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NORTHERN DISPOSAL AREA – ASSESSMENT OF SOURCE MATERIAL, ECOLOGICAL AND SEDIMENT QUALITY EFFECTS ASSESSMENT OF DISPOSAL

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Cover Illustration: Disposal Barge under tow

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1. INTRODUCTION

In 2013, Coastal Resources Ltd (CRL) was granted a Dumping Permit (permit 568) from Maritime New Zealand (MNZ) for the disposal of 50,000 m^3 per annum of dredged material (from various Auckland marinas) at a new deep-sea spoil disposal site east of Great Barrier Island (now referred to as the "Northern Disposal Area" (NDA)). This consented volume has been varied for certain periods to provide for specific disposal projects, including for 127,000 m^3 between November 2014 and November 2015 to provide for the disposal of capital dredging spoil from the Sandspit Marina. This Permit has subsequently had a number of variations and owing to legislative changes and is now administered by the Environmental Protection Authority (EPA), as the Marine Consent EEZ900012.

To date, over 400 trips to the disposal ground have been undertaken with approximately 199,800 m^3 of dredged spoil disposed (as at 1 April 2018). Disposal material has come from Pine Harbour Marina, Half Moon Bay Marina, Sandspit Marina, Hobsonville Marina and Hobsonville Point. The characteristics of the sediment quality and biota present in these different source sites are described and discussed in section 2.

At the time of the original application a pre-cautionary approach was taken (as this was a new marine disposal site) and a low annual disposal volume was sought. It has now becoming apparent that the disposal site will be the main site for the disposal of dredged spoil from marinas and marine facilities in the Auckland Region, and from marinas in the Waikato Region in the future. The maintenance dredging of most marinas in Auckland will continue to be required and is becoming increasingly important for navigation, including the continuation of public ferry services which utilise a number of Auckland Marinas (Pine Harbour, Bayswater, Hobsonville for example). CRL has investigated the proposed future requirements of the Auckland and Waikato regions in the foreseeable future and has determined an increased annual dumping volume is required. Therefore, CRL are applying for a new marine dumping consent to dispose of up to 250,000 m^3 per year of capital and maintenance dredging spoil from the Auckland and neighbouring regions for a 35-year period.

This document provides a description of the process of characterising sources sites, summary information of the quality of disposal material from each source site disposed at the NDA site and site description based on all the data collected from the NDA.

1.1 Historical Disposal Options

The disposal of marine sediments at sea has long been conducted in the Auckland Region. The following outlines the history of disposal activities in the Auckland Region.

1.1.1 Previous Dredging Disposal Grounds

Two dredging disposal grounds were used for many years in the 1980s near Rangitoto Island by Ports of Auckland. Assessment of the sites in 1988 and 1989 revealed several conclusions on the impact they were having on the surrounding ecosystems (Roberts *et al.*, 1991). Although recovery of the benthic fauna in the region was evident, it was apparent that there was a permanent change in the composition of the species (Roberts *et al.*, 1991). These two sites were located in shallow areas where species composition is typically diverse and populations abundant. The impact assessment also concluded that effects could have been lessened if the dredged sediments had been dumped on sub-stratum texturally similar to that of the principle source (Roberts *et al.*, 1991).

1.1.2 Pine Harbour

Under an Auckland Council consent, small volumes of sediment (3,000 m^3 per year) from Pine Harbour marina basin and access channel were disposed of as a thin layer in an area 500 to 1000 m north of the access channel for a period between 1997 and 2009. The benthic biota in the disposal area was monitored before and after the disposal events and showed that disposal may have had an effect on the diversity and abundance but that this was at a level that was masked by season changes. Thus, any effects were short lived and recolonization occurred in a relatively short period. Due to changes in council thinking, it was not possible to renew the disposal consent so disposal ceased in 2010.

1.1.3 Noises Disposal Site

A site within the boundaries of the Hauraki Gulf was used for disposal of dredged sediment by the Ports of Auckland until 1992. This site was in 32 m water depth and was located centrally between Tiritiri Matangi Island and Waiheke Island in the Inner Hauraki Gulf. Consent was granted for disposal of 270,000 m^3 of dredged sediment at the site. Post-disposal monitoring identified a higher than expected level of contaminants and it was also determined that not all of the originally dumped sediment could be accounted for, which implied a loss off-site. Controversy over these findings resulted in Ports of Auckland withdrawing permit applications for further disposal operations. Consequently, the Noises disposal site was used only once.

The Disposal Options Advisory Group (DOAG) was set up in 1993 to examine and report on the disposal options of dredged materials especially regarding specific disposal operations at the Noises Disposal site by the Ports of Auckland, discussed above. Based on assessment of the options, DOAG concluded that continuing marine disposal should be moved to a site north of Cuvier Island, which would be located in waters deeper than 100 m. These studies and others by the Parliamentary Commissioner for the Environment resulted in the discontinuation of disposal operations by the Ports of Auckland at the Noises Disposal site, which would now be located in the boundaries of the Hauraki Gulf Marine Park.

1.1.4 Auckland Explosives Dumping Ground

For a period, predominantly muddy dredged sediment was removed from various ports and marinas in the Auckland area and was disposed of at the Auckland Explosives Dumping Ground (AEDG). This site is located on the continental slope east of Cuvier Island in New Zealand's Exclusive Economic Zone (EEZ) at water depths ranging from 500 to 1300 m. Prior to 2016, this was under the control of MNZ and disposal permits were issued on a case by case basis.

In 2016, the management of disposal of waste in New Zealand's EEZ became the responsibility of the EPA under the EEZ Act (2012) and the Discharge and Dumping Regulations. Dumping of certain material at sea is allowed if authorised by a marine consent. The most common types of material that are disposed of are dredge spoil from ports and harbours, and decommissioned vessels. The AEDG is one of five existing explosives dumping grounds in New Zealand's EEZ and these are the preferred locations for dumping of waste. Dumping in the EEZ outside of these areas is possible, but any such proposal will require a greater level of environmental impact assessment and justification as to why existing sites cannot be used.

The AEDG is simultaneously used by the Royal New Zealand Navy to dispose of unexploded munitions abandoned on the sea floor since WWII. When these munitions are discovered, they are transported to the site to be permanently disposed of in an area deemed safe because of its depth and distance from the coastline.

New Zealand is a signatory to the 1996 London Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972. The aim of the protocol is to "protect and preserve the marine environment from all sources of pollution and take effective measures (according to scientific, technical and economic capabilities) to prevent, reduce and where practicable eliminate pollution caused by dumping or incineration at sea of wastes or other matter." Despite the fact that the London Dumping Convention and the 1996 Protocol, to which New Zealand is a signatory, calls for extensive environmental monitoring of established dredge spoil disposal sites, the AEDG has never been surveyed or monitored exclusively for dredge spoil disposal. The extreme water depth and danger in sampling around the munitions make the required monitoring of this site virtually impossible and the impacts of years of disposal operations at the site and on the surrounding areas is unknown.

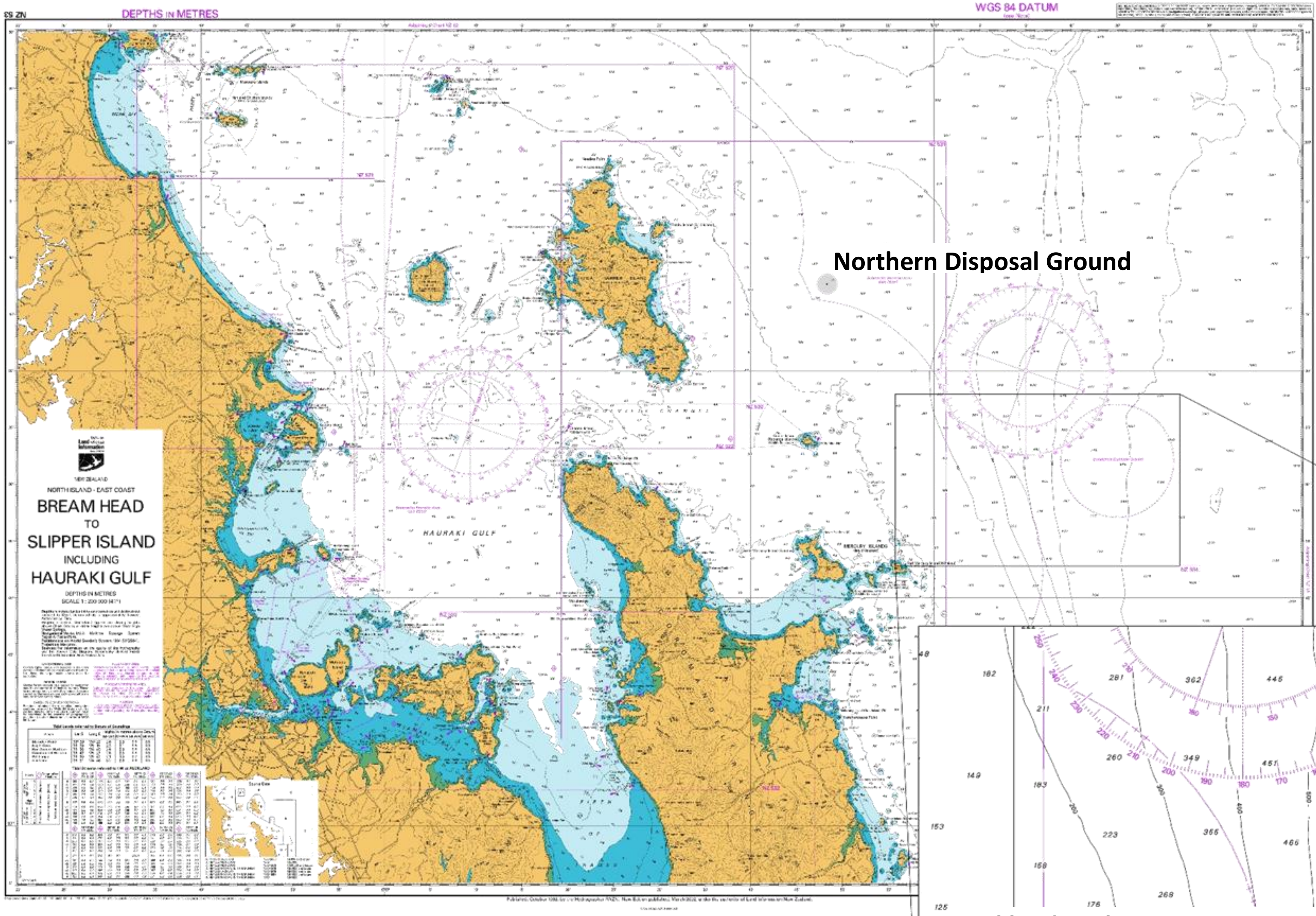
The AEDG is not suitable for future use for the following reasons:

- Lack of information on physical, chemical and biological characteristics of the seabed,
- Presence of explosives poses a threat to vessel operators and environmental monitors;
- Disposal sites must be monitored under London dumping convention and 1996 Protocol; and
- The AEDG is too deep to practically monitor.

1.1.5 Northern Disposal Area

In 2008, CRL applied for a permit to establish a disposal area with a 1,500 m radius circle centred on 36^{o} 12.3403'S and 175^{o} 48.002'E. The NDA is located just outside the Auckland Council region in the EEZ. The marine charts of the area show it is relatively flat muddy sands in approximately 135 to 140 m water depth.

In November 2012, a permit (No. 568) to dispose of up to 50,000 m^3 per year was granted by MNZ. The permit 568 required characterisation and approval of the source material prior to dredging and disposal at the site at no greater than three yearly intervals per source site. Additional monitoring of the sediment quality and benthic biota in and around the disposal site following disposal volume trigger points of 10,000 m^3, 50,000 m^3 and then at each additional 50,000 m^3 is required. Due to legislative changes, the MNZ permit 568 is now EPA consent EEZ900012.



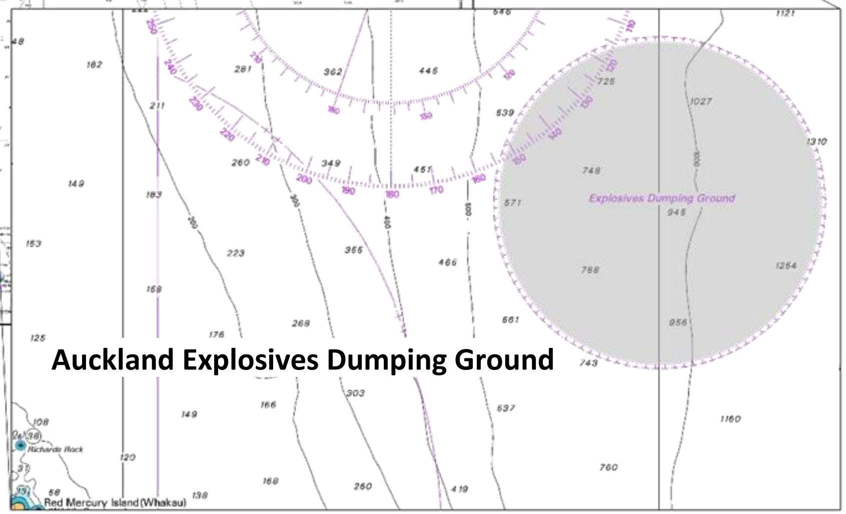


Figure 1.1 Hydrographic chart of the northeast coastal region of New Zealand with Northern Disposal Ground, and inset showing location of the Auckland Explosives Dumping Ground.

2. SOURCE DREDGE MATERIAL CHARACTERISATION

2.1 Dredge Material Characterisation Process

Prior to characterisation of the material to be dredged an assessment of alternatives to disposal at sea should be conducted. Once it has been determined that disposal at sea is the selected option, then the methodology for characterisation of dredge material is outlined in the "New Zealand Guidelines for Sea Disposal of Waste" (MSANZ, 1999). These guidelines require a detailed description or characterisation of the dredge material to enable thorough assessment of an application to dispose dredge material or other matter at sea.

The characterisation of dredge material and its constituents must include:

- origin, total amount, form, and average composition
- properties: physical, chemical, biochemical and biological
- toxicity
- persistence: physical, chemical, and biological
- potential for accumulation and biotransformation in biological materials or sediments.

The guidelines outline a four level procedure for dredge material characterisation, which is consistent with international best practice. A level 1 investigation reviews the existing information on the dredge material. A level 2 investigation is concerned with the physical and chemical characterisation of the dredge material. Level 3 and 4 investigations require various toxicity and bioaccumulation testing. If the data collected at one level are insufficient to make a decision about the permissibility of dumping then the characterisation process will proceed to the next level. Figure 2.1 illustrates the dredge material characterisation process.

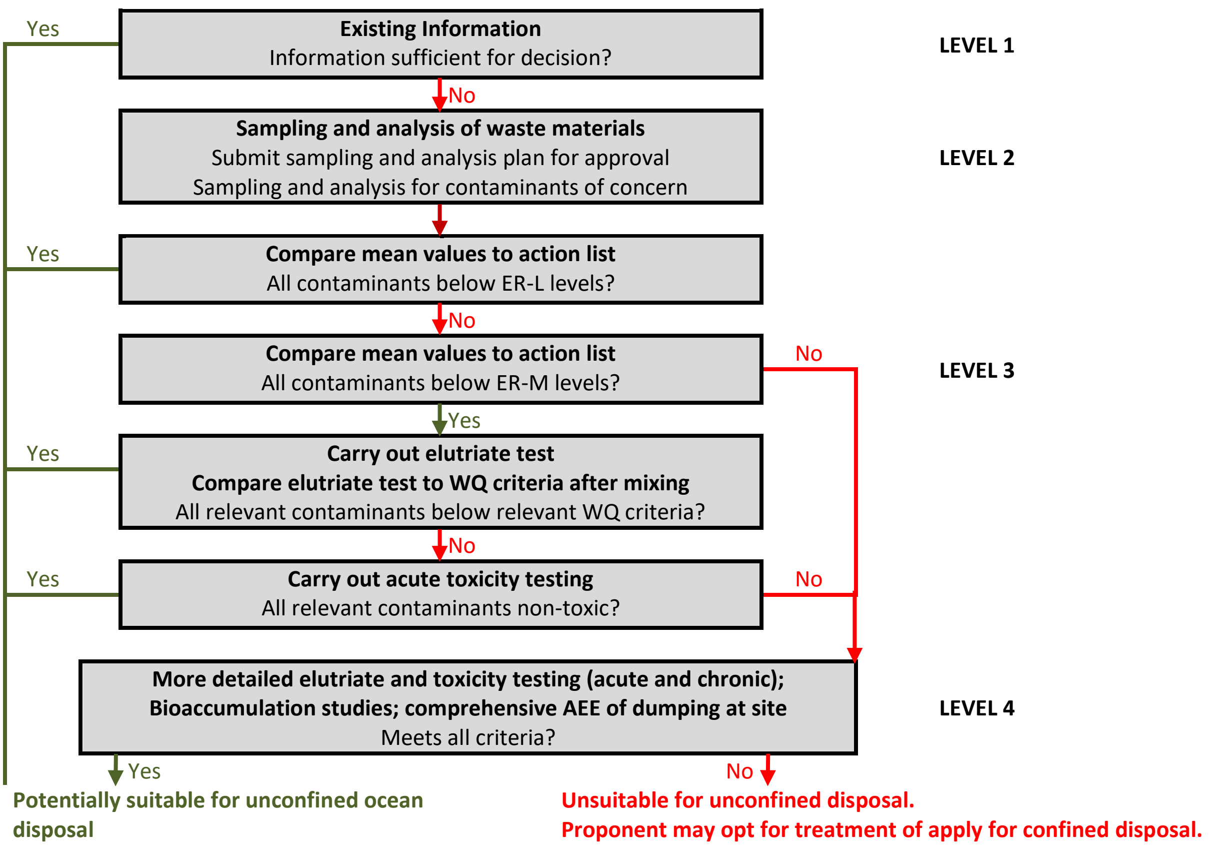


Figure 2.1 Dredge Material Characterisation Process

2.1.1 Sediment Quality Criteria

The "New Zealand Guidelines for Sea Disposal of Waste" (MSANZ, 1999) specify a set of sediment quality guidelines referred to as the action list. These were devised prior to the current ANZECC (2000) interim sediment quality guidelines (ISQG). The action list guidelines and the ANZECC ISQG are listed in Table 2.1. MSANZ (1999) describes the action list values as tentative and should be revised as international criteria are updated and/or New Zealand criteria (such as ANZECC) are developed.

Table 2.1 Sediment Quality Guidelines

Analytical Parameter	Action List		ANZECC	
	ER-L GUIDELINE (Effects Range-Low)	ER-M GUIDELINE (Effects Range-Median)	ISQG-Low	ISQG-High
METALS & METALLOIDS (mg/kg dry weight)				
Antimony			2	25
Arsenic	8.2	70	20	70
Cadmium	1.5	10	1.5	10
Chromium	80	370	80	370
Copper	65	270	65	270
Lead	50	220	50	220
Mercury	0.15	1.0	0.15	1.0
Nickel	21	52	21	52
Silver	1.0	3.7	1.0	3.7
Zinc	200	410	200	410
ORGANOMETALLICS				
Tributyltin (as µg Sn/kg dry weight)	5*	72*	5 (9#)	70
ORGANICS (µg/kg dry weight)*				
Total PCBs	23	180	23	-
Total Petroleum Hydrocarbons (mg/kg dry weight)			280#	550#
Organochlorine Pesticides (µg/kg dry weight)*				
Hexachlorobenzene	2	2.3		
DDD	2	20	2	20
DDE	2.2	27	2.2	27
Total DDT	1.6	46	1.6	46
Aldrin	26	260		
Dieldrin	0.02	8	0.02	8
Chlordane	0.5	6	0.5	6
Endrin	0.02	8	0.02	8
Heptachlor	3.2	32		
Lindane	0.32	1.0	0.32	1.0
Polynuclear Aromatic Hydrocarbons (µg/kg dry weight)*				
Acenapthene	16	500	16	500
Acenapthalene	44	640	44	640
Anthracene	85	1100	85	1100
Fluorene	19	540	19	540
Napthalene	160	2100	160	2100
Phenanthrene	240	1500	240	1500
Low Molecular Weight PAHs	552	3160	552	3160
Benzo[a]anthracene	261	1600	261	1600
Benzo[a]pyrene	430	1600	430	1600
Dibenz[a,h]anthracene	63	260	63	260
Chrysene	384	2800	384	2800
Fluoranthene	600	5100	600	5100
Pyrene	665	2600	665	2600
2-methylnapthalene	70	670	70	670
High Molecular Weight PAHs	1700	9600	1700	9600
Total PAHs	4000	45000	4000	45000
Radionuclides ¤				

* Normalised to 1 percent organic carbon. If the sediment total organic carbon content is not 1 percent, then the measured dry weight concentration of each organic contaminant must be normalised to a 1 percent total organic carbon basis before comparing it with the concentrations listed in the table. For example, if the TOC of the sediment is 0.5 percent, then each measured organic contaminant concentration must be doubled before comparison with the tabulated values above.

\# revised guideline as per Simpson, *et al*. (2013)

¤ Under New Zealand law, no waste or other matter containing radioactive material may be dumped. Radioactive material means any article containing a radioactive substance giving it a specific radioactivity exceeding 100 becquerels per gram and a total radioactivity exceeding 3000 becquerels.

