT was commissioned by Port of Waterford to carry out a Natura Impact Assessment of their proposed dredging and disposal programme in the port. The Natura Impact Statement (NIS) (AQUAFACT, 2017) provides the information required in order to establish whether or not the proposed dredging activity and the proposed disposal activity, both alone and in combination, was likely to have a significant impact on the nearby Natura 2000 sites in the context of its conservation objectives and specifically on the habitats and species for which the site has been designated.

Following the Screening Stage, the designated Natura 2000 sites of relevance to the proposed dredging activities are the River Barrow and River Nore SAC (Site Code: 002162) and the Lower River Suir SAC (Site Code: IE002137). The designated Natura 2000 sites of relevance to the proposed disposal activities are Hook Head SAC (Site Code: IE000764) and Saltee Islands SAC (Site Code: IE000707). Figure 4.7 illustrates the location of the SACs in relation to the proposed dredging and disposal locations.

The Lower River Suir SAC (Site Code: IE002137)

The Lower River Suir SAC comprises the freshwater stretches of the River Suir immediately south of Thurles, Co. Tipperary to the tidal stretches as far as the confluence with the Barrow/Nore immediately east of Cheekpoint in Co. Waterford and many tributaries along the way.

The site is an SAC selected for the presence of the priority habitats on Annex I of the E.U. Habitats Directive - alluvial wet woodlands and Yew Wood. The site is also selected as an SAC for floating river vegetation, Atlantic salt meadows, Mediterranean salt meadows, old oak woodlands and eutrophic tall herbs, all habitats listed on Annex I of the E.U. Habitats Directive. The site is also selected for the following species listed on Annex II of the same directive - Sea Lamprey, River Lamprey, Brook Lamprey, Freshwater Pearl Mussel, Crayfish, Twaite Shad, Atlantic Salmon and Otter.

The NIS carried out by AQUAFACT (2017) concluded that the presence of the dredger and the temporary increases in suspended sediments generated within the dredge areas will not impede the movement of migrating fish as salmon, shad and lampreys which have evolved for and are adapted to migrating through turbid estuarine waters with high levels of suspended sediments. Otter are also adapted to turbid estuarine environments and are limited to within 80m of the shore. No impacts were predicted for these qualifying interests.

River Barrow and River Nore SAC (Site Code: IE002162)

The River Barrow and River Nore SAC consists of the freshwater stretches of the Barrow/Nore River catchments as far upstream as the Slieve Bloom Mountains and it also includes the tidal elements and estuary as far downstream as Creadan Head in Waterford.

The site is an SAC selected for alluvial wet woodlands and petrifying springs, priority habitats on Annex I of the E.U. Habitats Directive. The site is also selected as an SAC for old oak woodlands, floating river vegetation, estuary, tidal mudflats, reef, *Salicornia* mudflats, Atlantic salt meadows, Mediterranean salt meadows, dry heath and eutrophic tall herbs, all habitats listed on Annex I of the E.U. Habitats Directive. The site is also selected for the following species listed on Annex II of the same directive – Sea Lamprey, River Lamprey, Brook Lamprey, Freshwater Pearl Mussel, Nore Freshwater Pearl Mussel, Crayfish, Twaite Shad, Atlantic Salmon, Otter, Desmoulin's Whorl Snail *Vertigo moulinsiana* and the Killarney Fern *Trichomanes speciosum*.

The NIS carried out by AQUAFACT (2017) concluded the pattern of suspended sediments as a result of the dredging activities would be similar to that before dredging and the range of turbidity is also similar. Any differences observed during dredging were not greater than differences observed from periods without dredging and are accounted for as natural temporal variation and are caused by the strong tidal and fluvial flows.

Given the above, there will be no significant negative impacts on the 3 Annex I habitats in the River Barrow and River Nore SAC (mud and sandflats, reefs and estuary) and there will be no impact on the conservation objectives (see Section 5.3.2) of these three habitats.

In addition, the presence of the dredger and the suspended sediments generated within the dredge areas will not impede the movement of migrating fish as salmon, shad and lampreys have evolved for and are adapted to migrate through turbid estuarine waters with high levels of suspended sediments. Otter are also adapted to turbid estuarine environments and are limited to within 80m of the shore. Therefore, no impacts were predicted for these qualifying interests.