The Australian and New Zealand Environment and Conservation Council (ANZECC) Interim Sediment Quality Guideline (ISQG) Low and ISQG-High values which have been derived from the effects range low (ERL) and median (ERM) described in Long and Morgan (1990) and updated in 1995 by Long *et al.* The above references present data to assess the potential for adverse biological effects occurring due to exposure of biota to toxicants in sediment. Two values are determined from the data for each chemical or chemical group. The ERL is the concentration at the low end (10^{th} percentile) of the range in which effects had been observed and the ERM is the concentration approximately midway (50^{th} percentile) in the range of reported values associated with biological effects. These values define three ranges in chemical concentrations that were anticipated to be:

(1) rarely (less than ERL),
(2) occasionally (between ERL and ERM), or
(3) frequently (greater than ERM) associated with biological effects.

There are few reliable data on sediment toxicity for either Australia or New Zealand samples from which independent sediment quality guidelines might be derived, and without a financial impetus there is little likelihood that further data will be forthcoming in the immediate future. Because of this, and as has been done in many other countries, the sediment quality guidelines are based on the best available overseas data. These have been refined based on current knowledge of existing baseline concentrations as well as by using local effects data as they become available. Therefore, the values provided by ANZECC (2000) are presented as interim sediment quality guidelines.

The values provided by ANZECC (2000), Long and Morgan (1990) and Long *et al.* (1995) are not standards but are presented as guidelines in evaluating sediment contaminant data.

The Auckland Regional Council have adopted a number of amendments to the ANZECC ISQG-Low guidelines when the values provided were considered inappropriate to the Auckland region. This is consistent with the ANZECC (2000) philosophy of developing trigger values appropriate to local conditions.

The ANZECC (2000) ISQG-Low values for copper and zinc are the same as the Hong Kong interim sediment quality values for dredge spoil disposal "ISQV" (Chapman *et al*. 1999). The Hong Kong data are based on local unpublished studies, which did not find toxic effects below these concentrations. The text accompanying the ANZECC (2000) guidelines asserts a high level of confidence in ERL values for copper and zinc and the guidelines have used ERL for other toxicants (Long *et al*. 1995). In Auckland Councils opinion there seems to be no justification for the substitution of ERL values with ISQV values in the ANZECC (2000) guidelines, so ARC have adopted the ERL values for copper and zinc. Further, the Auckland Council's "traffic light" system has been defined to classify a site and provide a management structure with the ERL values set as the red trigger values. Table 2.2 lists the Sediment Quality Guideline values for Red, Amber and Green conditions.

- Concentrations < Green, then OK
- Concentrations = Amber, then predict and investigate future trends
- Concentrations > Red, then investigate impacts

Table 2.2 Sediment Quality Trigger Values For Red, Amber and Green Conditions

Parameter	Red	Source of Red Value	Amber	Green	Source of Amber Green Value
Cadmium	>1.2	Long *et al*, 1995	0.7 - 1.2	<0.7	ISQG CCME
Copper	>34	Long *et al*, 1995	19 - 34	<19	ISQG CCME
Mercury	>0.15	ISQG ANZECC	0.13 – 0.15	<0.13	ISQG CCME
Lead	>50	ISQG ANZECC	30 - 50	<30	ISQG CCME
Zinc	>150	Long *et al*, 1995	124 - 150	<124	ISQG CCME

The ARC suggested amendments (Table 2.3) to the ANZECC ISQG-Low trigger values from ARC (2004) for organochlorines because:

- The ANZECC (2000) dieldrin low value was unrealistically low, often below commonly quoted analytical detection limits and would be exceeded in most Auckland sediments.
- ARC believes that no-effects data as well as effects data should be included in derivation of guidelines for contaminants that are present at low concentrations because there is a low reliability in derived values from effects data alone (Diffuse Sources Ltd. 2002). The ANZECC (2000) values for organochlorines are based on the ERL values of Long *et al.* (1995) that were derived from effects data alone.

Table 2.3 Auckland Council Amendments to Trigger Values for Organic Compounds in Sediment (µg/kg, ppb, dry weight)

Compound	ARC	ANZECC	
		ISQG-Low	ISQG-High
p,p'-DDT	3.2	1	7
p,p'-DDD	1.2	2	20
p,p'-DDE	2.1	2.2	27
Total DDT	3.9	1.6	46
Chlordane	2.3	0.5	6
Lindane	0.3	0.32	1
Dieldrin	0.72	0.02	8

A revision of the ANZECC sediment quality guidelines was published in 2013, Simpson, *et al*. (2013). This largely confirmed the ANZECC ISQG values for metals but recommended some changes for organic compounds, tributyl tin and proposed ISQG values for Total Petroleum Hydrocarbons.

Simpson, *et al*. (2013) revised ANZECC ISQG low value of 5.0 µg Sn/kg dry weight to 9.0 µg Sn/kg dry weight for tributyl tin based on more recent information. No guidelines are presented or published for the degraded tin compounds, however, as tributyl tin degrades the toxicity progressively reduces ANZECC (2000) the guideline for tributyl tin would be a conservative substitute. The ISQG-high guideline concentration was unchanged. Values are to be normalised to 1% organic carbon. If the sediment organic carbon content is markedly higher than 1%, the ISQG should be reduced accordingly, since additional carbon binding sites reduce contaminant bioavailability. It is recommended that the use of normalisation should, however, be limited to organic carbon concentrations between 0.2 and 10% (Batley *et al*., 2002).

Total petroleum hydrocarbons are common sediment contaminants and there are now sufficient effects data to derive a SQGV. They comprise a broad group of hydrocarbons, including crude and refined oils that are usually classified according to the number of carbon atoms contained in their alkane chains. Generally, TPH concentrations are reported as C6-C9, C10-C14, C15-C28, C29-C36 TPHs, where the numbers refer to the number of carbon atoms. Once in the sediment, TPHs will generally adsorb to sediment particles, particularly those with high concentrations of organic matter. Some TPHs may dissolve, disperse and evaporate, while other TPHs may undergo biological or photo-degradation. The solubility, reactivity, transport, and degradability of TPHs generally decreases as their size increases (i.e. as the number of carbon atoms increases). As a consequence of the poorly defined nature of TPHs contaminants and of these processes, the composition of TPHs in contaminated sediments is very complex and will vary considerably from site to site. Therefore, the toxic effects of TPH-contaminated sediments will also vary greatly.

Typical limits of reporting (LORs) for TPHs by most analytical laboratories are 25 mg/kg for C6-C9, 50 mg/kg for C10-C14, 100 mg/kg for C15-C28, and 100 mg/kg for C29-C36. This equates to an overall LOR of 275 mg TPHs/kg.

Based on the available effects data and the routinely achieved LOR for TPHs, it was proposed that the LOR of 280 mg/kg be used as a SQGV. An arbitrary ISQG-High value of 550 mg TPH/kg was also proposed. While this initial approach is considered simplistic, and does not consider the differences in toxicity of the various TPH fractions, without improved LORs and stronger cause-effects relationships, more complex guidelines are not appropriate.

For the proposes of evaluating pre dredging sediment quality data and post disposal sediment quality data for the potential for adverse ecological effects, it is considered that the ANZECC (2000) guidelines together with the Simpson, *et al*. (2013) revisions as shown in Table 2.1, provide the most suitable set of guidelines for New Zealand. The Auckland Council's "traffic light" system provides a further level of assurance of the level of ecological effects likely.

The guidelines above are related to each single contaminant, with the exception of organic contaminants in which the guideline takes into account the modifying effects of organic carbon. An emerging field of research in intertidal soft shore communities has started to investigate the effects of multiple stressors, such as additive synergistic or opposing antagonistic effects. At present, the science is still investigating the presence of these multiple stressor effects. There is some suggestion that particle size has a significant effect on the toxicity of some metals. The science is currently not sufficiently advanced to develop robust universal guidelines.

In addition the guidelines are based on total recoverable concentrations not all of the recovered contaminant concentration is biologically available, as such the comparison with the ANZECC ISQG's is only a first step in the screening process outlined below, and should not be a "standard" with which to pass of fail.

However as more research is completed and understanding of the complex relationships between sediment quality, availability, habitat and ecology improves revisions should continue to be made to the guidelines.

2.1.2 Level 1 investigation

Level 1 of the investigation involves the collection and review of existing information about the dredge material to assess whether or not the information is sufficient to make a decision about disposal at sea.
The review needs determine:

a) whether or not a decision can be made on an application without further testing on the basis that:
    - the material to be dumped at sea is uncontaminated and small in volume or
    - in the case of a dredging project, previous investigations have shown that the dredged material is pristine and the sediments can be demonstrated to be still in their natural condition

or, where a decision cannot be made without more information:

b) what the contaminants of concern are based on the site history review and pre-existing data on the sediments, if any; and
c) whether or not the geometric mean levels of the identified contaminants of concern in the waste are below the best available sediment quality guidelines.

It is generally accepted that if existing information is older than 3-5 years, further testing will be required to confirm this is still the case.

The following applies only to material to be dredged from shallow seabed locations.

The nature of the waste

Marine sediments may require no more than an assessment of particle sizes and a detailed review of their potential to release floating material or contaminants.

Previous history of the site from where the waste originates

The historical uses of the excavation site and catchment should be evaluated with particular attention to any usage that could have resulted in contamination, such as horticulture, farming, mining, industrial and residential uses. The historical investigation of the site and surrounding area should pay particular attention to potential sources of pollution adjacent or upstream, the location of effluent or stormwater discharges etc., and previous dredging, dumping, or landfilling. The sources of contamination may not always be obvious, as, for example, run off from adjacent agricultural land where herbicides and biocides have been used. Usage of the site as a marina has the potential for contaminants from boat hulls, mooring structures, haul out and maintenance areas, stormwater, refuelling points.

Site condition

Whether in relation to excavated or dredged material, an assessment of site condition should include information about the use of both the current site and adjacent sites, and about potential sources of pollution. Presence of waste, oils or other materials in drains can indicate contamination of adjacent sediments.

Previous studies

The sediments in major ports and established marinas are very likely to have been studied previously. A search for studies of sedimentology, sediment and water pollution, oceanography and marine ecology relating to the area to be dredged should include the files of relevant government departments, the scientific literature, environmental and planning studies, unpublished consultants' reports and postgraduate theses.

Contaminants of concern

The review of existing information should identify all contaminants of concern with reference to the New Zealand action list (Table 2.1).

If the level 1 review concludes that there is insufficient information to make a decision regarding the acceptability of the material for sea dumping, a level 2 investigation will be required.

2.1.3 Level 2 investigation

A level 2 investigation requires a comprehensive physical and chemical characterisation based on samples of the dredge material concerned. The aim of such an investigation is to identify any contaminants of concern if data from the level 1 investigation are insufficient. Sampling will be representative of the geographic extent of the area to be dredged and the entire depth of sediment to be dredged.

A sampling plan taking into account the following is to be submitted to the EPA for approval prior to the level 2 sampling. The sampling plan is to comprise of the level 1 assessment justifying the sampling plan for the level 2 assessment. In addition is should include contingencies to cover variations from those expected based on the level 1 assessment, and to include a sampling plan for a level 3 assessments if required.

Numbers of samples or cores required

The number of samples or cores required is dependent on the variability of the sediments and their pollutant content, which may depend on a large number of factors. However, it is generally true that sediments in locations where the geography is relatively uniform and distant from point sources of pollution will require a minimum number of cores to be adequately characterised. On the other hand, sediments near the shore in a geographically complex embayment, with great changes in depth, shoreline configuration and many point sources of pollution will require a maximum number of cores for adequate characterisation. Additional cores may also be needed if a large area is being subjected to very shallow dredging, or fewer cores may be required in small areas of deep dredging.

Table 2.4 contains a guide to the number of cores to be collected. When preparing the sampling and analysis plan the necessity for a greater or lesser number of cores should be assessed. In general, sampling must be sufficiently intense so that if contaminants are present in concentrations greater than those permitted to be disposed at sea, they will be detected. If the composition and quality of the sediments to be dredged is unlikely to have changed over time, it is not necessary to sample each time maintenance dredging is carried out. Detailed sampling will be required at intervals of 3 to 5 years. Exemptions are possible for pristine areas, provided that it can be demonstrated that they are still pristine.

Table 2.4 Guide to Number of Core Samples Required

Volume to be Dredged (cubic metres)	**Number of Cores**
0–5,000	3
5,000–15,000	4
15,000–100,000	10
Each additional 100,000	3 additional

Selection of sampling sites

At contaminated sites where there is a history of pollution, except where the dredge volume is small, the USEPA approach of stratifying the site into arbitrarily sized blocks and randomly sampling in each block is to be adopted. The size of blocks can be varied so that the sampling density is greater in locations where the probability of high levels of contamination is greatest, if so desired, and blocks can be large if there is evidence that the concentrations of contaminants are unlikely to vary much across the site.

For large or complex sites where there is little information available, it is recommended that an initial pilot sampling programme be carried out, comprising 5-10% of the cores that would be taken in the full-scale study, analysed for the full range of chemical parameters. The pilot programme must sample the full range of depositional environments to be dredged. The results of this study would be used to make an appropriate sampling design and identify the contaminants of concern for the full-scale study.

If localised areas of the dredge site are thought to be highly contaminated (e.g. as a result of point source pollution) this sediment should be assessed separately using a stratified random design. This will allow the material to be handled separately and prevent relatively clean material being identified as contaminated.

At uncontaminated sites where there is no history of pollution or where the sediments have previously been found to be uncontaminated, a stratified random sampling grid should also be used (i.e. randomly sampling within each grid square or specified proportion of grid squares) but fewer samples are required and the whole dredging site can be treated as a single site (i.e. the data from the whole site can be averaged (geometric mean) to determine whether it meets the permissible levels for sea disposal (Table 2.1).

Sub-sampling of cores

Generally, contamination is confined to the top 50-100 cm of sediment. Where contamination is found below 1 m it is usually because sediments have been dredged or disturbed, or because sedimentation rates are very high (e.g. close to industrial sites, outfalls or where streams discharge into an estuary). The thinnest layer that can be reliably dredged and selectively handled is between 30 and 50 cm so sampling at smaller intervals is of no value.

Cores are to be sampled as follows:

- The top 50 cm of the core (or to the depth of dredging if less than 50 cm) is to be composited as a single sample for analysis. In most cases, this material will contain the highest levels of contaminants.
- A second sample is to be taken from the 50–100 cm interval.
- Below 1 m, cores should be composited in 1 m lengths for analysis, or in greater intervals if it can be demonstrated that the chemical composition is relatively uniform. If contamination is found below 1 m, then analysis should be conducted on the core sub-sampled at 50 cm intervals to determine the extent of the contamination.

Appropriate decontamination procedures must be followed when sub-sampling from cores to avoid cross-contamination of samples.

Mass of sample required

The approximate mass of material necessary for particular analyses is set out in Table 2.5 below. These are the weights of sample considered desirable for a site that may contain a large variety of different contaminants and therefore require a number of different analyses, as well as replicates and check samples. In many cases, a lower sample mass would be sufficient, but given that the cost of re-sampling is high compared to the cost of collecting extra samples, it is prudent to collect as much material as is likely to be required. Table 2.5 also includes the minimum mass of sediment necessary for reliable analysis of a single sample.

Table 2.5 Amount of sediment required for various analyses

Analytical Parameter	Amount required (g, wet weight)
Organic compounds	100–250
Metals	10–100
Miscellaneous analyses	50–100
Grainsize	50–200
Total organic carbon	10–50
Moisture content	10–50

Sample collection, handling, storage, preservation and labelling

Sample handling techniques must ensure that changes in the composition of the samples as a result of chemical, physical or biological action are minimised, that cross contamination of samples does not occur during sub-sampling and subsequent handling, and that samples are not lost or mixed up between sampling and arrival at the analysing laboratories.

Generally in theory, samples to be analysed for trace metals should not come in contact with metals, and samples to be analysed for organic compounds should not touch plastics. In practice, the corer will be either be metal or plastic and duplicate sampling with different corers is not economical; therefore the use of a single sample container such as a plastic zip lock bag is generally sufficient. Samples for chemical analysis should be frozen, the sample container should be filled to two thirds of its volume and immediately chilled; the sample should be frozen as soon as possible after sampling. Samples for grain size analysis should be chilled but not frozen. Samples for toxicity testing should have all macro-invertebrates removed by sieving through a 0.5 mm sieve.

Waterproof labels and ink should be used, preferably pre-printed. The labels should be placed outside the sample bag inside a second bag facing out clearly visible. The label information should include site, date, depth, analysis, and handling required.

Quality assurance and quality control

The specific quality control and quality assurance procedures are aimed at minimising the potential for sample contamination and monitoring key events in the sampling procedure in order to detect contamination should it occur. Sample containers and all sample equipment, including the survey vessel, should be cleaned prior to sampling to a degree appropriate to the investigation and the analyses required. Sampling should occur in a manner that avoids or minimises contamination and effective use of field and equipment blanks should be utilised.

All field procedures must be documented using the standard procedures routinely used in New Zealand in contaminated site investigations as follows:

- Written standard operating procedures (SOPs) are to be included in the sampling and analysis plan and variations from SOPs, and the reasons for such variations, noted.
- Field conditions (weather, tides, currents), station locations, sampling methods and handling and storage methods, field numbers, date, time, identity of sampler should be noted in ink in the field log and field descriptions of sediments recorded as collected.
- A sample inventory log and a sample tracking log must be maintained.
- Chain-of-custody forms that list all sample numbers and locations and the analyses and detection limits required of each sample are to accompany each sample to the laboratory. At each stage of

handling, the samples are to be checked against the chain-of-custody forms and after receipt by the laboratory, a checked form sent back to the sampling organisation.

- Laboratories must be accredited with a recognised laboratory accreditation organisation and must be experienced in the analysis of marine sediments and solid wastes.

Physical characterisation

It is necessary to evaluate the physical characteristics of waste to determine its potential impact on the environment and the need for chemical and/or biological testing. The basic physical characteristics to be determined are volume, basic sediment grainsize (where applicable), specific gravity of solids, and moisture content data. Moisture content is required on all samples as results are customarily expressed as dry weight. The proportion of litter and other anthropogenic items in the waste should also be considered. The persistence of the waste in the environment and its tendency to degrade should be considered. If the waste appears very littered with persistent matter such as plastics, the material may be unacceptable for dumping at sea.

Chemical characterisation

No single list of chemicals to be analysed can be valid for all wastes proposed for sea dumping. For example, with respect to dredging operations, the ports and harbours of the major cities are likely to contain a wide variety of chemicals that will vary greatly according to the local geology and the types of development that have occurred there (Table 2.6).

The heavy metals (e.g. copper, lead, zinc) and metalloids (e.g. arsenic) are among the most common and widespread pollutants in New Zealand. They are present in most contaminated sediments, sometimes at very high levels. Other more site-specific contaminants are ammonia, total petroleum hydrocarbons, polynuclear aromatic hydrocarbons, organochlorine pesticides, polychlorinated biphenyls, tributyl tin and pentachlorophenol. Marine sediments in harbours adjacent to cities or near concentrated areas of industry often contain multiple groups of pollutants. Other contaminants are rare and are often only associated with specific industries, e.g. dioxins with the pulp and paper industry.

Testing for metals and inorganic and organic compounds listed in Table 2.6 will be required if a particular source of such contamination at the site where the waste is generated is identified. Detection limits should be sufficient to allow comparison with the lower effects range guideline for sediment toxicity, as shown in Table 2.1**Error! Reference source not found.**. For most New Zealand harbours, this will include heavy metals and metalloids (arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc) as a minimum, with the addition of organic contaminants such as total petroleum hydrocarbons (TPH), polynuclear aromatic hydrocarbons (PAH), organochlorine pesticides, tributyl tin and other antifouling compounds on a case by case process as indicated by the level 1 assessment. If organic contaminants are tested, total organic carbon should be added to the testing, as this is required for comparison with the sediment quality guidelines.

Generally, if the mean concentrations for all substances detected in waste are found at levels below the ER-L and or ANZECC ISQG-Low in Table 2.1**Error! Reference source not found.**, then the material is determined to be suitable for unconfined ocean dumping and does not require further testing. However, if there is significant variability between samples and at least one is above the ER-L and or ANZECC ISQG-Low, additional sampling and testing may be required in order to establish whether there are significant “hot spots”, and the biological availability and toxicity of the sediments in the “hot spot”. The additional sampling would be aimed at defining the geographic extent and thickness of the "hot spot", and be suitable to define any dredging management protocols.

Table 2.6 Substances for Which Testing May Be Required

PARAMETER	PRACTICAL QUANTIFICATION LIMIT (PQL) (mg/kg dry weight except where specified)
1. Basic sediment characteristics	
Moisture Content	0.1%
Total organic carbon	0.1%
Particle size and settling rate*	
2. Organic compounds	
Organochlorine pesticides, including:	0.001 (each individual species)
total chlordane[1], oxychlordane, dieldrin, aldrin, heptachlor, heptachlor epoxide, methoxychlor, endrin, DDD, DDE, DDT, alpha and beta BHC, lindane, endosulfan (total alpha, beta and sulphate), hexachlorobenzene	
Organophosphorus compounds	0.01 (each individual species)
Total PCBs	0.005
Polynuclear Aromatic Hydrocarbons (PAH), including:	0.01 (each individual species)
napthalene, acenapthalene, acenapthene, fluorene, phenanthene, anthracene, fluoranthene total, benz[b]fluoranthene, benzo[k]fluoranthene, indeno[1,2,3-cd]pyrene, dibenz[ah]anthracene, chrysene, coronene, perylene, pyrene, benzo[e]pyrene, benzo[a]pyrene,	
Sum of PAHs	0.1
Total petroleum hydrocarbons (TPH)	10
Phenolics	1
Volatile chlorinated hydrocarbons	0.05-5
Chlorobenzenes	0.05
Chlorinated organics	varies according to toxicity
Benzene, toluene, ethylbenzene, xylene	0.20
Non-organochlorine pesticides:	0.005 (each individual)
Organophosphates, Carbamates, Pyrethroids, Herbicides	
Miscellaneous organics	varies according to toxicity
Dioxins	0.02 µg/kg
Organotin compounds	0.2 µg/kg
3. Metals and metalloids	
Aluminium[2]	200
Antimony	0.1
Arsenic	0.5
Cadmium	0.1
Chromium	0.5
Cobalt	0.5
Copper	0.5
Iron	50
Lead	1
Nickel	0.5
Manganese	1
Mercury	0.01
Selenium	0.01
Silver	0.1
Vanadium	2
Zinc	0.5
4. Inorganics	
Cyanide	0.01
Total Kjeldahl nitrogen (TKN)	0.01
Total phosphorus (TP)	0.01
Ammonia	0.1
5. Other	
Radionuclides[3]	35 Bq/g
Biological oxygen demand	
Presence of viruses, bacteria, yeasts, parasites[4]	

* Size distribution (sieve + hydrometer) and rates of settlement after 50% and 90% of settlement, in seawater. Includes interpretative statement in relation to sea disposal.
1 Here defined as the sum of alpha and gamma chlordane and heptachlor
2 Not a contaminant but included because it can be a useful normalising element
3 Needs only be done once for any particular dredge area
4 Need only be assessed for sewage sludge or for particular dredge areas where sewage disposal is known to occur

If the level 2 review concludes that there is insufficient information to make a decision regarding the acceptability of the material for dumping, a level 3 investigation will be required.

2.1.4 Level 3 investigation

If the concentration of one or more of the contaminants measured in the level 2 assessment at a site falls between the ER-L or ANZECC ISQG-Low and the ER-M or ANZECC ISQG-High guidelines (Table 2.1**Error! Reference source not found.**) or any future updated values, the dredge material will require a level 3 investigation involving elutriate and possibly acute toxicity testing.

Elutriate testing, determines whether contaminants present in the dredge material are mobile and will transfer to the water once dredged of dumped. The results of elutriate testing are to be compared to the ANZECC marine water quality criteria (or other appropriate criteria such as USEPA) after the application of an appropriate dilution factor. If the elutriate test results exceed the relevant criteria after initial dilution, the dredge material should be further tested (toxicity to water and benthic organisms).

Elutriate testing

Elutriate testing, determines whether contaminants present in the material to be dredged are mobile and will transfer to the water once disturbed either at dredging or at dumping. It determines whether contaminants will leach from the dredged material in toxic concentrations. The release can occur by physical processes (e.g. directly from sediment pore water) or by a variety of chemical changes (e.g. the oxidation of metal sulphides and the release of contaminants adsorbed to particles or organic matter). Where possible a fresh (unfrozen), representative sediment sample should be tested from the site which had the sediment quality guideline exceedence. However, the samples tested for sediment chemistry are often the same sample tested for elutriate testing, and these samples are specified to be stored frozen.

The elutriate test is carried out by shaking the sediment samples with 4 times the volume of seawater from the dredging site at room temperature for 30 minutes, then allowing the samples to settle for 1 hour. The supernatant is then centrifuged or filtered (0.45 µm) and analysed using analytical methods appropriate for determining ultra-trace levels in seawater (i.e. where possible, at least ten times lower than the ANZECC 2000 marine water quality criteria or other appropriate criteria).

The results of elutriate testing are to be compared to the ANZECC marine water quality criteria (or other appropriate criteria such as USEPA or as specified in a regional coastal plan) after the application of an appropriate dilution factor. Initial mixing is defined as that which occurs within four hours after dumping. The elutriate test uses a dilution of 1:4, which greatly overestimates water quality impacts because within a four hour period dilutions would normally be hundreds of times that, or greater still if disposal is to an open ocean site. The test data must therefore be entered into the model, if available, or multiplied by an appropriate dilution factor after four hours in order to assess whether or not the water quality criteria will be exceeded after disposal.

Elutriate testing of dredged sediments (including the measurement of trace elements and ammonia) from a range of dredging projects in New Zealand indicate:

- no significant breaches of water quality criteria for trace elements in elutriates. Minimal dilution was required for zinc in some cases to reduce the concentration to acceptable levels

- ammonia concentrations routinely exceed criteria. However, dilution reduces concentrations rapidly to acceptable levels where dilution is available
- minimally contaminated sediments with constituent concentrations well below screening levels will generally not produce high concentrations of metals in elutriate. Similar results have also been found in some instances where contaminants are at concentrations between ER-L and ER-M levels. This indicates that in the main contaminants are strongly adsorbed into sediment particles, particularly where organic matter and/or sulphide levels are high.

As shown in Figure 2.1 if the elutriate test results exceed the relevant criteria after initial dilution, the material should be further tested (toxicity to water and benthic organisms) or an appropriate mixing zone agreed with the issuing authority.

Acute toxicity testing

If results from elutriate testing exceed the relevant water quality criteria after initial dilution, the next step in the testing is an acute toxicity test of the waste using suitably sensitive marine organisms. If elutriate testing showed contaminant concentrations in water after initial dilution, close to but not exceeding the relevant water quality criteria, additional toxicity testing might still be appropriate. If it is found to be non-toxic at the acute level, the material is then considered suitable for unconfined ocean dumping.

If the material is found to be acutely toxic, the applicant may opt to

a) treat the waste to make it less contaminated, or
b) undertake a level 4 investigation, or
c) consider either dumping into a confined/contained site at sea, or not to dump at sea at all.

If the waste is found to be acutely toxic and the applicant decides not to perform further testing, or if the results of more intensive testing show the waste to be still toxic, then the waste is not acceptable for unconfined sea dumping.

Toxicity testing may be of significant benefit to the applicant if it demonstrates that sediment contaminant levels, although exceeding ER-L or ANZECC ISQG-Low criteria, are non-toxic because they are not biologically available. This has been demonstrated frequently in the United States (USEPA 1992). Contaminated sediments most likely to be non-toxic for this reason are those which are fine-grained, organic and rich in sulphides.

The use of level 3 testing on individual sample exceedances is conservative as average contaminant concentrations are likely to be lower, therefore if individual site samples are classified as not suitable the overall average concentration may dilute the effects making the material suitable. While the dredge material is assessed for suitability for disposal under the criteria above, the quality of the seabed sediments at the disposal site are required to remain under the ANZECC ISQG-low guideline values as a condition of the disposal consent. Therefore dredge material from a source site will only be acceptable if the average concentration of all contaminants is below the ANZECC ISQG-low guideline values.

With the stratified sampling studies required there is significant scope to apply dredging management practices to separate unsuitable material from material disposal of at sea.

2.1.5 Level 4 investigation

A level 4 investigation is used when the geometric mean of one or more contaminants in the dredge material is above the ER-M or ANZECC ISQG-High level (Table 2.1) for any individual parameter, or where, at the previous level, a dredge material is found to be acutely toxic or has otherwise failed to meet any of the stipulated criteria. The dredge material is then regarded as being probably unsuitable for unconfined disposal at sea.

However, the applicant may elect to carry out further assay to evaluate acute toxicity in a more comprehensive manner, as well as chronic and bio accumulative effects and prepare a comprehensive assessment of environmental effects. A level 4 investigation will of necessity also involve a more comprehensive evaluation of the environmental conditions and status of the dump site.

Irrespective of the toxicity testing the average concentration of any of the contaminants in the dredge material is not to exceed the ANZECC ISQG-low guideline values.

2.1.6 Biological Characterisation

Introduced (non-indigenous) plants and animals are recognised as one of the most serious threats to the natural ecology of biological systems worldwide (Wilcove *et al*. 1998, Mack *et al*. 2000). New Zealand's geographic isolation makes it particularly vulnerable to marine introductions because more than 95% of its trade in commodities is transported by shipping, with several thousand international vessels arriving and departing from more than 13 ports and recreational boat marinas of first entry (Inglis 2001). The country's geographic remoteness also means that its marine biota and ecosystems have evolved in relative isolation from other coastal ecosystems. New Zealand's marine biota is as unique and distinctive as its terrestrial biota, with large numbers of native marine species occurring nowhere else in the world.

The numbers, identity, distribution and impacts of non-indigenous species (NIS) in New Zealand's marine environments are poorly known. A recent review of existing records suggested that by 1998, at least 148 species had been deliberately or accidentally introduced to New Zealand's coastal waters, with around 90 % of these establishing permanent populations (Cranfield *et al*. 1998). To manage the risk from these and other non-indigenous species, information is needed on the diversity and distribution of species present within the dredging source areas, together with information on the diversity and distribution of species present along the dredge transport routes, at the disposal area and on the nearby shorelines.

In addition to the characterisation of quality of dredge material, a characterisation of marine biosecurity risks associated with dredging area and the transportation route to the disposal area is required.

The number and type of samples required to assess a dredge area will vary from area to area. If the dredge area is adjacent to vertical structures, such as wharf piles, or shoreline that could lead to NIS being entrained in the dredge material, then these areas should also be assessed.

2.1.6.1 Number of samples

The number of samples required is determined from area to be dredged, its complexity and history.

At sites where there is a history of NIS, a stratified approach of dividing the site into arbitrarily sized blocks and randomly sampling in each block is to be adopted. The size of blocks can be varied so that the sampling density is greater in locations where the probability of NIS being present is greatest. Blocks can be large if there is evidence that NIS are unlikely to vary much across the site. This will allow the dredge material to be handled separately and allow for possible treatments to prevent transport of unwanted NIS, or at least make them non-viable. At sites where there is a history of no NIS and no reasons to believe otherwise, then the number of samples required can be reduce. However a stratified random, sample approach should still be used.

2.1.6.2 Survey methods

Because different species have different habitat preferences, different sampling methodologies are required to assess the different habitats that NIS are likely to occur in.

Wharf pile

While dredging is of sediment from the sea floor, adjacent habitats could be disturbed by the dredge, thus the wharf piles and step rocky break waters are often required to be assessed. The outer face of wharf piles are to be assessed at different depths from low tide to seabed. Sample can include continuous video recording of the wharf pile face, high resolution still images of selected depths and diver collected scraping samples from quadrat at selected depths. Care should be taken to assess piles that have been present for at least 12 months. Rocky break water walls should be sampled at low tide in areas adjacent to dredging operations. Samples can include still images of quadrats or hand sorted, enumerated counts of species present in quadrats. All samples should be clearly labelled and a log of field conditions recorded.

Benthic biota

Biota present within the sea floor sediment to be dredged should be sampled either by diver operated core sampler or by surface operated grab sampler, the grab sampler can either be quantitative from a fixed area or qualitative from an unknown area. Each sample should be a minimum of 2L volume and be washed through a 1.0mm (or smaller) mesh sieve and animals retained on the sieve collected, preserved and returned to the field laboratory for sorting and identification. Sieving and samples preservation should occur within 6 hours of sample collection. A suitably qualified and experienced person should conduct sample species identification.

Epibenthos

If larger benthic organisms are expected to be present then these should be sampled using an Ocklemann sled or similar device. The sled should be towed for a standard distance, typically 100 m, along the seabed such that the mouth of the sled partially digs into the sediment and collects organisms in the surface layers to a depth of a few centimetres, before being retrieved. The mesh size used in the sled should be sufficiently small as to retain species of interest. The entire contents should be sorted and either identified in the field or bagged, labelled and persevered for later identification.

Some epibenthos species such as benthic scavengers and fishes are more mobile and thus require different sampling methods. The use of baited Opera house fish traps, Fukui-designed box traps, Starfish traps and Shrimp traps should be considered, if these mobile species are identified as of interest.

2.2 Dredge Material Origins

Between November 2012 and 1 April 2018, material from six locations has been characterised, dredged and disposed of at the NDA. Each site has been the subject of at least one characterisation study (Bioresearches, 2012, 2013, 2014, 2016, 2017, 2017b; Golder Associates Ltd, 2013a, 2013b, 2013c, 2017). The characterisation of dredged material ensures that the dumping of this material is suitable for transport to and disposal at the disposal site, and does not assist in the spread of invasive, non-indigenous species or contaminated sediments to the dumping site and avoids unnecessary adverse effects on the resident biota.

Generally the biota present in shallow sheltered coastal waters is unlikely to survive on the seabed at the NDA site. However if during transport to the site, an incident occurs that results in some of the material being discharged from the barge, then there is potential for release and survival of biota resulting in the spread of any unwanted biota in the dredge material. There is also a risk that spawning may occur in some species while in the barge and that the larvae may be able to be spread by currents. The extent of the spread would depend on the length of time the larvae are planktonic, the speed and direction of the currents, and if a suitable habitat for settlement is present in the path. The level of risk of biota survival largely depends on the biology of the species, and is further discussed in section 4.4. The biology and risks of the species identified below are summarised in Appendix 1.

The following summarises the various sediment source site characterisation studies conducted to date.

2.2.1 Sandspit Marina

In May 2014, the benthic biota and sediment quality of the proposed marina and access channel were assessed prior to construction of the marina (Bioresearches, 2014). Benthic biota and sediment quality samples were collected from twelve sites, six intertidal and six subtidal (Figure 2.2). The benthic biological communities found within the proposed marina basin sediments were not particularly diverse and consisted mostly of bivalves and polychaete worms.

Two non-indigenous species were known to be found in the proposed marina basin sediments: the bivalve, *Theora lubrica* and the polychaete worm, *Glycera americana*. During sampling at the 12 stations for both benthic biota and sediment quality, three additional non-indigenous species were observed: the pacific oyster, *Crassostrea gigas*, the Asian paddle crab, *Charybdis japonica* and the Australian drop tunicate, *Eudistoma elongatum*. No evidence of the previously reported Parchment worm, *Chaetopterus* sp., Asian date mussel, *Arcuatula senhousia* or Clubbed tunicate, *Styela clava* (Grace, 2014), was found during the biota and sediment surveys.

T. lubrica, G. americana and the pacific oyster are considered to be well-established in New Zealand waters and pose a negligible marine biosecurity risk. The Asian paddle crab, *C. japonica*, is present in several estuaries in the Hauraki Gulf. The spread of this species is undesirable, however adults are unlikely to survive smothering by sediments in the barge. The Australian droplet tunicate is unlikely to survive smothering by sediment and if stress-induced larval release occurs, the larvae are viable for only a few hours. On-site management of the dredging and disposal allowed the dredged sediment to sit on land for 7-10 days prior to being loaded on the disposal barge, further reducing the risks posed by *C. japonica* or *E. elongatum* during the transport and disposal of the spoil, however the effectiveness of this was not assessed.

Figure 2.2 Marina Basin Sample Sites for Pre Dredging Study 2014

Due to this being a new marina, the depth of sediment to be dredged was significant and the methodology called for layered sampling. Sample cores were divided into up to four sections based on sediment sample depth; A (0-0.5 m), B (0.5-1.0 m), C (1.0-2.0 m), D (2.0-3.0 m). The analysis varied in each of these sub samples, based on the expected contaminants.

Concentrations of cadmium, chromium, copper, lead, mercury and zinc were all below the Effects Range - Low (ER-L) guideline values.

The highest concentrations of arsenic recorded exceed the ER-L guideline value of 8.2 mg/kg dry weight as taken from Table 5 in Maritime Safety Authority of New Zealand (1999). At the time of sampling compliance was under the control of MNZ and therefore the MSANZ 1999 Table 5 guidelines were in effect, however the more recent ANZECC 2000 guidelines are currently accepted by EPA. All concentrations of arsenic in the proposed Sandspit Marina were below the ANZECC ISQG low guideline value for arsenic of 20 mg/kg dry weight. The concentrations of arsenic were generally low, however concentrations were elevated at Stations 4A, 4B, 4C, 5A, 5B, 5C, 5D, 7A, 7B, 8B, 8C and 10A. The distribution of elevated concentrations of arsenic suggests an anthropogenic source rather than a geological source.

The highest concentrations of nickel recorded exceed the ER-L guideline value of 21.0 mg/kg dry weight as taken from Table 5 in Maritime Safety Authority of New Zealand (1999). The concentrations of nickel were generally low, however concentrations were elevated at Stations 1D, 2A and 2B. The distribution suggests that the harder sandstone reef sediment is richer in nickel than the other softer sediments in the area. Given that the sediments that contain the elevated nickel are rock that needed to be ground to analyse, it is unlikely that the elevated concentrations of nickel will present environmental risks.

None of the three antifouling co-biocide compounds (Diuron, Irgarol or Isoproturon) analysed for were detected in any of the samples tested. Monobutyl tin, tributyl tin and triphenyl tin were not detected in any of the sediment samples tested. Dibutyl tin was only detected at low levels in the sample from Station 5A. No organochlorine pesticides were detection in any of the sediment samples tested. Total petroleum hydrocarbons (TPH) were not detected in any of the samples tested.

The reported concentrations of the individual polycyclic aromatic hydrocarbons (PAHs) tested were generally below the method detection limits. Low concentrations of Phenanthrene, Benzo[a]pyrene (BAP), Benzo[b]fluoranthene + Benzo[j] fluoranthene, Benzo[g,h,i]perylene, Fluoranthene and Pyrene were detected at Stations 2B and 10B. Concentrations of all individual PAHs detected were below the ER-L guideline values presented in Table 5 in Maritime Safety Authority of New Zealand (1999). The concentrations of low molecular weight, high molecular weight, and total PAHs were all well below the ER-L guideline values as presented in Table 5 in Maritime Safety Authority of New Zealand (1999).

When the sediment samples from the Stations 1D, 2A, 2B, 4A, 4B, 5B and 8B were mixed with seawater, the elutriate extract showed that the concentrations of arsenic and nickel varied. The concentration of nickel increased in the elutriate extracts from Station 1D and 2B, but was unchanged at Station 2A. The hard, nickel rich rock sediments were consequently not disposed of at the disposal site, avoiding any adverse effects on the biota as a result of elevated concentrations of nickel in the water. The concentration of arsenic increased in the elutriate extracts from Station 4A, 4B and 5B, and was unchanged at Station 8B. The increased arsenic concentrations in the elutriation extracts from stations 4A, 4B and 5B were not above the USEPA Criterion Continuous Concentration (CCC) (36 µg/L), therefore adverse biological effects are not expected.

2.2.2 Hobsonville Point

In April 2016, the benthic biological communities in sediments from sites within the footprint of the area to be dredged, bio-fouling organisms from the shoreline breakwaters and wharf poles, and the chemistry of the sediments to be dredged, were sampled following an EPA and MPI approved methodology (Golder Associates Ltd, 2017). The report did not present the raw data but mentioned that only one marine pest species was found during this survey, the Mediterranean fanworm (*Sabella spallanzanii*) on the wharf structure. The Mediterranean fanworm presents a risk of spread due to its robustness and extended planktonic larval dispersal life stage. However none were found in the sediments to be dredged, they were only present on structures adjacent. MPI approved the dredging and disposal without additional pest biota management.

Eighteen sediment sites were sampled with cores to an unspecified depth and tested for contaminants (Golder Associates Ltd, 2017). It is unknown if the depth of sampling corresponded with the depth of dredging. No layered subsampling was conducted nor could it be determined if this was required. The concentrations of cadmium, chromium, copper, lead, nickel and zinc were all below the ANZECC ISQG low guideline values. The concentration of arsenic exceeded the ER-L guideline (8.2 mg/kg dry weight) at all sites however did not exceed the ANZECC ISQG low guideline value of 20 mg/kg dry weight. The concentration of mercury exceeded the ANZECC ISQG low guideline value of 0.15 mg/kg dry weight at 16 of the 21 sample sites. TPHs were generally not detectable in all 21 samples. However, two samples contained TPH in the higher C_{15}-C_{36} carbon number band with 160 mg/kg and 45 mg/kg (SC 5 and SC 6 respectively). Simpson, *et al.* (2013), summarised studies undertaken on TPH toxicity and marine biota and recommended a SQG low guideline of 280 mg/kg and a SQG High of 550 mg/kg. As such, the TPH concentrations recorded were below the SQG low guideline.

The interpretation of tributyl tin in the Golder Associates Ltd (2017) report was not correct in that guidelines refer to tributyl tin and not the combined totals of tributyl tin compounds. At both sites SC4 and SC5, tributyl tin exceeded the ISQG low guideline and the revised guideline (Simpson *et al*., 2013) but not the ISQG high values. Individual PAH compound concentrations and low and high molecular weight PAHs and total PAH concentrations were all less than the appropriate ANZECC ISQG low guidelines.

Elutriate testing of Hobsonville Point sediments has shown that when dredged and disposed, the sediment will release some constituents to surrounding seawater. The most significant constituent to be released will be ammoniacal-nitrogen. Although present, the concentrations are reduced well below the ANZECC (2000) marine trigger values with low dilution. Trace element concentrations in elutriate were low and for the detected concentrations a low amount of dilution during disposal would ensure that no chronic effects would occur.

2.2.3 Hobsonville Marina

The benthic biological communities from sites within the Hobsonville Marina basin sediments, bio-fouling organisms from the marina breakwaters and marina poles (Figure 2.3 A), and the chemistry of the sediments (Figure 2.3 B), to be dredged were sampled in April 2014 (Bioresearches, 2013) and in November 2016 (Bioresearches, 2017), following a MNZ, EPA and Ministry for Primary Industries (MPI) approved methodology.