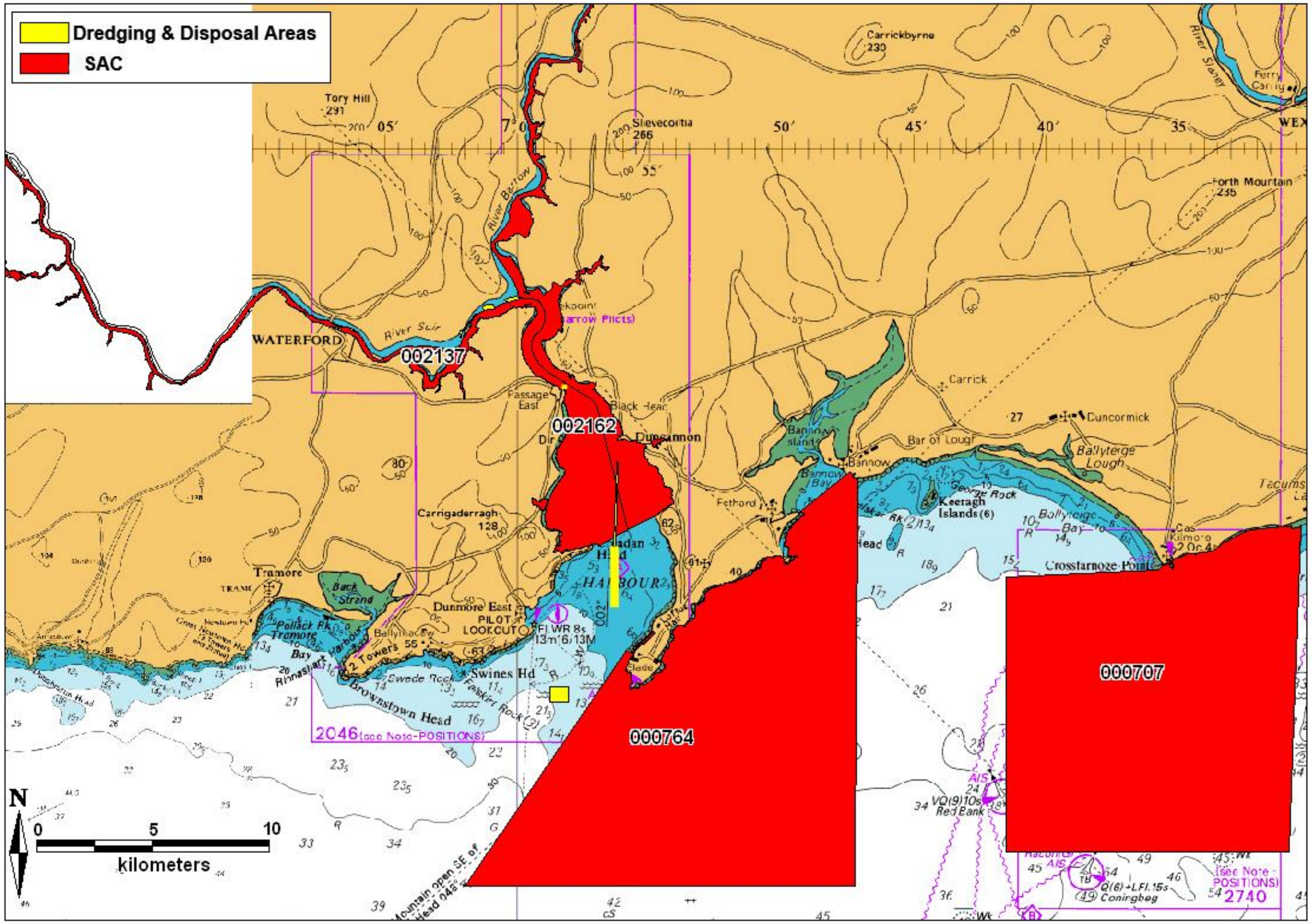


Figure 4.7: Location of the relevant Natura 2000 sites in the vicinity of the dredging and disposal sites.