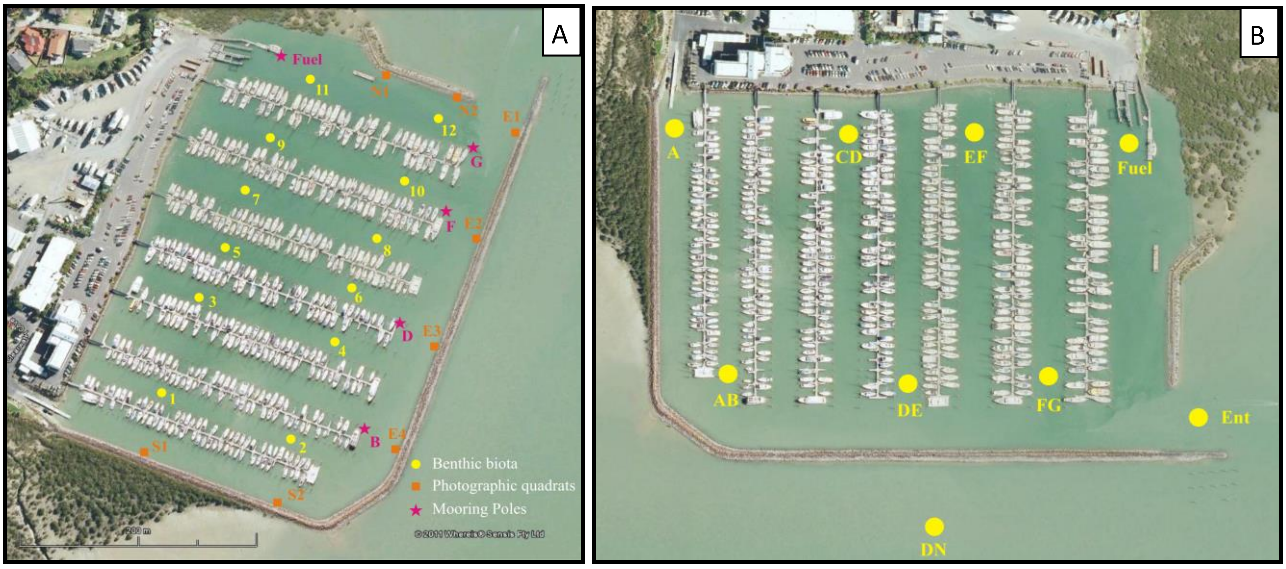


Figure 2.3 Marina Basin Sample Sites for Pre Dredging Study 2016, A. Biota, B. Sediment Quality

In 2014, the benthic biological communities found within the marina basin sediments were not particularly diverse and consisted mostly of polychaete worms, although the bivalve *Theora lubrica* was relatively ubiquitous throughout the marina basin, albeit at a very low density. In 2016, the biota was again numerically dominated by polychaete worms, in particular *Cossura consimilis*. The diversity of species present in the marina sediments increased between 2014 and 2016, with five species recorded in 2016 not present in 2014. These included three common species/taxa of polychaete worm (*Heteromastus filiformis*, *Prionospio aucklandica* and Syllidae), a single individual of the amphipod (*Monocorophium sextonae*) and a juvenile crab. Two non-indigenous species were found in the marina basin sediments; the bivalve, *T. lubrica* and the polychaete worm, *Glycera americana*. Both species are considered to be well-established in New Zealand waters, and thus their distribution range will not be extended if accidentally released en route to the disposal site. Neither species are expected to survive at the disposal site.

In 2014, most of the pole samples had very few organisms in them, the marina poles appearing to be relatively clean at most locations. In 2016, poles B, D, F and G contained a greater diversity of species and the biomass was dominated by large adult Pacific oysters, (*Crassostrea gigas*). The oysters appear to provide substrate for the other species. Three non-indigenous species were found encrusting the marina poles. These were, Mediterranean fan worm, (*Sabella spallanzanii*), Pacific oyster, (*C. gigas*) and the Asian date mussel (*Arcuatula senhousia*). The Asian date mussel and Pacific oysters are all well-established in Auckland and Coromandel regions and thus their distribution range will not be extended if accidentally released en route to the disposal site. The Mediterranean fanworm presents a risk of spread due to its robustness and extended planktonic larval dispersal life stage. However none were found in the sediments to be dredged, they were only present on structures adjacent. MPI approved the dredging and disposal without additional pest biota management.

Eight sediment sites were sampled with cores to the depth of dredging, and tested for contaminants from within the marina (Figure 2.3 B). Sub samples of sediment from sampling locations A, CD, EF and Fuel were combined into a composite sample (Composite Near) and sub samples of sediment from sampling locations AB, DE, FG and Entrance were combined into a second composite sample (Composite Off).

In 2016, the sediments within the Hobsonville Marina basin showed arsenic concentrations typical of West Auckland sediments and characteristic of the Henderson Creek catchment sediments Auckland Regional Council (ARC) (2001). While elevated above the ER-L guideline (8.2 mg/kg dry weight) they did not exceed the ANZECC ISQG low guideline value of 20 mg/kg dry weight. Copper exceeded the ANZECC ISQG low guideline value of 65 mg/kg dry weight at the Fuel site and was elevated at site EF. Elutriation testing showed that while only detectable quantities of arsenic were released into the water on disturbance, it is unlikely that adverse effects will result as water quality guideline values were not exceeded.

PAH compound concentrations were all less than the appropriate ANZECC ISQG low guidelines and both low and high molecular weight PAHs and total PAH concentrations. No antifouling co-biocide compounds were detected within the composite sediment samples taken from the marina basin.

Tests on the composite samples showed tributyl tin compound concentrations were less than the revised ANZECC ISQG low value, but that the Near shore sample was elevated. The individual site samples (CD, EF and Fuel) showed that sediment from sites EF and Fuel exceeded the revised ANZECC ISQG low value. The concentrations detected in 2016 were significantly higher than those detected in 2014. Elutriation testing conducted in 2014 showed that no detectable quantities of tributyl tin were released into the water on mixing, and that the best available detection limits were insufficient.

2.2.4 Half Moon Bay Marina

In April 2013, the benthic biological communities from sites within the Half Moon Bay marina, bio-fouling organisms from the marina breakwaters and marina poles were assessed (Golder Associates Ltd, 2013b). Three target marine pest species were found in Half Moon Bay Marina, these included the Asian paddle carb, *Charybdis japonica*, Clubbed sea squirt, *Styela clava* and the Mediterranean fan worm, *Sabella spallanzanii*. All three species were previously known to be established in parts of New Zealand, including the Hauraki Gulf. In addition to the target species, two other non-indigenous species were observed, the small bivalve

Theora lubrica, in marina sediments and the Pacific oyster, *Crassostrea gigas*, on the rock walls.

In April 2013, the chemistry of the sediments to be dredged were sampled following a MNZ approved methodology (Golder Associates Ltd, 2013a). Four cores from eleven areas were tested for metals and TPH and three composite samples were tested for antifouling compounds (Figure 2.4). The concentrations of arsenic, cadmium and chromium were all below the ANZECC ISQG low guideline values. The concentration of mercury exceeded the ANZECC ISQG low guideline value of 0.15 mg/kg dry weight throughout the marina. The concentration of copper at the northern areas bounding the maintenance yard area (1, 2, 3, 4) exceeded the ANZECC ISQG low guideline value of 65 mg/kg dry weight but not the ANZECC ISQG high guideline value of 270 mg/kg dry weight. Copper concentrations were lowest in the areas 9, 10 and 11. The concentration of lead exceeded the ANZECC ISQG low guideline value of 50 mg/kg at sites 4 and 7. The concentration of nickel exceeded the ANZECC ISQG low guideline value of 21 mg/kg at sites 7, 9, 10 and 11. The concentration of tributyl tin in the composite samples exceeded the ANZECC ISQG low guideline value of 0.005 mg/kg dry weight. None of the samples tested exceeded the ANZECC ISQG high guideline values. TPHs were not detected in any of the sediment samples.

Previous (Golder Associates Ltd, 2010) elutriate testing of the Half Moon Bay Marina sediments showed that there was little measurable release of contaminants to seawater during disposal. The concentrations were below USEPA (2006) Criterion Maximum Concentration (CMC) for the protection of marine organisms.

Figure 2.4 Half Moon Bay Marina sediment core sample locations

2.2.5 Pine Harbour Marina

The benthic biological communities from sites within the Pine Harbour Marina basin sediments (Figure 2.5 A), bio-fouling organisms from the marina breakwaters and marina poles (Figure 2.5 B), and the chemistry of the sediments (Figure 2.5 C) to be dredged were sampled in November 2012 (Bioresearches, 2012) and February 2016 (Bioresearches, 2016), and from the access channel in June 2013 (Bioresearches, 2013) and February 2016 (Bioresearches, 2016), following a MNZ, EPA and MPI approved methodology.

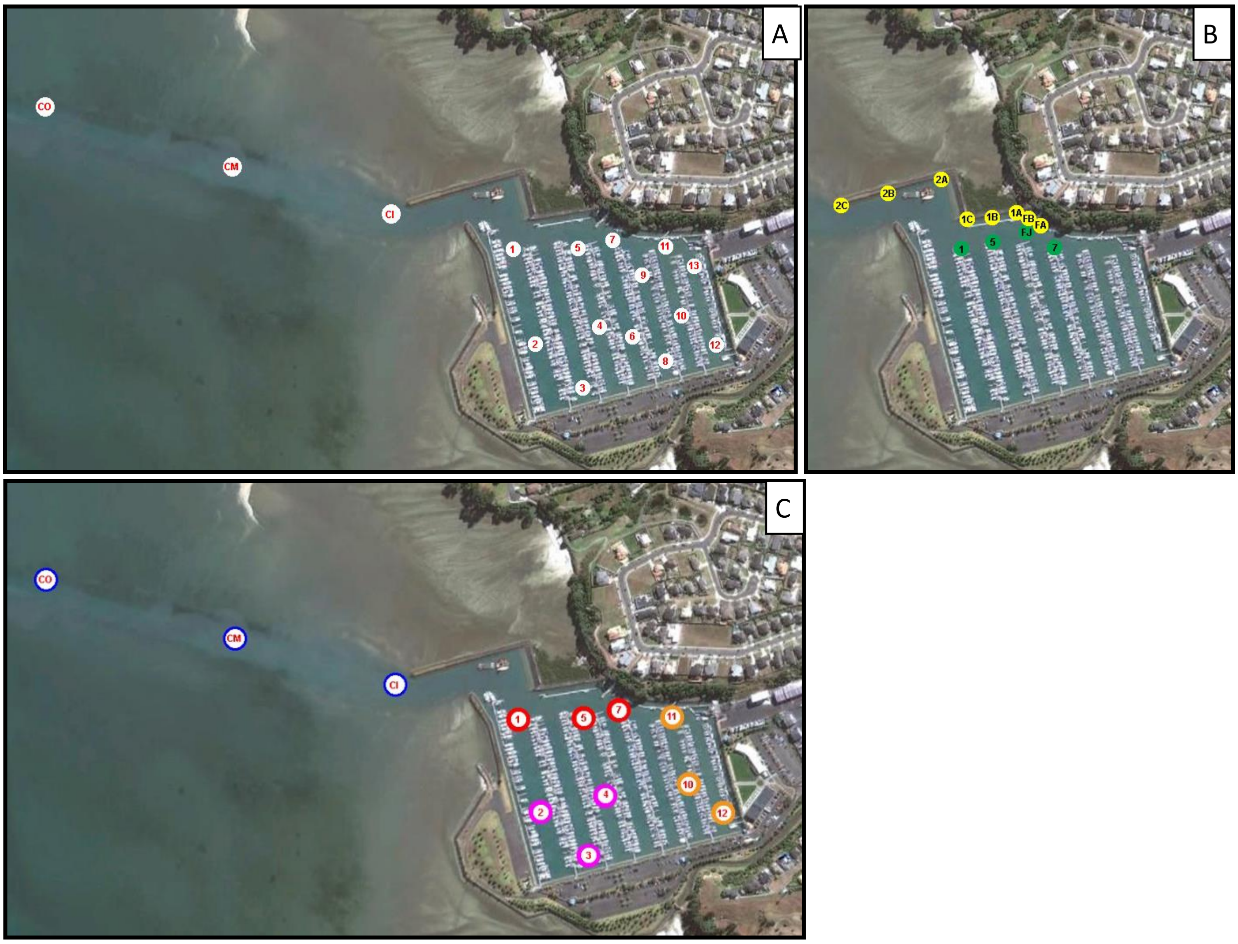


Figure 2.5 Marina Basin and Access Channel Sample Sites for Pre Dredging Study 2016, A. Benthic Biota, B. Fouling, C. Sediment Quality

Species composition consisted of organisms typically found in the Auckland region, in areas with slight to moderate contamination. In 2016, the biota was numerically dominated by polychaete worms in particular *Cossura consimilis*, *Heteromastus filiformis* and *Prionospio aucklandica* and the bivalve *Theora lubrica.* The bio fouling communities on the poles and walls were not particularly diverse when present, the Pacific oyster, *Crassostrea gigas* was the dominant species. Four non-indigenous species were found in the samples from the Pine Harbour Marina area. The non-indigenous species included two molluscs, *T. lubrica* and *C. gigas*, the polychaete worm, *Sabella spallanzanii*, and one bryozoan, *Watersipora arcuata*. The Mediterranean fan worm (*S. spallanzanii*) is only a recent arrival, (sometime between 2013 and 2016) in the Pine Harbour Marina despite its abundance in other areas of the Waitematā Harbour. All of these species are invasive, non-indigenous organisms, however, some are well-established in New Zealand waters and it is understood that there are no current control programmes operating for these species in Auckland. None of these species are expected to survive at the disposal site, however there is a small risk that larvae of some species could spread from a disposal event if the right conditions occurred.

Nine sediment sites were sampled with cores to the depth of dredging, and tested for contaminants from within the marina and additional three sites were sampled in the access channel. The concentrations of arsenic, cadmium, chromium, lead, mercury, nickel and zinc were all below the ANZECC ISQG low guideline values. The concentration of copper at the Inner sites (10, 11, 12) and Site 3 exceeded the ANZECC ISQG low guideline value of 65 mg/kg dry weight but not the ANZECC ISQG high guideline value of 270 mg/kg dry weight. Copper concentrations were lowest in the access channel. While the concentration of copper in samples from sites 3, 10, 11 and 12 are elevated above the ANZECC ISQG low value of 65 mg/kg dry weight, they would be diluted by other sediments dredged from the basin and access channel to an average concentration less than the ANZECC ISQG low. In addition, the elutriation results indicate copper is bound to the sediment and would not be released into the water column on disposal. Concentrations of all individual PAHs tested were below the ANZECC ISQG low guideline values. The concentrations of low and high molecular weight and total PAHs were all well below the ANZECC ISQG low guideline values. TPHs were not detected in any of the sediment samples.

2.2.6 Whitianga Marina

In July 2017, the benthic biological communities from sites within the marina basin sediments, bio-fouling organisms from the marina breakwaters and marina poles, and the chemistry of the sediments to be dredged, shown in Figure 2.6, were assessed following methodology approved by both EPA and MPI (Bioresearches, 2017b).

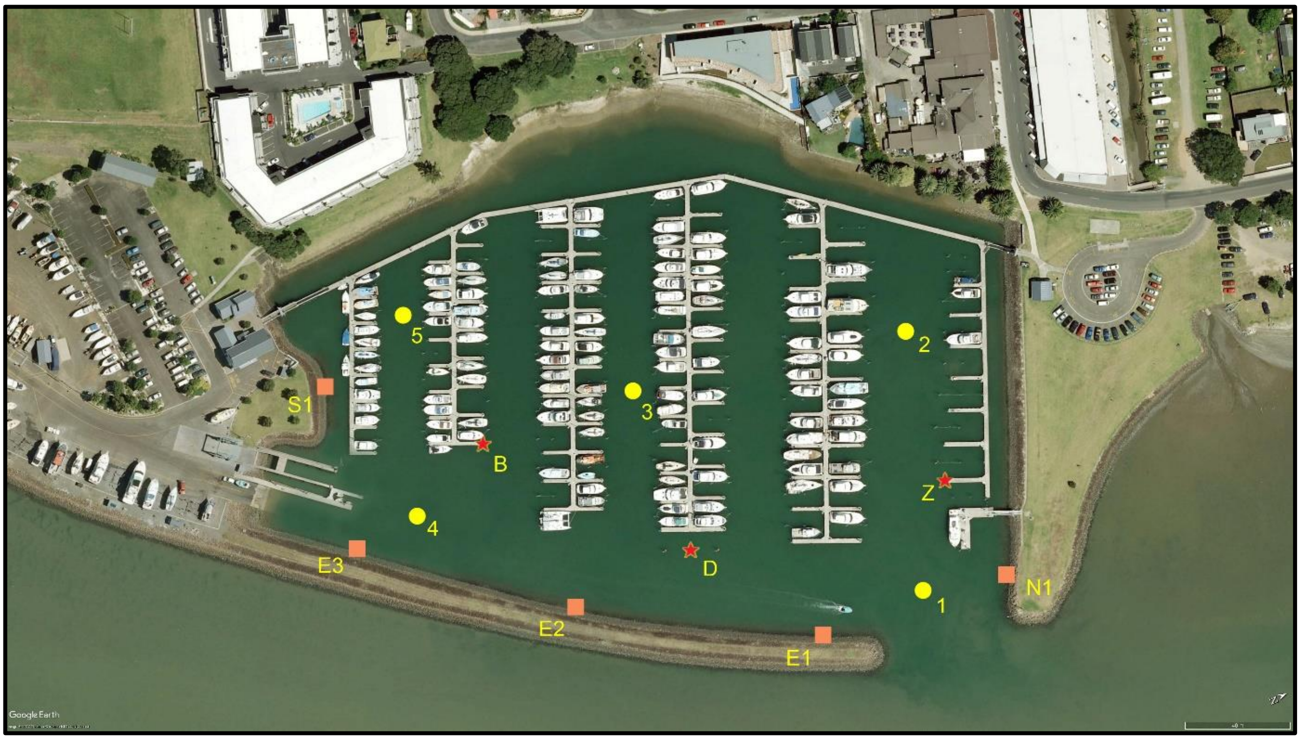


Figure 2.6 Sample Sites for Pre Dredging Study (bio-fouling marina breakwaters (■) and marina poles (★), benthic biota and sediment quality (●))

The benthic biological communities found in the marina basin sediments were generally not very diverse or abundant, the communities were numerically dominated by polychaete worms particularly *Cossura consimilis* and *Heteromastus filiformis* both of which are relatively tolerant of fine sediments. The concentrations of contaminants may have limited the abundance of some species of polychaete worms such as *Prionospio aucklandica*. Two non-indigenous species were found in the marina sediments; the bivalve *Theora lubrica* and the polychaete worm *Glycera americana*. Neither species was present in significant numbers with only 4 *Theora lubrica* recorded in the entrance and 2 *Glycera americana* recorded within the marina. Both species are considered to be well-established in New Zealand waters, and thus their distribution range will not be extended if accidentally released en route to the disposal site. Neither species are expected to survive at the disposal site, nor have they been detected in any samples from the disposal site.

The bio-fouling biological communities on the marina poles were very sparse, with low numbers of species and generally low numbers of individuals. The biological communities at low tide areas of the marina breakwater walls, were sparse but moderately diverse. The greatest diversity was recorded near the entrance to the marina. Only one non indigenous species was found in the encrusting communities in the marina; the Pacific oyster (*Crassostrea gigas*) on the rock walls. The oysters are well-established in New Zealand waters, and thus their distribution range will not be extended if accidentally released en route to the disposal site, nor are they expected to survive at the disposal site.

Sediment at sites in the inner part of the marine contained high proportions (75 - 100%) of silt and clay, while those at the entrance and between Z and E piers were significantly courser. The sediment in the inner marina area sites (2, 3, 4, 5) were described as Silt (Z), while the entrance site (1) was described as slightly gravelly muddy Sand ((g)mS).

The sediments within the Whitianga Marina basin showed arsenic concentrations within 25% of the ANZECC ISQG low guideline value of 20 mg/kg dry weight, but did not exceed it. Mercury exceeded the ANZECC ISQG low guideline value of 0.15 mg/kg dry weight at sites 3, 4 and 5 in the inner marina area. Elutriation testing showed that while only detectable quantities of arsenic were released into the water on disturbance, it is unlikely that adverse effects will result as water quality guideline values were not exceeded. Sediment quality studies (Bioresearches, 2014b) in estuaries on the Coromandel Peninsular have shown elevated concentrations of arsenic and mercury, which were attributed to natural sources, there is no evidence to suggest otherwise at Whitianga.

No other metals tested exceeded the ANZECC ISQG low guideline values. Individual polycyclic aromatic hydrocarbon compound concentrations were all less than the appropriate ANZECC ISQG low guidelines as were both low and high molecular weight PAHs and total PAH concentrations.

No tributyl tin compounds were detected within the sediment samples taken from the marina basin.

While the sediments from sites 3, 4 and 5 exceed the ANZECC ISQG low values for mercury the exceedence was relatively small and the volume of sediment to be dredged from the inner marina is expected be low in comparison to the dredged from the entrance area (Site 1) which has low concentrations of mercury. Thus, the sediments from the Whitianga Marina entrance and basin are of such a quality that the disposal of dredged sediment at sea is unlikely to result in adverse biological effects as a result of contaminants in the sediment.