Hook Head SAC (Site Code: IE000764)

The site of conservation interest at Hook Head comprises an area of marine subtidal reefs to the south and east of the Hook Head Peninsula and includes the sea cliffs from Hook Head to Baginbun and Ingard Point. The peninsula forms the eastern side of Waterford Harbour, while to the east it adjoins the estuary mouth of Bannow Bay. The site contains three habitats listed under the EU Habitats Directive, *i.e.,* large shallow inlets and bays, reefs and sea cliffs.

The NIS carried out by AQUAFACT (2017) concluded that as the dredging plumes do not extend beyond Dunmore East and therefore, they will have no interaction with the Hook Head SAC. The spoil disposal does not disperse sufficient distance to impact on the 'shallow water inlet and bay' habitat of the Hook Head SAC. The 'reefs' habitat is located *c*. 800m to the southeast of the disposal site. The dispersed spoil will not reach this habitat until at least 6 years after the initial dump and then only in concentrations of <0.25m.

The plume will not extend towards the reef habitat until *c*. 6 years after the initial disposal operation and deposition levels will be <0.25cm. The area south of the reefs is sandy and the reefs are adapted to sand being carried in their direction by strong water movements in the area. No negative impacts on reefs are expected from the disposal operations.

Saltee Islands SAC (Site Code: IE000707)

This site comprises the Saltee Islands and a large area of the surrounding seas. There are two islands (Great Saltee and Little Saltee) and a constellation of islets and rocks. The islands are situated *ca* 4 to 5km off the south Wexford coast. As a group, they constitute a broken reef that protrudes from a seabed of sand and shell. The reef has a north-east/south-west orientation and is typically strewn with boulders, cobbles and patches of sand and gravel. Bedrock is metamorphic schist and gneiss. The site is of high conservation importance for marine habitats, with reefs, sea caves, large shallow bays, and intertidal sediments well represented.

This site is of high conservation importance for the occurrence of several habitats which are listed on Annex I of the EU Habitats Directive, of which reefs are of exceptional quality and diversity. The site is of international importance for breeding seabirds and also has two species which are listed on Annex I of the EU Birds Directive. In addition, the site has a breeding population of Grey Seal, an Annex II species on the EU Habitats Directive.

The NIS carried out by AQUAFACT (2017) concluded that as grey seal occurrences in Waterford Harbour are considered minimal, no impact is predicted on this species from the dredging activities. The grey seal may forage from Great Saltee Island to the disposal site area, however it is a mobile species and if it is foraging in the area when the disposal operations are been carried out it will vacate the area temporarily if it is disturbed. Therefore, the impact on this qualifying interest is negligible.

In summary, the AQUAFACT NIS (2017) concluded that the proposed dredging and disposal operations would not negatively impact on the integrity of the Natura 2000 sites, their qualifying interests or marine mammals.

4.3.2. Benthic Survey 2023

AQUAFACT International Services Ltd. (APEM Group) carried out a subtidal benthic ecology survey within the Port of Waterford and the wider Barrow, Nore and Suir Estuaries as part of Non-Statutory Environmental Report (NSER) in respect of 2026-2033 Navigation Maintenance Dredging application. To carry out this subtidal benthic assessment, AQUAFACT surveyed a total of 27 stations on the 23rd and 24th May 2023.

Estuarine communities in the Suir, Barrow and Nore estuaries were generally characterised by low numbers of species and individuals. Analysis of the benthic communities present at the Port of Waterford, Little Island, Cheekpoint and Passage East stations reveal that these stations can be classified as belonging to one of the four common benthic community habitat types occurring in the River Barrow and River Nore SAC namely the habitat 'Muddy estuarine community complex'. This community is present intertidally and subtidally from Cheek Point and Great Island northward to New Ross and extends up the Suir estuary. The substrate of this community complex is predominantly of fine material. The distinguishing species for this group are the bivalves *Scrobicularia plana* and *Macoma balthica,* the amphipod *Corophium volutator,* the polychaete *Streblospio shrubsolii,* and the oligochaetes *Tubificoides pseudogaster* and *Tubificoides benedii.* These species are indicative of variable salinity community (NPWS, 2011). The Duncannon stations can be classified as belonging to another of the four common benthic community habitat types occurring in the River Barrow and River Nore SAC namely Fine Sand with *Fabulina fabula* community. This subtidal community is confined to the southern margin of this site at the mouth of Waterford Harbour. Its northern limit is broadly delineated by a line extending from Crooke on the western side to Balinphile on the eastern side of the Waterford Harbour. The biological community is distinguished by the co-occurrence of moderately large numbers of the bivalve *Fabulina fabula* and the polychaete *Nephtys hombergii*. Also frequently present are the polychaetes *Owenia* and *Magelona filiformis* and the bivalve *Mactra stultorum.*