2.3 Quantities

Between the approval of the MNZ disposal permit 568 and 1 April 2018, a total of 199,800 m^3 of sediment has been disposed at the Northern Disposal Area. Table 2.7 summarises the volumes of sediment disposed from each source site over time.

Table 2.7 Disposal volumes at the Northern Disposal Area

Year	Site	m^3
2013	Pine Harbour Marina	10,157
2013	Half Moon Bay Marina	6,000
2014	Pine Harbour Marina	4,800
2014	Sandspit	3,500
2015	Sandspit	102,595
2016	Sandspit	800
2016	Pine Harbour Marina	12,202
2016	Hobsonville Marina	9,744
2017	Hobsonville Marina	1,391
2017	Pine Harbour Marina	7,162
2017	Hobsonville Point	29,740
2017	Whitianga Marina	2,652
2018	Pine Harbour Marina	3,130
2018	Hobsonville Marina	5,927

2.4 Sediment type

Sediment particle size information varies in detail between the source site assessments. Sediment from within Pine Harbour Marina, Half Moon Bay Marina, Sandspit Marina and Whitianga Marina were generally dominated by muds with varying degrees of sand and gravel sized particles. The sediments in the access channel at Pine Harbour Marina and the area at Hobsonville Point were sandy with smaller proportions of gravel and mud. Sediments in Hobsonville Marina were mostly silt sized with some sand. When the volume of sediment disposed is taken into account from each source site, the average sediment particle size has been gravelly Mud, with approximately 6% gravel, 39% sand and 55% silt and clay.

Some of the deeper sediments from Sandspit Marina were cohesive clay that would remain as the lumps it was dug up in, whereas the other sediments were significantly less cohesive and would have mixed together as a thick liquid during and after dredging.

2.5 Chemical Characterisation

As summarised above in the origin site summaries, the chemical composition of the source sites varies considerably. In order to obtain an approximate average concentration of contaminants in the material disposed prior to the disposal site monitoring events, the average concentrations of contaminants per source sites have been weighted based on volume disposed. Volume weighted average concentrations have been calculated for the cumulative disposal volumes of 50,000 m^3, 100,000 m^3, 150,000 m^3 and 200,000 m^3 to coincide with the volumes disposed prior to the disposal site monitoring studies (Table 2.8).

Table 2.8 Volume Weighted Average Concentrations of Contaminants in Disposal Sediments.

	Year	2015	2015	2016	2018	ANZECC	
	Monitoring	50K	100K	150K	200K		
	Volume m³	50000	100000	149798	199800	Low	High
Dry Matter	g/100g	58.5	63.6	61.5	51.1		
Total Organic Carbon	g/100g dry wt	0.88	0.66	0.74	0.84		
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg							
Total Recoverable Arsenic	mg/kg dry wt	6.0	5.1	5.6	7.0	20	70
Total Recoverable Cadmium	mg/kg dry wt	0.048	0.042	0.043	0.050	1.5	10
Total Recoverable Chromium	mg/kg dry wt	25.0	24.4	24.7	22.9	80	370
Total Recoverable Copper	mg/kg dry wt	30.3	20.6	24.1	23.3	65	270
Total Recoverable Lead	mg/kg dry wt	12.3	8.8	10.2	12.9	50	220
Total Recoverable Mercury	mg/kg dry wt	0.069	0.048	0.052	0.083	0.15	1
Total Recoverable Nickel	mg/kg dry wt	10.6	9.9	9.9	9.3	21	52
Total Recoverable Zinc	mg/kg dry wt	60.2	45.6	50.9	56.0	200	410
Tributyl Tin (1% TOC)							
Tributyltin	µg/kg dry wt	<10.6	<10.9	<10.2	<10.0	9#	70#
Polycyclic Aromatic Hydrocarbons Trace in Soil (1% TOC)							
Low Molecular Weight PAHs *	µg/kg dry wt	<39.2	<51.0	<49.8	<41.0	552	3160
High Molecular Weight PAHs *	µg/kg dry wt	<41.8	<54.3	<61.7	<54.4	1700	9600
Total PAHs *	µg/kg dry wt	<80.9	<105.3	<111.6	<95.4	4000	45000
Total Petroleum Hydrocarbons in Soil, GC							
Total hydrocarbons (C7 - C36)	mg/kg dry wt	<81.4	<75.7	<105.6	<99.6	280#	550#

* = normalised to 1 % total organic carbon, # = revised guideline as per Simpson, *et al*. (2013) < = Concentrations are averages of a number of concentrations the < indicates some or all of the raw concentrations were less than the detection limit as reported by the laboratory in the individual site reports.

For example, the first 50,000 m³ disposed included spoil from Pine Harbour Marina (PHM) in 2013, Halfmoon Bay Marina (HMB) in 2013, Pine Harbour Marina in 2014, and Sandspit Marina in 2014 and 2015. For copper the average concentration of all the samples collected from each site was calculated for each site. For Pine Harbour Marina and Halfmoon Bay Marina all the sediment dredged was included in the 50,000 m³ disposed, therefore the average concentrations were multiplied by the volume dredged from each site. Monitoring at the disposal site was conducted part way though the disposal of material from Sandspit Marina, therefore the average concentration from the Sandspit marina samples was multiplied by the volume disposed from the site, as calculated by, 50,000 – sum of volumes from Pine Harbour Marina and Halfmoon Bay Marina. The weighted average concentration was then calculated by summing site average x volume values and dividing by the total volume disposed (50,000), resulting in a volume weighted average copper concentration of 30.3 mg/kg (Table 2.9).

Table 2.9 Example volume weight average calculations

Year	2013	2013	2014	2014	2015	2013	2013	2014	2014	2015	2015	ANZECC	
Site	PHM	HMB	PHM	Sandspit	Sandspit	PHM	HMB	PHM	Sandspit	Sandspit	50K		
Volume (v)	10157	6000	4800	3500	102595	10157	6000	4800	3500	25543	V= 50000	Low	High
	Site average (x)					Site average * volume (v)					$\frac{\sum(x * v)}{V}$		
Copper	62.8	87.0	7.4	11.0	11.0	637634	522000	35520	38500	280973	30.3	65	270

Despite the sediment characterisations at;

- Half Moon Bay Marina in 2013 recording an average concentration of copper, mercury and tributyl tin greater than the ANZECC ISQG low trigger values,

- Pine Harbour Marina in 2016 recording an average concentration of copper and TPHs greater than the ANZECC ISQG low trigger values,
- Hobsonville Point in 2016 recording an average concentration of mercury greater than the ANZECC ISQG low trigger value,

only the weighted average concentrations of tributyl tin showed exceedances of the modified ANZECC ISQG low trigger value of 9.0 µg/kg dry weight. However, the majority of the concentrations of tributyl tin recorded in the individual samples were less than the method detection limits, so actual average values are likely to be much less.

2.6 Biological Characterisation

As summarised above in the origin site summaries, each source site has a slightly different composition of biological communities. However, in general, soft sediment from marina basins were dominated by polychaete worms and the bivalve, *Theora lubrica.* The bio fouling communities on the poles and walls were not particularly diverse, and when present the Pacific oyster, *Crassostrea gigas* was the dominant species. All Auckland marinas now have the non-indigenous bivalves *T. lubrica*, *C. gigas*, and the polychaete worm *Sabella spallanzanii* present in them. In addition, the bryozoan, *Watersipora arcuata,* Asian paddle carb, *Charybdis japonica*, Clubbed sea squirt, *Styela clava* and the Asian date mussel, *Arcuatula senhousia* have been recorded in at least one of the Auckland marina source sites. The Sandspit Marina source site was a little different to the other sources sites in that it was located outside of the Waitematā Harbour and was an undeveloped marina site. The site contained both intertidal and subtidal habitats and the number of non-indigenous species found included, the bivalve, *T. lubrica* and *C. gigas*, the polychaete worm, *Glycera americana*, the Asian paddle crab, *C. japonica* and the Australian drop tunicate, *Eudistoma elongatum*.

All of these species are invasive, non-indigenous organisms, however, they range in how well-established in New Zealand waters they are from restricted to isolated areas to being well established throughout New Zealand. There are no current eradication / control programmes operating for these species in Auckland. None of these species are expected to survive smothering by sediment when dredged or at the significantly deeper (140 m) disposal site. The Sandspit source site was the only site which undertook additional controls to prevent the transport of non-indigenous organisms. On site management of the dredging and disposal allowed the dredged sediment to sit on land for 7-10 days prior to being loaded on the disposal barge, further reducing the risks posed by *Charybdis* or *Eudistoma* during the transport and disposal of the spoil. Similar on site management options are not available at established working marinas. Alternative treatment to eliminate invasive species from each barge load of dredge spoil by chemicals or heat, either introduce additional pollutants or are unworkable, ineffective, costly and mostly untested.

3. SITE DESCRIPTION

In order to maintain a satisfactory level of monitoring required under the London Convention, the disposal site needs to be located in water depths that seabed is largely undisturbed by wave action, but not too deep that sampling of the seabed is made impractical. As such the continued use of the NDA is significantly more practical and economic than the AEDG site.

3.1 Location

The Northern Disposal Area site is located approximately 25 km east of Great Barrier Island, directly north of Cuvier Island (Figure 3.1), outside the territorial seas located in the EEZ and defined as a 1,500 m radius circle centred on 36° 12.3403'S and 175° 48.002'E.

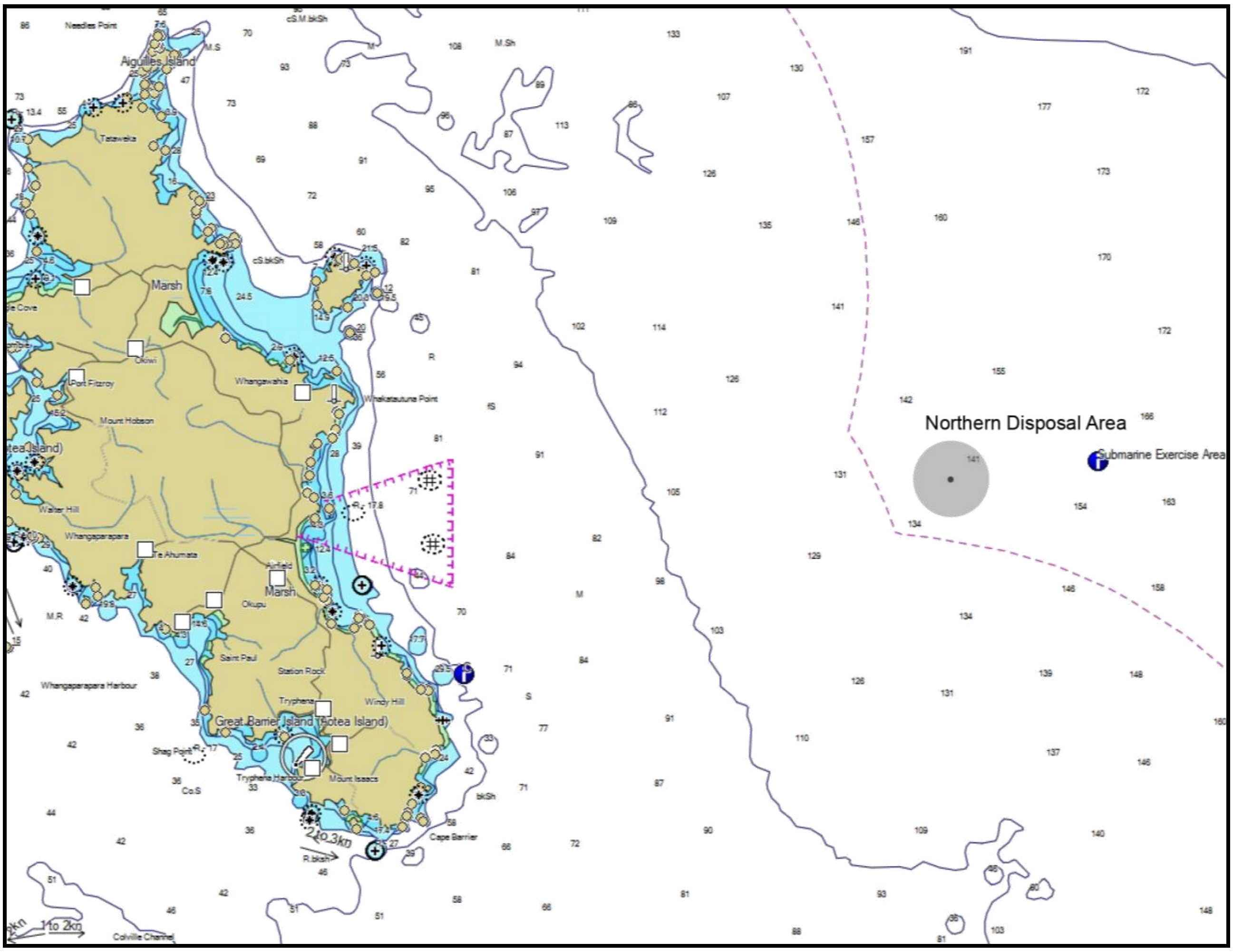


Figure 3.1 Location of the Northern Disposal Area.

3.2 Current Sediment Quality

The previously disposed sediment was visually obvious in the cores (Appendix 3) from the disposal centre site and at 100 m and the E and W 250 m cores. The sediment was softer and darker allowing for greater penetration of the corer than at the more distant sites. The lack of a base layer at the disposal centre site and 100 m sites prevents the determination of the thickness of disposed sediment layer on top of the original seabed sediment. Additional single core samples were collect at the 250 m compass points. These show that the layer of darker material, presumably disposal sediments, was present at the W and E cores ranging between 158 mm and 195 mm depth, with an average depth of 77 mm at cores from N and S. While there was, what appeared to be a mottled bioturbated surface layer in the cores from 500 m and beyond in the disposal area, this was present at the Control sites, indicating it is natural and not disposal related.

Particle size at the disposal centre site was statistically finer than the other disposal area and the Control sites, as a result of the disposal of fine sediments. The disposal centre site had approximately 20% less sand, 6% more silt and 13% more clay than the surrounding sites. Sediments at all sites were classified as sZ, slightly sandy Silt. All sites had sediments, which were poorly sorted and strongly fine skewed, with the exception of the disposal centre site, which was poorly sorted and strongly coarse skewed.

The concentrations of all contaminants measured were below the ANZECC ISQG's where available. The presence of previously disposed sediments was reflected in the concentrations of arsenic, copper, lead, mercury and zinc were elevated at the disposal centre site in comparison with the other disposal area sites and control sites, while concentrations of dry matter, cadmium, chromium and nickel were similar or lower. No total petroleum hydrocarbons were detected with or around the disposal area. Redox, pH, dissolved oxygen and salinity were not analysed in sediments from the disposal area. While total organic carbon (TOC) was analysed in the pre dredge sediments it was not analysed at in the disposal site samples. This was due to the pre dredging samples requiring TOC to standardise the organic compounds analysed for comparison with the guidelines, and no organic compounds requiring standardisation being analysed in the disposal area.

3.3 Sediment Quality History

Under MNZ permit 555, 4,800 m^3 of sediment from Pine Harbour Marina was disposed of at the NDA during March and April 2010 as a test, prior to the granting of a longer term permit (permit 568 now EEZ900012). The seabed sediment quality was assessed prior to and following the test disposal. Under EPA consent EEZ900012 as of 1 April 2018, a volume of 199,800 m^3 had been disposed at the NDA. The consent has required monitoring of sediment quality after 10,000 m^3 (Bioresearches, 2013a), 50,000 m^3 (Bioresearches, 2015), 100,000 m^3 (Bioresearches, 2015a), 150,000 m^3 (Bioresearches, 2017a) and 200,000 m^3 (Bioresearches, in press) had been disposed.

Disposal trials undertaken with MNZ Permit 555 reported sediment particle size data pre and post-test disposal from 21 sites ranging in distance and direction from the disposal point (Figure 3.2 & Table 8.5). This data showed that within sites there was variation in the results obtained between pre and post-test disposal, even at sites distant from the disposal point and not expected to be effected by the test disposal. Disposal trials undertaken with MNZ Permit 555 undertook elutriation of the sediments from the disposal site after 4,800 m^3 of sediment were deposited in the area. These results showed that the contaminants present in the dredge spoil were not mobilised once within the disposal site. Therefore, it was predicted that any dispersal and concentration of contaminants will be due to the physical movement of the sediment clasts to which they are bound. This is most likely to occur due to sediment transport preferentially sorting fine sediment into a surficial layer. Based on the available data, it was predicted that most transport is likely to occur as the near-bed density flow erodes and transports surficial sediment close to the impact point on the seabed. The limited data collected during the trials indicated that this process diluted the contaminants.

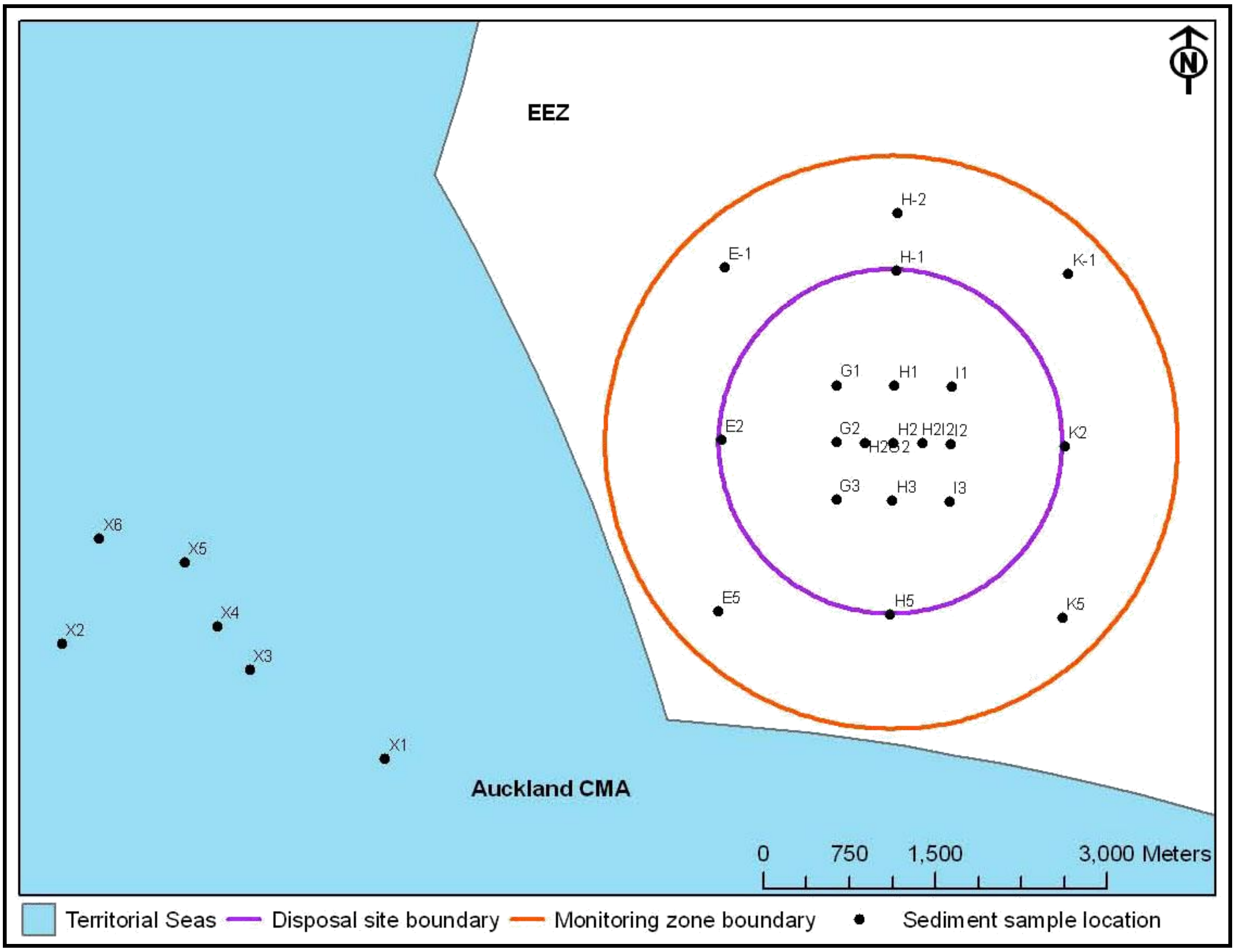


Figure 3.2 Locations where sediment cores were collected before and after disposal of 4,800 m^3 of dredged material.

The EPA consent EEZ900012 requires analysis of sediments on axes throughout the Disposal Area with a minimum of thirteen sampling sites and a control site included. Monitoring was also required at four sites midway between the sites on the boundary (i.e. the sites beyond the boundary should be in a NE, SE, SW and NW direction from the site centre) at a distance of 250 m beyond the Disposal Area boundary. Thus, sixteen sample sites within and around the disposal area were sampled and an additional three control site samples were collected from 2500 m south of the disposal centre site, as shown in Figure 3.3.

Each sample site was located using pre-determined GPS points, and the boat “anchored” with dynamic positioning. A gravity corer attached by rope was then allowed to fall to the seabed and retrieved by winch. At each sampling site, two 70 mm diameter clear barrel cores were taken using a gravity corer with sufficient mass to achieve at least 100-150 mm penetration. On retrieval of the core barrels, the bottom was sealed and the cores photographed with a label and scale to show layers in the sediment collected. The top 50 mm from both cores at the required sites were combined, homogenised and 50 g sub-sampled for grain size with remainder used for sediment chemistry. All samples were double bagged in clean zip lock plastic bags with a waterproof label between the two bags, and chilled for transport.