Multivariate analysis of the faunal grabs from 2023 identified 4 statistically significant groups that can be said to belong to these SAC biotope communities. The muddy estuarine community complex includes 3 of these groups (Groups a, b, and c) and can be classified as the JNCC biotopes SS.SMu.SMuVS.PolCvol *Polydora ciliata* and *Corophium volutator* in variable salinity infralittoral firm mud or clay (EUNIS code A5.321) and SS.SMu.SMuVS.MoMu – Infralittoral fluid mobile mud (EUNIS code: A5.324). The Fine Sand with *Fabulina fabula* community (group d) is classified as the JNCC biotope SS.SSa.IMuSa.FfabMag – *Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand (EUNIS code A5.242).

SS.SMu.SMuVS.PolCvol - *Polydora ciliata* and *Corophium volutator* in variable salinity infralittoral firm mud or clay (EUNIS code A5.321) is characterised as variable salinity clay and firm mud characterized by a turf of the polychaete *Polydora ciliata* along with the amphipod *Corophium volutator*. Other important taxa include the polychaetes *Pygospio elegans, Hediste diversicolor, Streblospio shrubsolii* and the oligochaete *Tubificoides benedii*. This biotope occurs only in very firm mud and clay and possibly submerged relict saltmarsh with a high detrital content. It is characterized, and can be separated from other biotopes, by a combination of the sediment characteristics and the very high density of *Polydora ciliata*. In some areas cyclical behaviour with regard its characteristic taxa have been reported with either *Polydora ciliata* or *Corophium volutator* increasing in dominance at the expense of the other. It is possible that changes in water quality or the sediment regime may be responsible for this (De Bastos & Hill, 2016).

SS.SMu.SMuVS.MoMu – Infralittoral fluid mobile mud (EUNIS code: A5.324) is characterised by fluid mobile mud suspended and deposited on each tide. In areas with very high quantities of suspended particulate material in the water column, it may become deposited around slack water when tidal currents fall. This can form fluid mud layers up to several metres thick becoming a transient habitat in its own right. Species present within this biotope will be those washed in from other communities such as *Nephtys hombergii*, *Capitella* spp. or oligochaetes (Tillin & Rayment, 2016).

SS.SSa.IMuSa.FfabMag – *Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand (EUNIS code A5.242) is characterised by stable, fine, compacted sands and slightly muddy sands in the infralittoral and littoral fringe, communities occur that are dominated by venerid bivalves such as *Chamelea striatula*. This biotope may be characterized by a prevalence of *Fabulina fabula* and *Magelona mirabilis* or other species of *Magelona* (*e.g., Magelona filiformis*). Other taxa, including the amphipod *Bathyporeia* spp. and polychaetes such as *Chaetozone setosa, Spiophanes bombyx* and *Nephtys spp.* are also commonly recorded. In some areas the bivalve *Spisula elliptica* may also occur in this biotope in low numbers. The community is relatively stable in its species composition, however, numbers of *Magelona* and *Fabulina fabula* tend to fluctuate (Tyler-Walters, 2018).

These benthic community types have been recorded within Waterford estuary since the characterisation of the waterbody by Kennedy (2008) and its designation as an SAC by NPWS (2011). Despite twice yearly dredging and disposal activities by Port of Waterford, the biotopes remain in a stable condition.