The sediment was analysed for particle size by the University of Waikato using a Malvern Laser Sizer particle size analyser. The sediment was analysed for total recoverable metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc) in the total sediment fraction, and for TPH by Hill Laboratories.

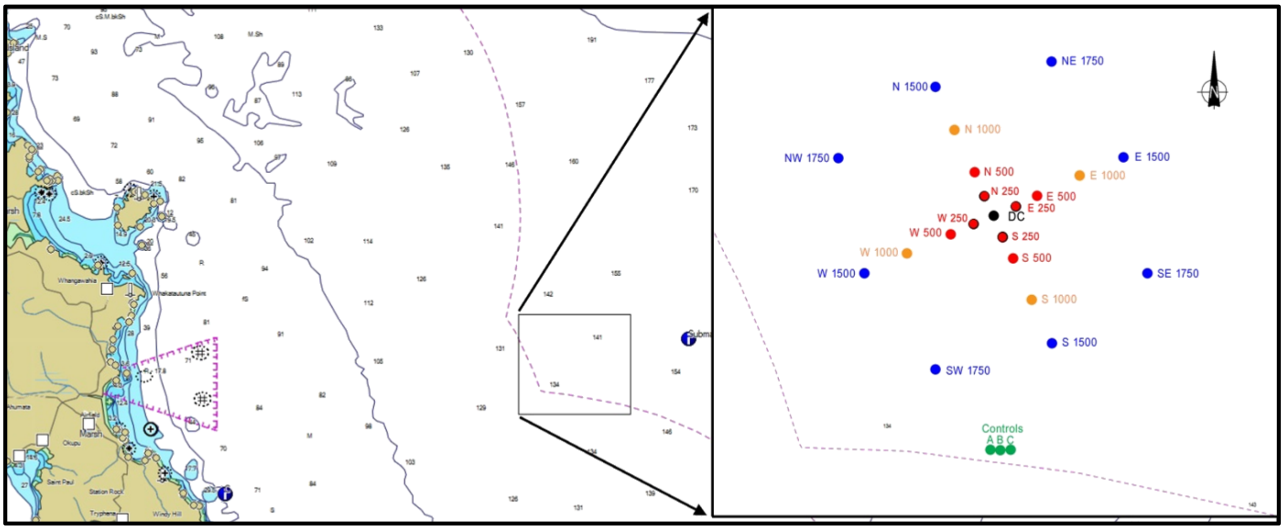


Figure 3.3 Seabed Sediment Quality Sampling Sites required by EEZ900012.

As a result of the elevated concentrations of nickel found in the surficial sediments at the Disposal Centre site in August 2013 (post 10,000 m^3), MNZ requested that three replicate samples of surficial sediment were collected at the Disposal Centre site and at 250 m on the key compass points, with the aim of quantifying the extent of the nickel rich surficial sediments. Therefore, three replicate samples were collected in December 2013 at the Disposal Centre, and four new sites at N250, E250, S250 and W250.

In August 2015 following the disposal of 100,000 m^3 of dredge spoil, four additional single core samples were collected at the 250 m N, E, W, S. On retrieval of the core barrels, the bottom was sealed and the cores photographed with a label and scale to show layers in the collected sediment. Similarly, in November 2016 following the disposal of 150,000 m^3 of dredge spoil, eight additional single core samples were collected at the 100 m N, S, 250 m N, E, W, S and 375 m N, S. On retrieval of the core barrels, the bottom was sealed and the cores photographed with a label and scale to show layers in the collected sediment.

3.3.1 Sediment Cores

After the disposal of 10,000 m^3, the sediment disposed of was obvious in the cores at the disposal centre site (Table 8.1). The sediment was softer and darker allowing for greater penetration of the corer. In August 2013 there was a layer of approximately 275 mm of disposed sediment on top of the original seabed sediment at the disposal site. In the subsequent additional sampling in December 2013, the maximum core depth was 319 mm, however, the corer did not penetrate far enough to reach the natural seabed sediment. This indicates that at least 50 mm of fresh sediment has been deposited between August 2013 and December 2013.

In August 2013, there was no darker disposal sediment on the surface of the seabed obvious at any of the sites other than the disposal centre site, indicating that disposal sediment had not spread far from its point of disposal. In December 2013, there was some indication that the disposed sediment had spread east, resulting in what appeared to be a 10 mm thick layer at the E 250 site. None of the other 250 m sites showed any visible indications of disposal sediment spreading.

Sediments in the disposal area beyond the 250 m radius and at the control sites were of similar density as shown by the similar depths of core penetration. The zone of surface mixing was similar throughout the study sites with the exception of the disposal site which had no obvious mixed layer. The lack of mixed layer at the disposal site is expected due to the continued addition of sediments via disposal events.

Following the disposal of 50,000 m^3, the disposed sediment was again obvious in the cores at the disposal centre site (Table 8.2). The cores did not penetrate far enough to determine the thickness of disposed sediment layer on top of the original seabed sediment. No cores were collected at the 250 m sites and the disposal sediment was not present in the 500 m cores.

Following the disposal of 100,000 m^3, sampling at the disposal centre site was not possible. This was likely the result of recent coarse material being disposed preventing the core from penetrating the seabed. The disposed sediment was visually obvious in the core nearest the disposal centre site (Table 8.3). At 250 m, a layer of darker material, presumably disposal sediments, was present ranging between 77 and 98 mm depth. Darker material on the surface of the cores at W 500 and W 1000 appears similar to the material at 250 m sites and may indicate disposal material. Given that this direction of spread is up slope and at a depth not expected to be effected by wave action, the distribution is likely to be the result of depositional conditions or location. No evidence of this layer was present in the cores from 500 m and beyond in the disposal area in the other directions.

Following the disposal of 150,000 m^3, the disposed sediment is visually obvious in the cores from the disposal centre site and at 100 m and the E and W 250 m cores (Table 8.4). The lack of a base layer at the disposal centre site and 100 m sites prevents the determination of the thickness of disposed sediment layer on top of the original seabed sediment. Additional single core samples were collected at the 250 m compass points. These show that the layer of darker material, presumably disposal sediments, is present at the W and E cores ranging between 158 mm and 195 mm depth, with an average depth of 77 mm at cores from N and S. No disposal sediments were present at 375 m N or S, or at any of the 500 m and beyond sites.

There is no evidence indicating that disposed sediment, once on the seabed, is spreading far from its point of disposal. The east west elongation of the disposal mound is likely to be the result of the direction of barge approach and minor variations in the timing and location of discharge, rather than a spread of the material once it has reach the seabed.

The sampling technique used is sufficient to detect layers of disposal sediments between approximately 30 and 150 mm. The collection of more than one disposal material thickness layer value along a compass bearing will allow mound slope to be calculated.

3.3.2 Sediment Particle Size

Following the disposal of 10,000 m^3, the particle size at the disposal centre site was finer than the other disposal area and control sites (Table 8.6). The particle size distributions at the 500 m, 1000 m, 1500 m, 1750 m and the control sites are all very similar, indicating background natural conditions. Sediment at all sites was classified as sZ, sandy Silt. There was no evidence indicating that disposed sediment, once on the seabed, had spread far from its point of disposal.

Following the disposal of 50,000 m^3, the particle size at the disposal centre site was coarser than the other disposal area and control sites (Table 8.7). The disposal site had approximately 20% more sand and approximately 20% less silt than the surrounding sites. The particle size distributions at the 500 m, 1000 m, 1500 m, 1750 m and the control sites are all very similar, indicating back ground natural conditions. Sediment at the disposal site was classified as mS, slightly muddy Sand, whereas the other sites were all classified as sZ, sandy Silt. Again, this indicates that sediment disposed of had not spread far from where it was deposited.

Following the disposal of 100,000 m^3, the particle size at the disposal centre site was coarser than the other disposal area and control sites (Table 8.8). The disposal site had approximately 20% more sand and approximately 20% less silt than the surrounding sites. The particle size distributions at the 500 m, 1000 m, 1500 m, 1750 m and the control sites are all very similar, indicating back ground natural conditions. However, the W 500 sample site showed greater differences than other sites, with a greater percentage of sand and clay, and less silt that other 500 m sites and sites beyond. This, linked with the darker material noted in the sediment cores, indicates some disposal material has been deposited at W 500. Since W 500 is upslope from the disposal site the material is likely the result of variability in the location of disposal, and not from the movement of previously disposed sediment on the seabed. Sediment at the disposal centre site was classified as mS, slightly muddy Sand. Whereas the other sites were all classified as sZ, sandy Silt, with one exception. W 1500 had a very small gravel component, possibly a piece of shell, resulting in a classification of (g)sM, slightly gravelly sandy Mud.

Following the disposal of 150,000 m^3, the particle size at the disposal centre site was statistically finer (Table 8.9, Figure 3.4) than the other disposal area and the control sites. The disposal centre site had approximately 20% less sand (●), approximately 6% more silt (●) and 13% more clay (●) than the surrounding sites. The sediments at all sites were classified as sZ, sandy Silt. Note in Figure 3.4 the dotes above the 500, 1000, 1500, 1750 are the average of four compass point sites at this radius from the disposal centre point. The N, E, W, S show the individual site values in relation to the radius average, in an attempt to show any directional trends. Similarly the control is an average of three sites. The DC sample point is a single sample point, hence no N, E, W, S points.

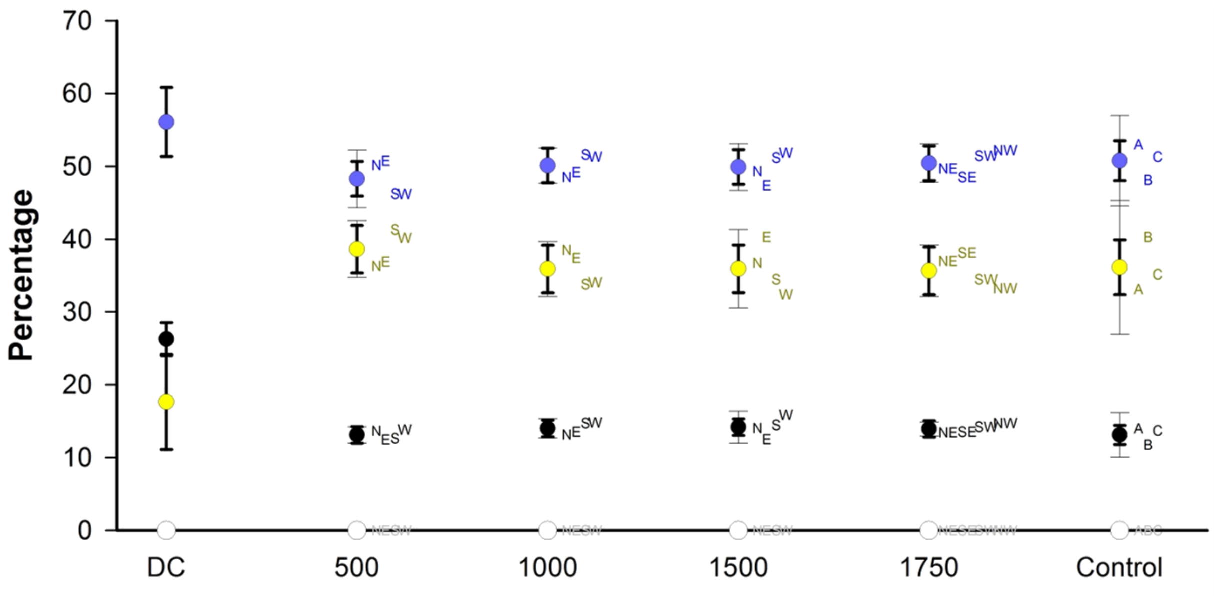


Figure 3.4 Particle Size Class Comparison with Distance from Disposal Centre Site (DC), After 150,000 m^3 Sediment Disposal. (○ Gravel, ● Sand, ● Silt, ● Clay, N, E, S, W = individual sites) (± 95% CI ⌶ and ± $HSI_{0.05}$ **I**)

The honest significant interval (HSI) error bar is a graphical representation of statistical difference (Andrews, *et al.*, 1980). HSI differs from the 95% confidence interval in that if the HSI error bars overlap there is no statistically significant difference, and if they do not overlap then there is a statistically significant difference between the two means. The 95% confidence interval has no such relationship with statistical significant difference, rather it shows the spread of data points around the average. The lack of statistically significant differences between the control site and 500 m, 1000 m, 1500 m, and 1750 m radius sample sites, indicates that sediment disposed of has not spread far from where it was deposited. Based on particle size data there was no evidence to suggest that disposal material has spread from the disposal centre site to the 500 m sites or beyond.

3.3.2.1 Changes Over Time

The percentages of sand sized particles have varied statistically significantly at the disposal centre site over time (Figure 3.5, Table 8.10). These changes are reflective of the variability in the quality characteristics of the source sediment disposed in the months prior to sampling (Table 3.1 and shown in Figure 3.5 as colour coded ★ symbols). The statistical tests indicate that the percentage of sand sized particles varies statistically significantly over time but not between sites, however the changes over time are different at different sites (Table 8.10).

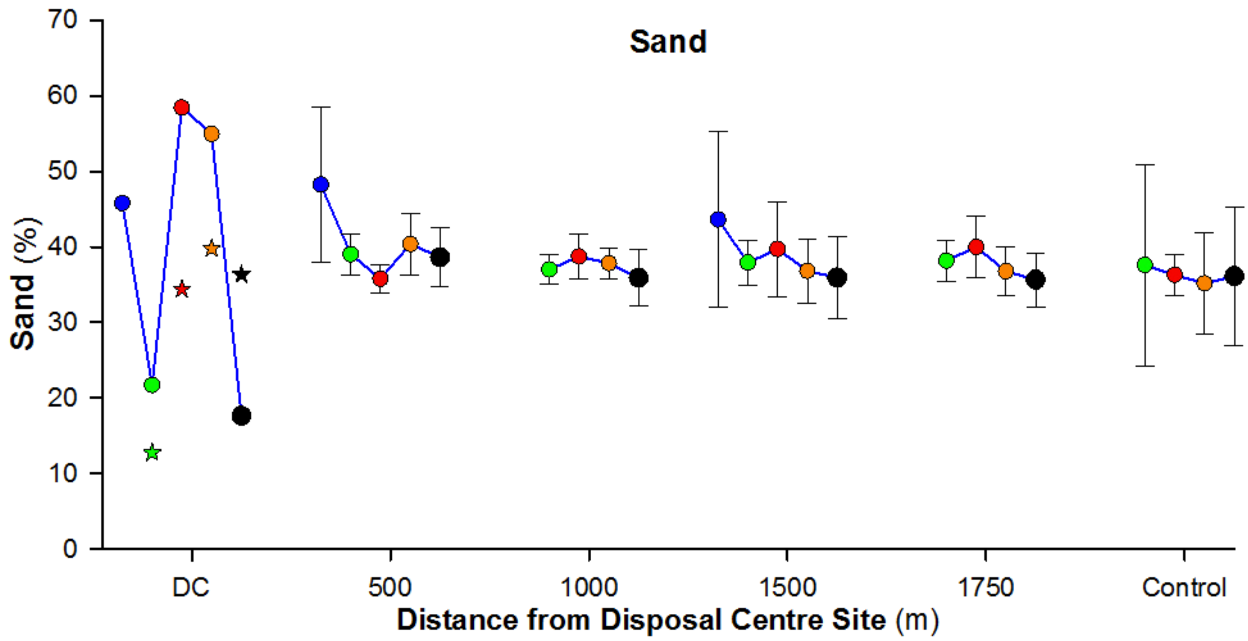


Figure 3.5 Comparison of the percentage of Sand sized particles with Distance from Disposal Centre Site (DC) and Over Time (± 95% CI Ɪ, **● Pre, ● 10k, ● 50k, ● 100k, ● 150k).**

Table 3.1 Average Percentages of Sediment Particle Size Classes in Disposal Sediments Prior To Disposal Monitoring Events

	Year	2013	2014	2015	2016
	Site	Pine Harbour Marina	Sandspit	Sandspit	Hobsonville Marina
	m^3	10,000	50,000	100,000	150,000
Gravel	%	8.64	7.06	8.01	7.02
Sand	%	12.74	34.38	39.76	36.31
Silt	%	29.12	26.36	24.10	27.34
Clay	%	49.51	32.20	28.14	29.33

The average percentage of sand sized particles has decreased over time between the 10,000 m^3 and 150,000 m^3 samples from the 500 m, 1000 m, 1500 m, 1750 m and the control sites, however these decreases were not statistically significant. No statistically significant changes occurred within each site (500 m, 1000 m, 1500 m, 1750 m and the control sites) over time. The lack of significant changes over time indicates no spread of disposal material has occurred as the disposal material varied over time and significant differences were recorded at the disposal centre site.

The pre disposal values are not directly comparable with the post disposal sampling as different sampling locations used and the sampling technique was slightly different, in that the total core depth was tested pre disposal as opposed to the top 5 cm of sediment in the post disposal sampling. Despite this, the pre disposal percentage of sand was largely similar to post disposal percentage at all but the disposal centre site, as expected.

To allow the statistical tests conducted above samples from each compass point were grouped by radius, this has the potential to mask finer geographical differences. Figure 3.8 shows each individual sample result graphically along with trends overtime. The blue trend lines do not show any ecologically significant changes in the percentage of sand over time for any sample site. The Disposal Centre site shows the greatest changes overtime reflective of the changes in disposal material quality, these changes are not displayed consistently in any of the other sample site. Visually the percentage of sand is higher than expected at site 500 W in August 2015 following the disposal of 100,000 m^3.

The percentages of silt sized particles have varied statistically significantly at the disposal centre site over time (Figure 3.6, Table 8.11). These changes are not particularly reflective of the variability in the quality characteristics of the source sediment disposed in the months prior to sampling (Table 3.1 and shown in Figure 3.6 as colour coded ★ symbols). The statistical tests indicate that the percentage of silt sized particles varies statistically significantly over time and between sites, however the changes over time are different at different sites (Table 8.11).

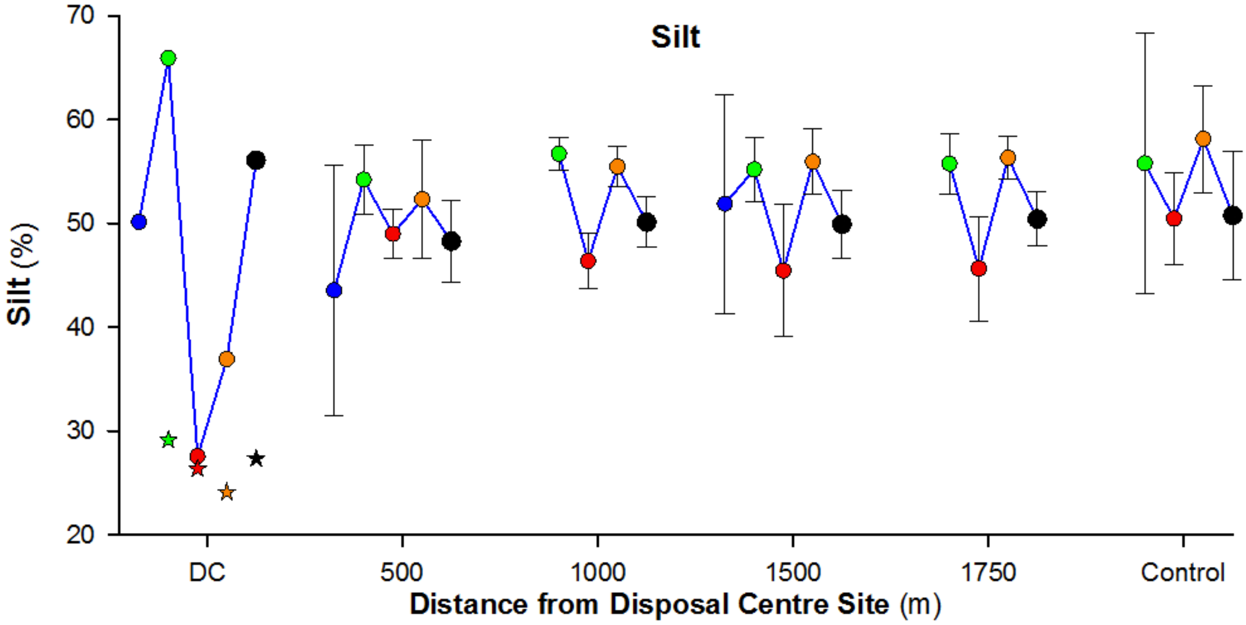


Figure 3.6 Comparison of the percentage of Silt sized particles with Distance from Disposal Centre Site (DC) and Over Time (± 95% CI Ɪ, **● Pre, ● 10k, ● 50k, ● 100k, ● 150k)**

The average percentage of silt sized particles has decreased statistically significantly over time between the 10,000 m^3 and 150,000 m^3 samples from the 500 m, 1000 m, 1500 m, 1750 m and the control sites. The statistically significantly decreases in silt content at the distant monitoring sites, compared with the variable silt content at the disposal centre site and the general lack of statistically significant differences between the control sites and the distant monitoring sites, indicates no detectable spread of silt sized particles from the disposal material has occurred.