4.3.3. Assessment of Impact

When considering the sensitivity of the benthic communities in the survey area to the proposed dredging activities, the sensitivity to extraction (dredging) as well as the sensitivity to siltation (both heavy siltation (30cm burial) and light siltation (5cm burial)) must be considered.

Based on the sedimentation models, sedimentation as a result of the plough disturbance is for the most part temporary, accumulating during periods of slack water, or in areas of eddy circulation. With the exception of identified 'sink' areas, accumulations are small, a few millimetres to 1 to 2 centimetres. Most accumulations are re-eroded on the following peak flows (predominantly on the flood). In the areas around Carters Patch, sedimentation of up to 1.5 cm was present for a maximum period of 6 hours before being re-eroded and in all cases, sedimentation rates and SSC levels increase after *c*. 2 days of ploughing. The worst-case scenario from the sedimentation model would be considered light siltation (5cm burial), but for the purposes of assessing the sensitivity of the benthic communities, heavy siltation will also be considered.

The sensitivity of SS.SMu.SMuVS.PolCvol to heavy siltation is described as low while sensitivity to extraction (dredging) is described as medium as dredging will remove the substrate resulting in the loss of *Polydora* tubes and *Corophium* that burrows up to 5cm deep. However, this biotope is widespread in the estuary and recolonisation will occur (De Bastos & Hill, 2016).

SS.SMu.SMuVS.MoMu and its fluid mud features are composed of high concentrations of suspended sediments in various phases of settlement, flow and resuspension. In addition, the fluid mud features of this biotope can vary in thickness from *ca.* 0.5m to up to 5m therefore the deposition of 5 or 30cm of fine sediment is unlikely to have a noticeable effect. This biotope is therefore classified as 'Not Sensitive' to light siltation (up to 5cm) or heavy siltation (up to 30cm) as siltation is a feature of this biotope. Sensitivity to extraction (dredging) is described as low as the fluid mud would return and be replaced within days in the neap cycle (Tyler-Walters, 2018).

The sensitivity of SS.SSa.IMuSa.FfabMag to heavy siltation (30cm) is described as 'Medium' if siltation overburdens the sediment. Tellinidae bivalves can migrate through 40cm in mud or 50cm in sand. Sensitivity to lighter siltation (5cm) is low. Sensitivity to extraction (dredging) is described as medium as most of the animals that occur in this biotope are shallowly buried and extraction of the sediment will remove the biological assemblage. Resilience is medium as some species may require longer than 2 years to re-establish (Tillin & Rayment, 2016).

5. Conclusion

The benthic community types recorded within Waterford estuary in the current survey have been present since the characterisation of the waterbody by Kennedy (2008) and its designation as an SAC by NPWS (2011). Despite twice yearly dredging and disposal activities by Port of Waterford the biotopes remain in a stable condition. The proposed dredging and disposal operations will not negatively impact on these benthic community types within the survey areas or on the integrity of the benthic community qualifying interests of the designated Natura 2000 sites of relevance to the proposed dredging activities.

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Appendix 1
Sediment Analysis Methodology

Sediment Analysis

AQUAFACT carried out the granulometric analysis using the traditional granulometric technique and has the necessary equipment required *e.g.,* Wentworth graded sieves, Easysize and GRADISTAT computer software, hydrogen peroxide, sodium hexametaphosphate, drying oven, beakers, mixers, electronic scales. AQUAFACT has carried out sediment analysis for all subtidal sampling programmes that it has been involved in.

AQUAFACT used the following methodology for the granulometric analysis:

1. Approximately 100g of dried sediment (previously washed in distilled water and dried) is weighed out and placed in a labelled 1L glass beaker to which 100ml of a 6 percent hydrogen peroxide solution is then added. This is allowed to stand overnight in a fume hood.
2. The beaker is placed on a hot plate and heated gently. Small quantities of hydrogen peroxide are added to the beaker until there is no further reaction. This peroxide treatment removes any organic material from the sediment which can interfere with grain size determination.
3. The beaker is then emptied of sediment and rinsed into a 63µm sieve. This is then washed with distilled water to remove any residual hydrogen peroxide. The sample retained on the sieve is then carefully washed back into the glass beaker up to a volume of approximately 250ml of distilled water.
4. 10ml of sodium hexametaphosphate solution is added to the beaker and this solution is stirred for ten minutes and then allowed to stand overnight. This treatment helps to dissociate the clay particles from one another.
5. The beaker with the sediment and sodium hexametaphosphate solution is washed and rinsed into a 63µm sieve. The retained sample is carefully washed from the sieve into a labelled aluminium tray and placed in an oven for drying at 100ºC for 24 hours.
6. The dried sediment should then be passed through a Wentworth series of analytical sieves (>8,000 to 63µm; single phi units). The weight of material retained in each sieve is weighed and recorded. The material passing through the 63µm sieve is also weighed and the value added to the value measured in Point 5 above.
7. The total silt/clay fraction is determined by subtracting all weighed fractions from the initial starting weight of sediment as the less than 63µm fraction was lost during the various washing stages.

8. The reporting of sediment samples will be as percentages within the following range of particle sizes:
    - PSA % <63
    - PSA % 63<125
    - PSA % 125<250
    - PSA % 250<500
    - PSA % 500<1000
    - PSA % 1000<2000
    - PSA % 2000<4000
    - PSA % 4000<8000
    - PSA % ≥8000

The grain size data will be used to determine Folk (1954) classification, which is standard in all AQUAFACT's reports.

The organic matter (Loss on Ignition) is be carried out by ALS Labs in Loughrea using the following methodology:

1. The collected sediments are transferred to aluminium trays, homogenised by hand and dried in an oven at 100º C for 24 hours.
2. A sample of dried sediment is placed in a mortar and pestle and ground down to a fine powder.
3. 1g of this ground sediment is weighed into a pre-weighed crucible and placed in a muffle furnace at 450ºC for a period of 6 hours.
4. The sediment samples are then allowed to cool in a dessicator for 1 hour before being weighed again.
5. The organic content of the sample is determined by expressing as a percentage the weight of the sediment after ignition over the initial weight of the sediment.

Appendix 2
Species List

JN1655 Port of Waterford																		
Station	**AphiaID**	**CP1A**	**CP1B**	**CP2A**	**CP2B**	**CP3A**	**CP3B**	**CP4A**	**CP4B**	**CP5A**	**CP5B**	**CP6A**	**CP6B**	**CP7A**	**CP9A**	**CP9B**	**CP10A**	**CP10B**
NEMERTEA	152391																	
Nemertea (indet)	152391																	
ANNELIDA	882																	
POLYCHAETA	883																	
PHYLLODOCIDA	892																	
Glyceridae	952																	
Glycera sp. (damaged)	129296																	
Glycera tridactyla	130130																	
Nereididae	22496																	
Hediste diversicolor	152302																	
Nephtyidae	956																	
Nephtys sp. (juv)	129370																	
Nephtys hombergii	130359		2	1				1		1	1						1	1
SPIONIDA	889																	
Spionidae	913																	
Spionidae	913			frag	1				frag					1				
Polydora cornuta	131143					7												
Pygospio elegans	131170		8			6												
Magelonidae	914																	
Magelona sp.	129341																	
Magelona filiformis	130268																	
Magelona johnstoni	130269																	
TEREBELLIDA	900																	
Cirratulidae	919																	
Tharyx killariensis	152269	22	27		1		2							6		1		
Pectinariidae	980																	
Lagis koreni	152367																	
SABELLIDA	901																	
Oweniidae	975																	