The pre disposal values are not directly comparable with the post disposal sampling as different sampling locations used and the sampling technique was slightly different, in that the total core depth was tested pre disposal as opposed to the top 50 mm of sediment in the post disposal sampling. Despite this, the pre disposal percentage of silt was largely similar to post disposal percentage at all but the disposal centre site, as expected.

To allow the statistical tests conducted above samples from each compass point were grouped by radius, this has the potential to mask finer geographical differences. Figure 3.9 shows each individual sample result graphically along with trends overtime. The blue trend lines show decreases in the percentage of silt over time for all sample sites. The Disposal Centre site shows the greatest changes overtime reflective of the changes in disposal material quality, these changes are not displayed consistently in any of the other sample site. With the exception of the Disposal centre site the sample sites follow the trends shown at the Control site. Visually the percentage of silt is lower than expected at site 500 W in August 2015 following the disposal of 100,000 m^3.

The percentages of clay sized particles have varied statistically significantly at the disposal centre site over time (Figure 3.7, Table 8.12). These changes are not particularly reflective of the variability in the quality characteristics of the source sediment disposed in the months prior to sampling (Table 3.1 and shown in Figure 3.7 as colour coded ★ symbols). The statistical tests indicate that the percentage of clay sized particles varies statistically significantly over time and between sites, however the changes over time are different at different sites (Table 8.12).

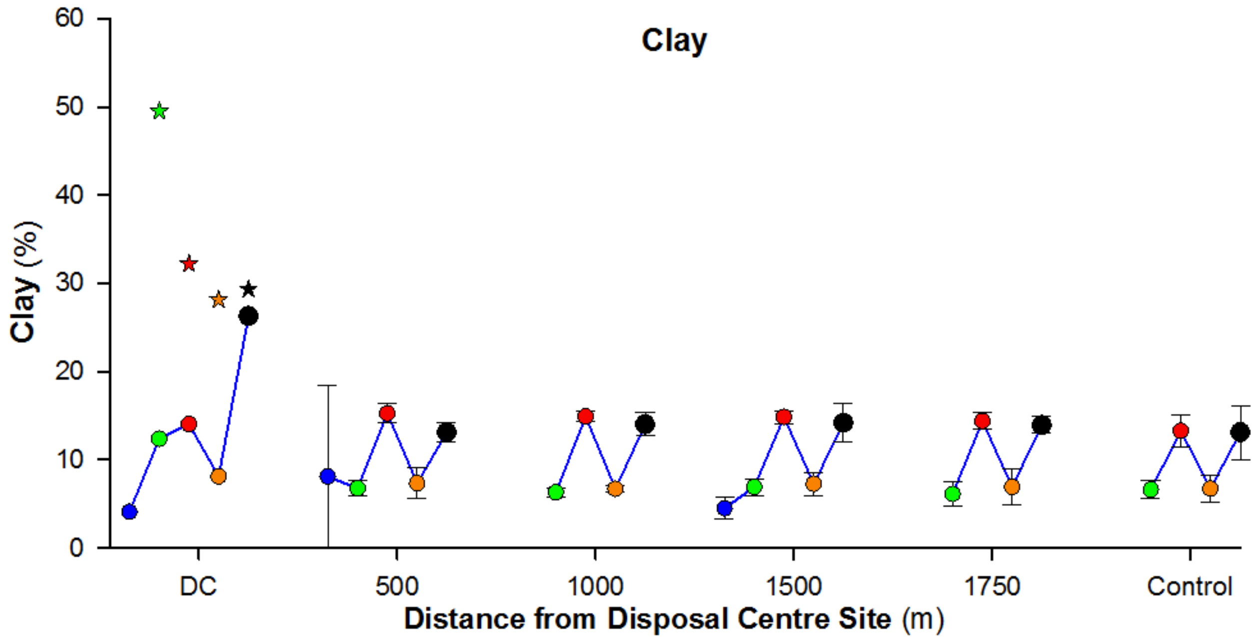


Figure 3.7 Comparison of the percentage of Clay sized particles with Distance from Disposal Centre Site (DC) and Over Time (± 95% CI Ɪ, ● **Pre,** ● **10k,** ● **50k,** ● **100k,** ● **150k)**

The average percentage of clay sized particles has increased statistically significantly over time between the 10,000 m^3 and 150,000 m^3 samples from the 500 m, 1000 m, 1500 m, 1750 m and the control sites. The statistically significantly increases in clay content at the distant monitoring sites, compared with the more variable clay content at the disposal centre site and the general lack of statistically significant differences between the control sites and the distant monitoring sites, indicates that no detectable spread of clay sized particles from the disposal material has occurred.

The pre disposal values are not directly comparable with the post disposal sampling as different sampling locations used and the sampling technique was slightly different, in that the total core depth was tested pre disposal as opposed to the top 5 cm of sediment in the post disposal sampling. Despite this, the pre disposal percentage of clay was largely similar or slightly less than post disposal percentage at all sites.

To allow the statistical tests conducted above samples from each compass point were grouped by radius, this has the potential to mask finer geographical differences. Figure 3.10 shows each individual sample result graphically along with trends overtime. The blue trend lines show decreases in the percentage of clay over time for all sample sites. The Disposal Centre site shows the greatest changes overtime reflective of the changes in disposal material quality, these changes are not displayed consistently in any of the other sample site. With the exception of the Disposal centre site the sample sites follow the trends shown at the Control site.

Sand (percentage)

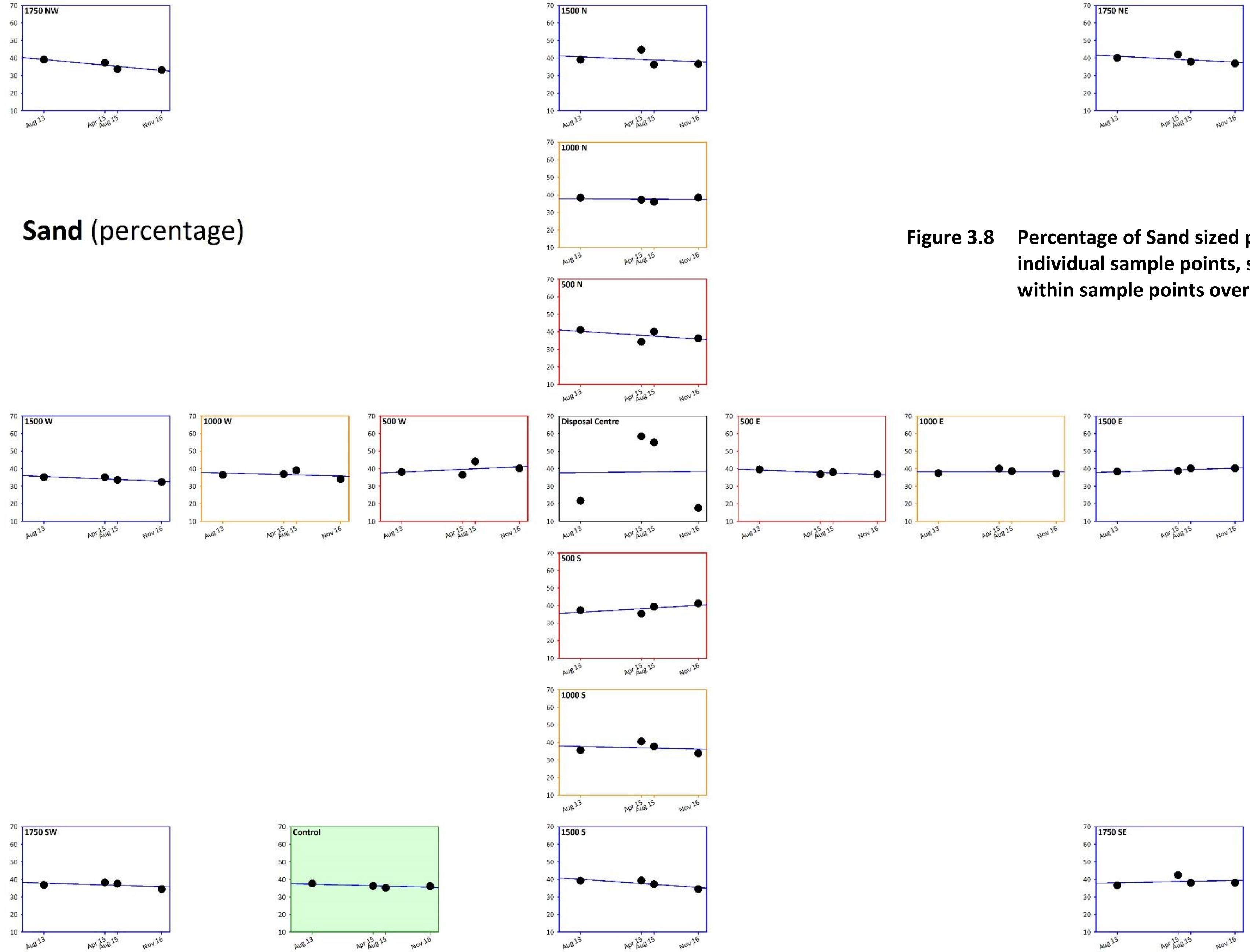


Figure 3.8 Percentage of Sand sized particles from individual sample points, showing trends within sample points over time

Silt (percentage)

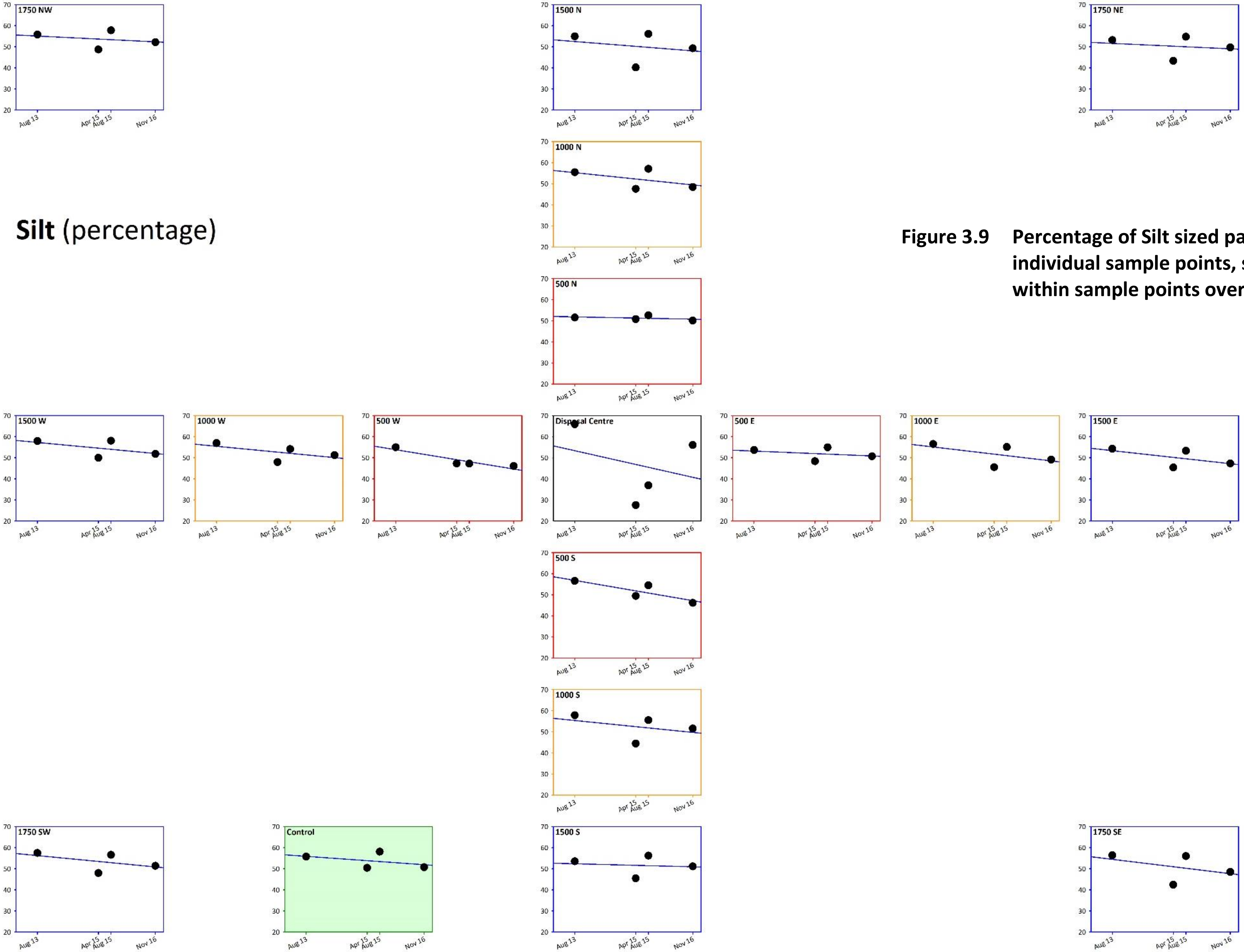


Figure 3.9 Percentage of Silt sized particles from individual sample points, showing trends within sample points over time

Clay (percentage)

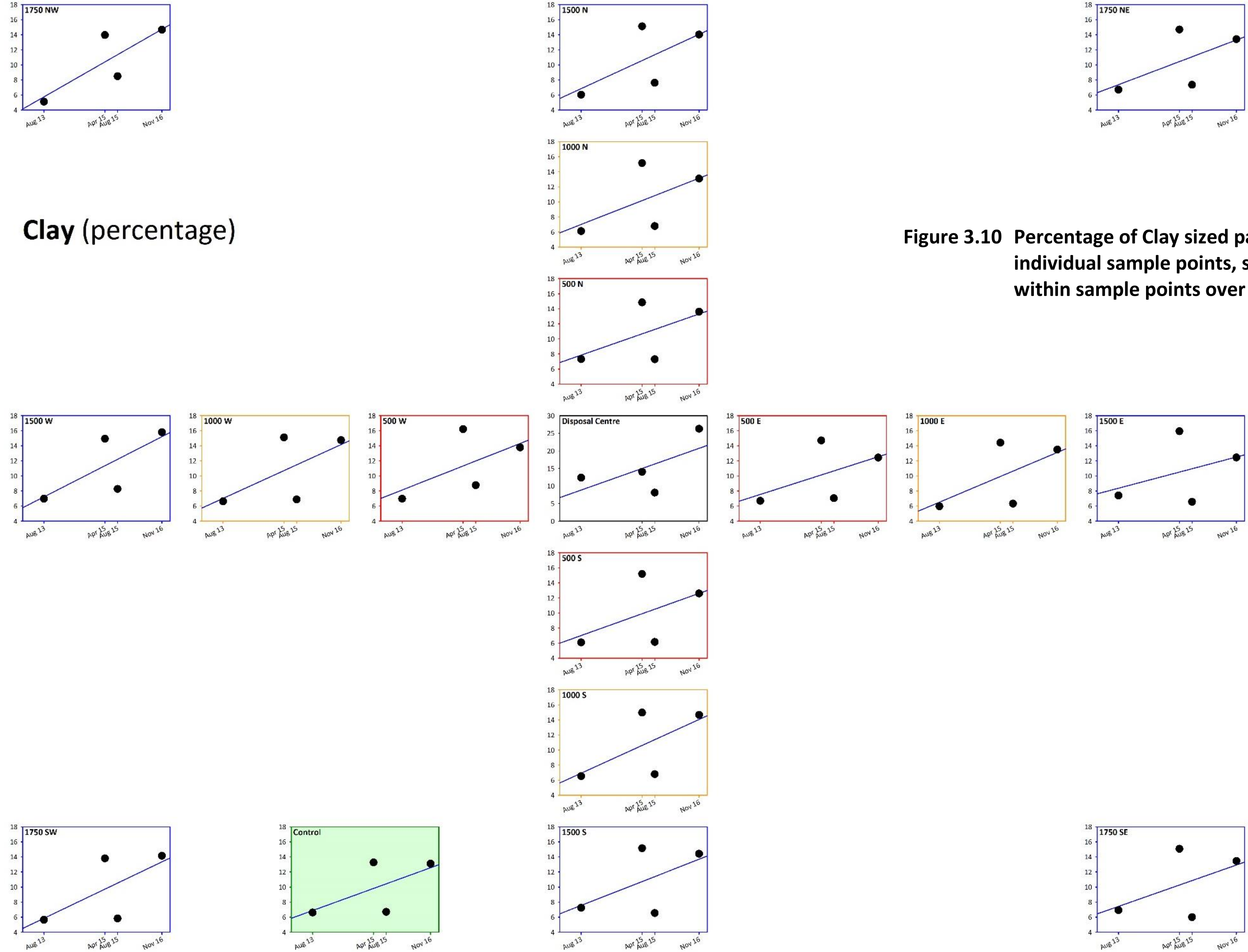


Figure 3.10 Percentage of Clay sized particles from individual sample points, showing trends within sample points over time

3.3.3 Sediment Chemistry

In August 2013, following the disposal of 10,000 m^3, the concentrations of arsenic, cadmium, chromium, copper, lead, mercury and zinc from within the disposal area were all below the ER-L and ANZECC ISQG low guideline values, as indicated by cell colour in Table 8.13. The concentrations of arsenic, copper, lead, mercury and zinc were elevated at the disposal centre site when compared with other sample sites within the disposal area and the control sites.

The concentration of nickel at all the sites, other than the disposal centre site, was below the ER-L and ANZECC ISQG low guideline of 21 mg/kg dry weight. The concentration of nickel at the disposal site was marginally above the guideline (24 mg/kg dry weight), which breached condition 10 of Permit 568. Sediment from Half Moon Bay Marina was the most recently disposed sediment in the disposal area. The pre-dredging sediment characterisation of the Half Moon Bay Marina sediment indicated nickel concentrations of between 12 and 23 mg/kg dry weight (Golder Associates Ltd (2013a). As a result of the breach of condition 10, additional samples were collected in December 2013 (Table 8.13). These samples showed the average concentration of nickel at the disposal centre site was 9.5 mg/kg dry weight, well below the guideline and the August 2013 concentration of 24 mg/kg dry weight. This is likely the result of clean sediments from the Pine Harbour Access channel being disposed of the in the period between August and December 2013, forming a layer greater than 50 mm. The pre-dredging sediment characterisation of the Pine Harbour Access channel sediment indicated nickel concentrations of between 5.9 and 8.0 mg/kg dry weight (Bioresearches, 2013). In December 2013, the average concentrations of nickel in the surficial sediments from the 250 m sites were all below the guideline and similar to the concentrations recorded in the wider disposal area in August 2013. The concentration of nickel at the E 250 site averaged 15.4 mg/kg dry weight, which was very slightly elevated above the concentrations recorded at other sites in the disposal area which average 14.3 mg/kg dry weight. This indicates that some of the nickel rich sediment disposed of at the disposal centre site prior to August 2013 has spread to the east. The E 500 sample collected in August 2013 did not show a significant variation from other disposal area samples at the time.

The sediment chemistry data suggest the disposed sediment has generally stayed were it was disposed. A thin layer of sediment has spread to beyond 250 m east of the disposal centre site, but not as far as 500 m east. It is not possible to determine when this sediment spread. It is considered most likely it occurred at the time of disposal, but could be the result of a gradual creep down slope after disposal.

In April 2015, following the disposal of 50,000 m^3, the concentrations of arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc from within the disposal area and control sites were all below the ER-L and ANZECC ISQG low guideline values, as indicated by cell colour in Table 8.15. The concentrations of copper and lead were elevated at the disposal centre site when compared with other sample sites within the disposal area and the control sites, while the concentrations of arsenic, cadmium, chromium, mercury, nickel and zinc were depressed or similar.

The concentration of copper at the disposal site was 14.3 mg/kg dry weight, which is comparable with that defined for the sediment from Sandspit Marina as the most recently disposed (Bioresearches, 2014). The average concentration of copper at the four 500 m sites was 5.53 mg/kg dry weight, which was marginally higher than the average of the sites further from the disposal site centre of 4.75 mg/kg dry weight. The concentration of copper at W 500 was the highest of the 500 m sites. As this site is up slope, it is likely to be the result of depositional conditions or variation in the location of disposal.

The concentration of lead at the disposal centre site was elevated by approximately 20% above the average of all the other sites. There is no indication of lead rich sediment spreading from the disposal site centre.

In August 2015, following the disposal of 100,000 m^3, the concentrations of arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc from within the disposal area were all below the ER-L and ANZECC ISQG low guideline values as indicated by cell colour in Table 8.16. The concentrations of chromium, copper, lead, mercury and zinc were elevated at the disposal centre site when compared with other sample sites within the disposal area, while the concentrations of arsenic, cadmium and nickel were depressed or similar.

The concentration of chromium recorded at the disposal centre site was statistically significantly higher than the concentrations recorded in the other sites in and around the disposal area. There was very little variation in the concentration of chromium across all sites outside of the disposal centre site with no statistically significant differences between the 500 m, 1000 m, 1500 m, 1750 m and control sites. The change in concentration of chromium was reflective of the quality of the sediment being disposed from Sandspit Marina (Bioresearches, 2014).

The concentration of copper at the disposal site was statistically significantly higher than at the other sites within and around the disposal area. Beyond the disposal centre site, the concentration of copper decreased with distance to a low at the control site, however, the differences between these sites are not statistically significant. The elevations in the average concentration of copper at the 500 m, and to a lesser extent the 1000 m sites, are the result of the presence of more copper rich disposal material at the W 500 and W 1000 sites, most likely due to variations in the disposal event locations. The change in concentration of copper at the disposal centre site was reflective of the quality of the most recent sediment being disposed from Sandspit Marina, Bioresearches (2014).