JN1655 Port of Waterford																		
Station	**AphiaID**	**CP1A**	**CP1B**	**CP2A**	**CP2B**	**CP3A**	**CP3B**	**CP4A**	**CP4B**	**CP5A**	**CP5B**	**CP6A**	**CP6B**	**CP7A**	**CP9A**	**CP9B**	**CP10A**	**CP10B**
Owenia borealis	329882																	
OLIGOCHAETA	2036																	
TUBIFICIDA	1511829																	
Naididae	2039																	
Tubificoides sp. (damaged)	137393				1													
Tubificoides benedii	137571					1	1								1			
ARTHROPODA	1065																	
MALACOSTRACA	1071																	
AMPHIPODA	1135																	
Oedicerotidae	101400																	
Perioculodes longimanus	102915																	
Pontocrates arcticus	102917																	
Pontoporeiidae	101406																	
Bathyporeia sp.	101742																	
Gammaridae	101383																	
Gammarus sp. (damaged)	101537																	
Corophiidae	101376																	
Corophiidae (damaged)	101376	3				1												
Corophium volutator	102101	2		1		16	6											
ISOPODA	1131																	
Sphaeromatidae	118277																	
Lekanesphaera hookeri	118953																	
CUMACEA	1137																	
Bodotriidae	110378																	
Cumopsis goodsir	110465																	
Pseudocumatidae	110384																	
Monopseudocuma gilsoni	422916																	
INSECTA	1307																	
Coleoptera larvae	118085														1			

JN1655 Port of Waterford																		
Station	**AphiaID**	**CP1A**	**CP1B**	**CP2A**	**CP2B**	**CP3A**	**CP3B**	**CP4A**	**CP4B**	**CP5A**	**CP5B**	**CP6A**	**CP6B**	**CP7A**	**CP9A**	**CP9B**	**CP10A**	**CP10B**
MOLLUSCA	51																	
GASTROPODA	101																	
LITTORINIMORPHA	382213																	
Hydrobiidae	120																	
Peringia ulvae	151628	13		1									1	1				
Naticidae	145																	
Euspira nitida	151894																	
BIVALVIA	105																	
MYTILIDA	210																	
Mytilidae	211																	
Mytilidae (juv)	211											1	2	1				1
IMPARIDENTIA	869600																	
Mactridae	230																	
Mactridae (juv.)	230																	
Mactra stultorum	140299																	
CARDIIDA	869602																	
Cardiidae	229																	
Cerastoderma edule	138998										1							
Tellinidae	235																	
Tellinidae (juv)	235																	
Fabulina fabula	146907																	
Macomangulus tenuis	878463																	
Macoma balthica	141579				1		2				1				1			
Semelidae	1781	1						1										
Abra alba	141433																	
ADAPEDONTA	869601																	
Pharidae	23091																	
Ensis sp.	138333																	
BRYOZOA	146142																	

JN1655 Port of Waterford																		
Station	**AphiaID**	**CP1A**	**CP1B**	**CP2A**	**CP2B**	**CP3A**	**CP3B**	**CP4A**	**CP4B**	**CP5A**	**CP5B**	**CP6A**	**CP6B**	**CP7A**	**CP9A**	**CP9B**	**CP10A**	**CP10B**
CYCLOSTOMATIDA	110724																	
Crisiidae	110806																	
Crisia eburnea	111696																+	
CHEILOSTOMATIDA	110722																	
Membraniporidae	110762																	
Conopeum seurati	111352								+									
ECHINODERMATA	1806																	
OPHIUROIDEA	123084																	
OPHIURIDA	123117																	
Amphiuridae	123206																	
Amphiuridae (damaged)	123206																	
Amphipholis squamata	125064																	

JN1655 Port of Waterford																		
Station	**AphiaID**	**W2A**	**W3A**	**W6B**	**L12A**	**PE3A**	**PE3B**	**DB1A**	**DB1B**	**DB2A**	**DB2B**	**DB3A**	**DB3B**	**DB4A**	**DB4B**	**DB5A**	**DB6A**	**DB6B**
NEMERTEA	152391																	
Nemertea (indet)	152391			1									1					
ANNELIDA	882																	
POLYCHAETA	883																	
PHYLLODOCIDA	892																	
Glyceridae	952																	
Glycera sp. (damaged)	129296															1		
Glycera tridactyla	130130										1	2	1	1				2
Nereididae	22496																	
Hediste diversicolor	152302				1													
Nephtyidae	956																	
Nephtys sp. (juv)	129370									4	2	1					1	
Nephtys hombergii	130359					1	1	1	2	1		3	2	3			1	

JN1655 Port of Waterford																		
Station	**AphiaID**	**W2A**	**W3A**	**W6B**	**L12A**	**PE3A**	**PE3B**	**DB1A**	**DB1B**	**DB2A**	**DB2B**	**DB3A**	**DB3B**	**DB4A**	**DB4B**	**DB5A**	**DB6A**	**DB6B**
SPIONIDA	889																	
Spionidae	913																	
Spionidae (damaged)	913														1			
Polydora cornuta	131143																	
Pygospio elegans	131170																	
Magelonidae	914																	
Magelona sp. (damaged)	129341														1			
Magelona filiformis	130268									1	5	1	2	3	2		5	1
Magelona johnstoni	130269										3			2	5			
TEREBELLIDA	900																	
Cirratulidae	919																	
Tharyx killiariensis	152269								1									
Pectinariidae	980																	
Lagis koreni	152367														1			
SABELLIDA	901																	
Oweniidae	975																	
Owenia borealis	329882									1								
OLIGOCHAETA	2036																	
TUBIFICIDA	1511829																	
Naididae	2039																	
Tubificoides sp. (damaged)	137393																	
Tubificoides benedii	137571																	
ARTHROPODA	1065																	
MALACOSTRACA	1071																	
AMPHIPODA	1135																	
Oedicerotidae	101400																	
Perioculodes longimanus	102915																	2
Pontocrates arcticus	102917												1					
Pontoporeiidae	101406																	

JN1655 Port of Waterford																		
Station	**AphiaID**	**W2A**	**W3A**	**W6B**	**L12A**	**PE3A**	**PE3B**	**DB1A**	**DB1B**	**DB2A**	**DB2B**	**DB3A**	**DB3B**	**DB4A**	**DB4B**	**DB5A**	**DB6A**	**DB6B**
Bathyporeia sp. (juv)/ damaged	101742											2	11	1		1		
Gammaridae	101383																	
Gammarus sp. (damaged)	101537	5			1													
Corophiidae	101376																	
Corophiidae (damaged)	101376																	
Corophium volutator	102101	1																
ISOPODA	1131																	
Sphaeromatidae	118277																	
Lekanesphaera hookeri	118953	1																
CUMACEA	1137																	
Bodotriidae	110378																	
Cumopsis goodsir	110465												1	2				2
Pseudocumatidae	110384																	
Monopseudocuma gilsoni	422916													1			2	
INSECTA	1307																	
Coleoptera larvae	118085																	
MOLLUSCA	51																	
GASTROPODA	101																	
LITTORINIMORPHA	382213																	
Hydrobiidae	120																	
Peringia ulvae	151628																	
Naticidae	145																	
Euspira nitida	151894								1									
BIVALVIA	105																	
MYTILIDA	210																	
Mytilidae	211																	
Mytilidae (juv)	211																	
IMPARIDENTIA	869600																	
Mactridae	230																	

JN1655 Port of Waterford																			
Station	**AphiaID**	**W2A**	**W3A**	**W6B**	**L12A**	**PE3A**	**PE3B**	**DB1A**	**DB1B**	**DB2A**	**DB2B**	**DB3A**	**DB3B**	**DB4A**	**DB4B**	**DB5A**	**DB6A**	**DB6B**
Mactridae	230													1			1	
Mactra stultorum	140299								2	1		1		1		9	1	
CARDIIDA	869602																	
Cardiidae	229																	
Cerastoderma edule	138998													1				
Tellinidae	235																	
Tellinidae (juv)	235							2	9	8	1		1	4	3		5	2
Fabulina fabula	146907								2	3	4	2	1	1	3		4	2
Macomangulus tenuis	878463															1		1
Macoma balthica	141579																	
Semelidae	1781																	
Abra alba	141433								1					1				
ADAPEDONTA	869601																	
Pharidae	23091																	
Ensis sp.	138333									1								
BRYOZOA	146142																	
CYCLOSTOMATIDA	110724																	
Crisiidae	110806																	
Crisia eburnea	111696																	
CHEILOSTOMATIDA	110722																	
Membraniporidae	110762																	
Conopeum seurati	111352																	
ECHINODERMATA	1806																	
OPHIUROIDEA	123084																	
OPHIURIDA	123117																	
Amphiuridae	123206																	
Amphiuridae (damaged)	123206								1									
Amphipholis squamata	125064													1				