The concentration of lead at the disposal centre site was statistically significantly higher than the average concentrations at the other sites within and around the disposal area. There was no indication of lead rich sediment spreading from the disposal site centre.

The concentration of mercury at the control sites was elevated with one of the replicate samples exceeding the ANZECC ISQG low guideline. The elevated mercury concentration at the control site is not related to the spoil disposal activity. The concentration of mercury from the disposal centre site was elevated but not statistically significantly different from the other sites within and around the disposal area. There is no indication of mercury rich sediment spreading from the disposal site centre.

The concentration of zinc at the disposal centre site was statistically significantly higher than the average concentrations recorded in the more distant samples including the controls. There was no indication of zinc rich sediment spreading from the disposal centre site.

In November 2016, following the disposal of 150,000 m^3, the concentrations of arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc from within the disposal area and control sites were all below the ER-L and ANZECC ISQG low guideline values as indicated by cell colour in Table 8.17. The concentrations of arsenic, copper, lead, mercury and zinc were elevated at the disposal centre site when compared with other sample sites within the disposal area, while the concentrations of cadmium, chromium and nickel were depressed or similar.

The concentration of arsenic from the disposal centre site was higher, but not statistically significantly, than the concentrations recorded at the other sites. The concentrations of copper, lead, mercury and zinc at the disposal centre site was statistically significantly higher than the average concentrations at the other sites within and around the disposal area. With the exception of the disposal centre site, the concentrations of arsenic, copper, lead, mercury and zinc at sites within and around the disposal area, were not statistically significantly higher than the concentrations at the control sites, indicating there was no spread of arsenic, copper, lead, mercury or zinc rich sediment from the disposal centre site following the disposal of 150,000 m^3 of spoil.

3.3.3.1 Changes Over Time

The concentrations of arsenic have varied statistically significantly at the disposal centre site over time (Bioresearches, 2017a). These changes are reflective of the variability in the quality characteristics of the source sediment disposed in the months prior to sampling (Table 3.2 and shown in Figure 3.11 as colour coded ★ symbols). The statistical tests indicate that the concentration of arsenic varies statistically significantly over time and between sites but the changes over time are different at different sites (Bioresearches, 2017a).

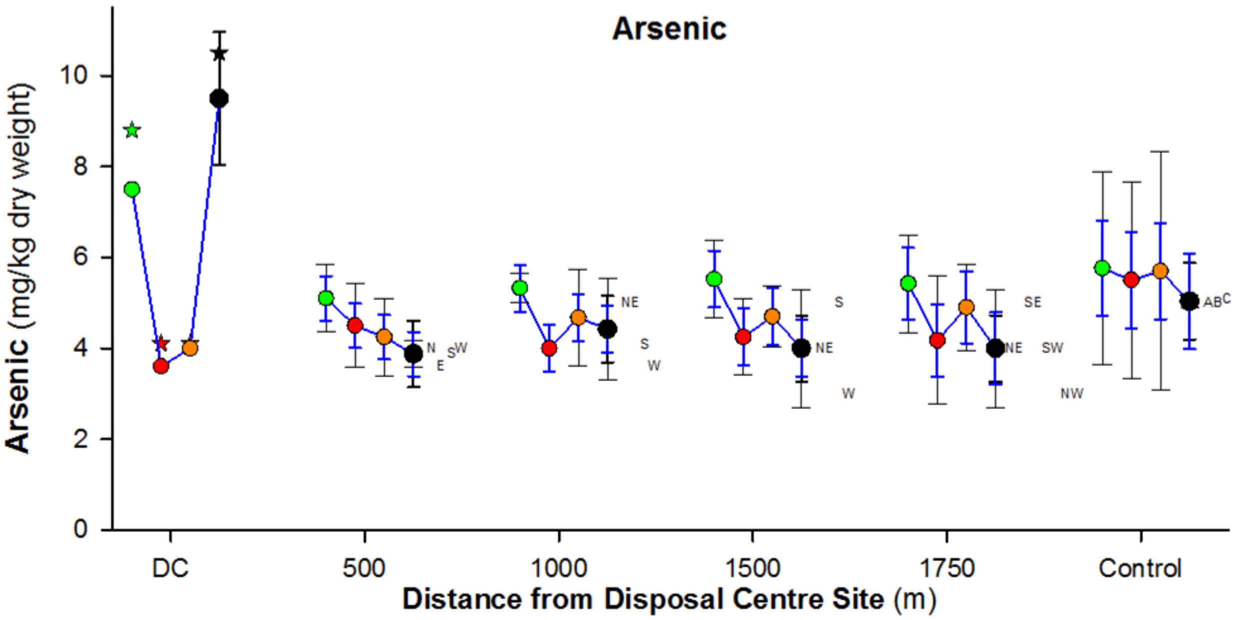


Figure 3.11 Comparison of Total Recoverable Arsenic with Distance from Disposal Centre Site (DC), after 150,000 m^3 Sediment Disposal (N, E, S, W = 150,000 individual sites) (± 95% CI ⌶ and ± $HSI_{0.05}$ ⌶) **and Over Time** (● 10k, ● 50k, ● 100k, ● 150k, ± $HSI_{0.05}$ ⌶)[1].

The average concentration of arsenic has decreased over time between the 10,000 m^3 and 150,000 m^3 samples from the 500 m, 1000 m, 1500 m, 1750 m and the control sites. The decreases were statistically significant at the 500 m, 1500 m and 1750 m sites but not the 1000 m or the control sites (Bioresearches, 2017a). While statistically significant, the decreases over time at the distant sites do not necessarily indicate the spread of disposal material as the disposal material has varied over time. However, it does indicate that the risk of adverse effects has decreased over time. The lack of an increase in the concentration of arsenic at the distant sites between the 100,000 m^3 and 150,000 m^3 samples, when the disposal centre site

[1] Note the different HSI bar colours the black bars compare statistical difference between sites after the 150,000 m^3 monitoring event, thus allowing the single centre sample to have a bar, but the blue bars compares differences within radius groups over time, which means the single sample centre sites do not have a bar.

increased, and the lack of statistically significantly differences between the distant sites and the control sites, provide evidence that the changes in concentration of arsenic at the distant sites are the result of natural variations in the concentrations of arsenic.

To allow the statistical tests conducted above samples from each compass point were grouped by radius, this has the potential to mask finer geographical differences, however Figure 3.19 shows each individual sample result graphically along with trends overtime. The Disposal Centre site shows the greatest changes overtime reflective of the changes in disposal material quality, these changes are not displayed consistently in any of the other sample site. The blue trend lines show decreases in the concentration of arsenic over time for all sample sites except the Disposal Centre site. With the exception of the Disposal Centre site the sample sites follow the trends shown at the Control site.

Table 3.2 Average Concentrations of Contaminants in Disposal Sediments Prior To Disposal Monitoring Events

	Year	2013	2014	2015	2016
	Site	Pine Harbour Marina	Sandspit	Sandspit	Hobsonville Marina
	m³	10,000	50,000	100,000	150,000
Dry Matter	g/100g	**41.2**	**68.8**	**68.8**	**43.8**
Total Organic Carbon	g/100g dry wt	**1.60**	**0.45**	**0.45**	**1.62**
Total Recoverable Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg					
Arsenic	mg/kg dry wt	**8.8**	**4.1**	**4.1**	**10.5**
Cadmium	mg/kg dry wt	**0.046**	**0.036**	**0.036**	**0.070**
Chromium	mg/kg dry wt	**25.9**	**23.7**	**23.7**	**24.0**
Copper	mg/kg dry wt	**62.8**	**11.0**	**11.0**	**38.4**
Lead	mg/kg dry wt	**17.4**	**5.3**	**5.3**	**25.7**
Mercury	mg/kg dry wt	**0.074**	**0.026**	**0.026**	**0.111**
Nickel	mg/kg dry wt	**11.7**	**9.2**	**9.2**	**9.6**
Zinc	mg/kg dry wt	**98.6**	**31.1**	**31.1**	**97.8**

The concentrations of cadmium have varied statistically significantly at the disposal centre site over time (Figure 3.12, Bioresearches, 2017a). These changes are reflective of the variability in the quality characteristics of the source sediment disposed in the months prior to sampling (Table 3.2 and shown in Figure 3.12 as colour coded ★ symbols). The statistical tests indicate that the concentration of cadmium varies statistically significantly over time and between sites (Bioresearches, 2017a). The concentration recorded at the disposal centre site was approximately half the concentration recorded in the other sites in and around the disposal area; the differences were statistically significant (Figure 3.12, Bioresearches, 2017a).

Figure 3.12 shows slight, non-statistically significant decreases in the concentration of cadmium over time at the 1000 m, 1500 m, 1750 m and the control sites. At the 500 m sites, the decreases in the concentration of cadmium followed a similar trend until the 150,000 m^3 sample, which showed a slight increase. The variability of the results as shown by the 95% CL error bars on Figure 3.12, indicate that the changes are most likely natural. The increased 150,000 m^3 500 m average cadmium concentration was the result of higher concentrations of cadmium at the N and E sites, however, these are higher than recorded in the disposal material so the spread of disposal material is unlikely to be the cause of the increased concentrations.

To allow the statistical tests conducted above samples from each compass point were grouped by radius, this has the potential to mask finer geographical differences, however Figure 3.20 shows each individual sample result graphically along with trends overtime. The 500 W site shows the greatest changes overtime. The blue trend lines show decreases in the concentration of cadmium over time at the Control site and all sites except the Disposal Centre site, 500 N, 500 E and 1000 E sample sites. Visually analysis of Figure 3.20 suggests that sites 500 W, 500 N and 500 S may have been influenced by the disposal material in August 2015 with lower concentrations of cadmium.

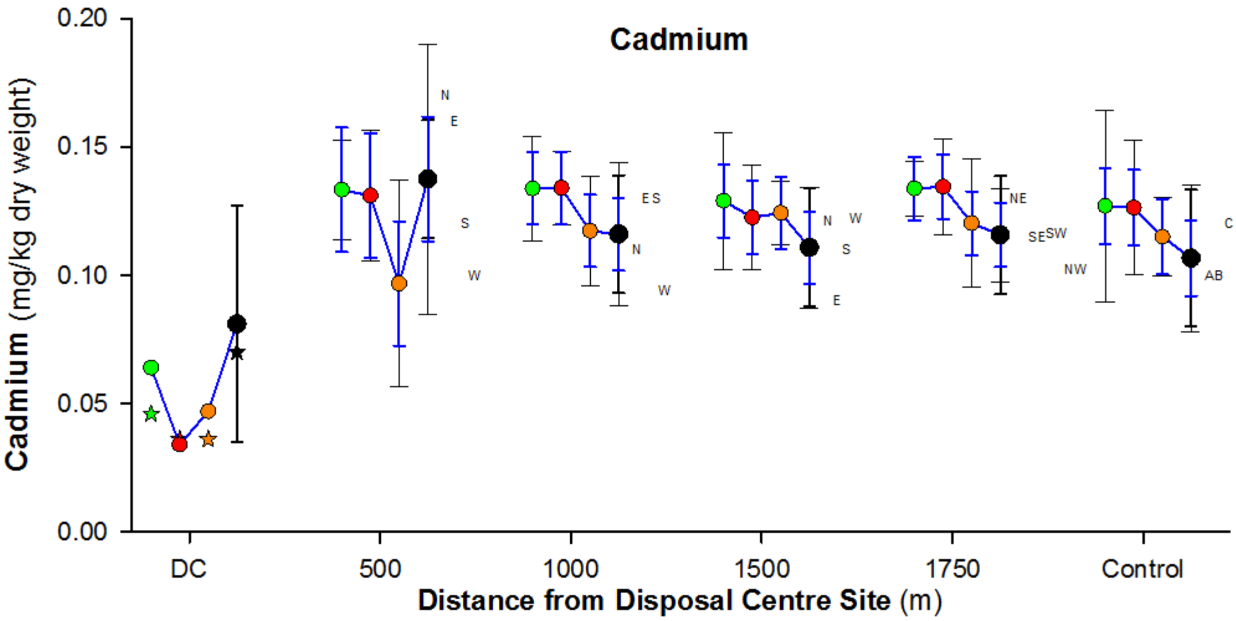


Figure 3.12 Comparison of Total Recoverable Cadmium with Distance from Disposal Centre Site (DC), after 150,000 m³ Sediment Disposal (N, E, S, W = 150,000 individual sites) (± 95% CI ⌶ and ± $HSI_{0.05}$ **⌶**) **and Over Time** (● 10k, ● 50k, ● 100k, ● 150k, ± $HSI_{0.05}$ **⌶**).

The concentrations of chromium have varied statistically significantly at the disposal centre site over time (Figure 3.13, Bioresearches, 2017a). These changes are generally reflective of the variability in the quality characteristics of the source sediment disposed in the months prior to sampling (Table 3.2 and shown in Figure 3.13 as colour coded ★ symbols). The statistical tests indicate that the concentration of chromium varies statistically significantly over time and between sites but the changes over time are different at different sites (Bioresearches, 2017a).

The average concentration of chromium has fluctuated and ultimately decreased similarly over time between the 10,000 m³ and 150,000 m³ samples at the 500 m, 1000 m, 1500 m, 1750 m and the control sites. The decreases at the 1500 m and 1750 m sites were statistically significant, although very small. The changes in the concentrations of chromium recorded are all within the likely natural background variation in the concentration of chromium.

To allow the statistical tests conducted above samples from each compass point were grouped by radius, this has the potential to mask finer geographical differences, however Figure 3.21 shows each individual sample result graphically along with trends overtime. The Disposal Centre site shows the greatest changes overtime reflective of the changes in disposal material quality, these changes are not displayed consistently in any of the other sample site. The blue trend lines show decreases in the concentration of chromium over time for all sample sites except the Disposal Centre site. With the exception of the Disposal Centre site the sample sites follow the trends shown at the Control site.

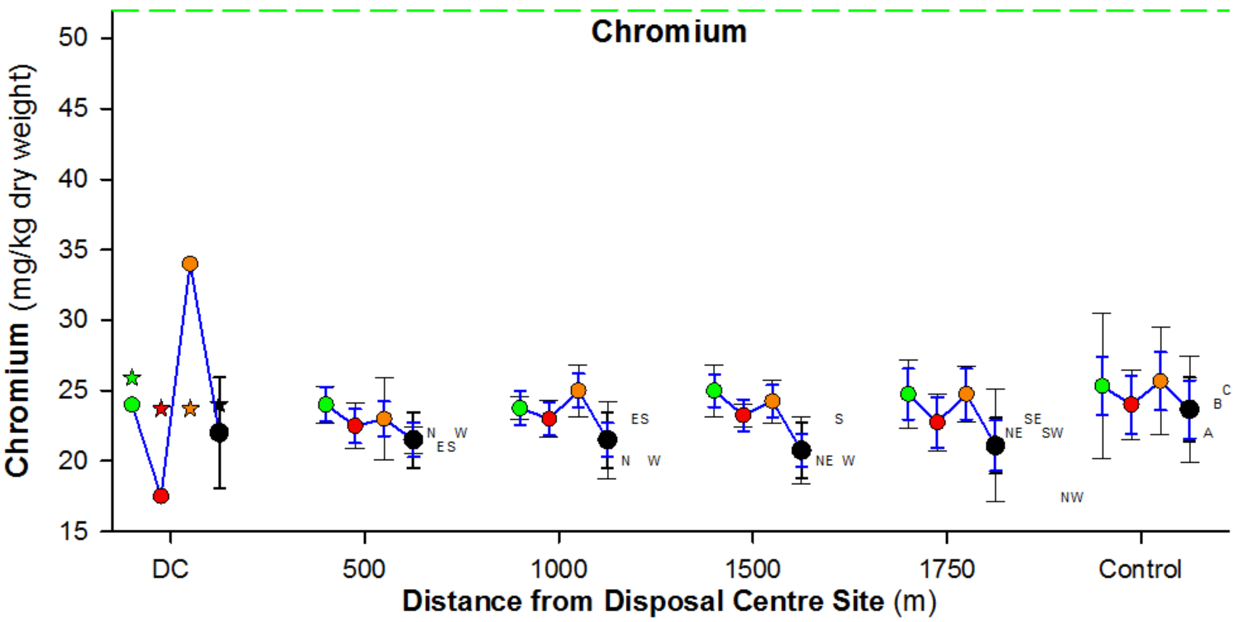


Figure 3.13 Comparison of Total Recoverable Chromium with Distance from Disposal Centre Site (DC), after 150,000 m³ Sediment Disposal (N, E, S, W = 150,000 individual sites) (± 95% CI ⌶ and ± $HSI_{0.05}$ ⌶) **and Over Time** (● 10k, ● 50k, ● 100k, ● 150k, ± $HSI_{0.05}$ ⌶). (- - - AC green guideline 52 mg/kg dry weight)

The concentrations of copper have varied statistically significantly at the disposal centre site over time (Figure 3.14, Bioresearches, 2017a). These changes are reflective of the variability in the quality characteristics of the source sediment disposed in the months prior to sampling (Table 3.2 and shown in Figure 3.14 as colour coded ★ symbols). The statistical tests indicate that the concentration of copper varies statistically significantly over time and between sites but the changes over time are different at different sites (Bioresearches, 2017a).

During each monitoring event the concentration of copper has generally decreased with distance from the disposal centre site. The differences between the average concentrations at each sampling distance within each volume sampling event are very small and not statistically significant. There is no consistent trend for increasing or decreasing concentration of copper over time across all sites. Beyond the disposal centre site, the differences in the concentration of copper between sample events and sample sites are very small and most likely within the natural background variation in the concentration of copper from the area. Hence, the concentration of copper does not provide significant evidence of the spread of disposal material from the disposal centre site.

To allow the statistical tests conducted above samples from each compass point were grouped by radius, this has the potential to mask finer geographical differences, however Figure 3.22 shows each individual sample result graphically along with trends overtime. The Disposal Centre site shows the greatest changes overtime reflective of the changes in disposal material quality, these changes are not displayed consistently in any of the other sample site. The blue trend lines show minor increases in the concentration of copper over time for all sample sites except the Disposal Centre site, 500 W, 1500 N, 1500 E, 1750 NW and 1750 SE. With the exception of the Disposal Centre site the sample sites showed similar concentrations and trends as shown at the Control site, any increases in concentration of copper at sites other than the Disposal Centre site are not ecologically significant.

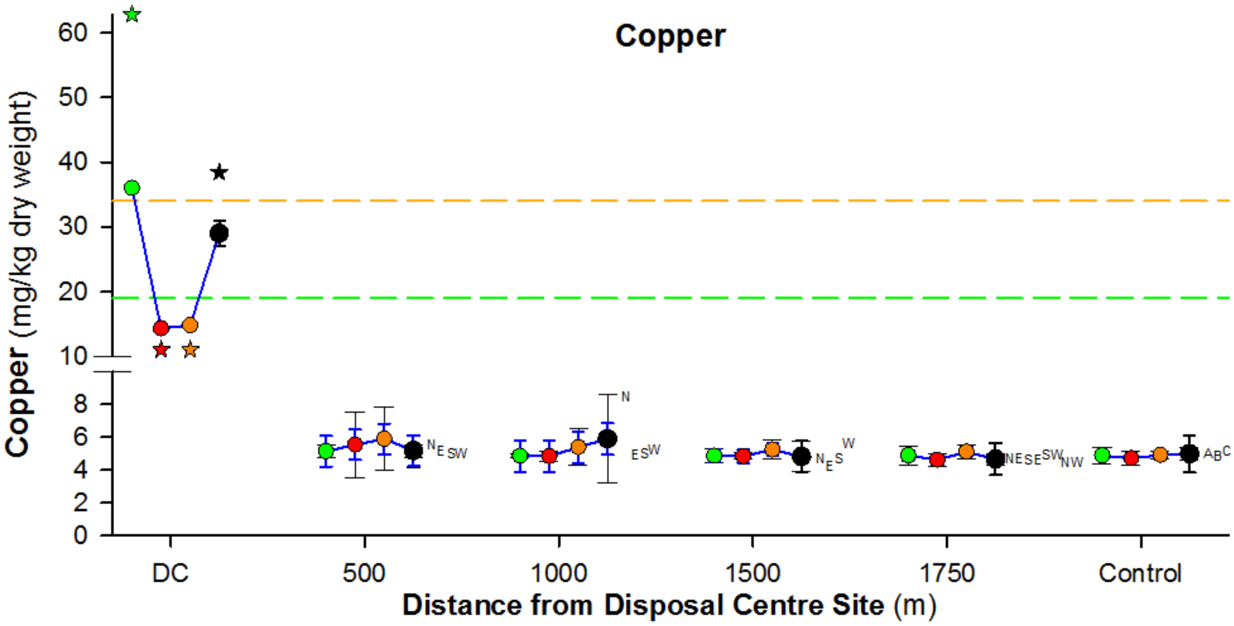


Figure 3.14 Comparison of Total Recoverable Copper with Distance from Disposal Centre Site (DC), after 150,000 m³ Sediment Disposal (N, E, S, W = 150,000 individual sites) (± 95% CI Ɪ and ± $HSI_{0.05}$ Ɪ) **and Over Time** (● 10k, ● 50k, ● 100k, ● 150k, ± $HSI_{0.05}$ Ɪ). (- - - AC green guideline 19 mg/kg dry weight, - - - AC red guideline 34 mg/kg dry weight)

The concentrations of lead have varied statistically significantly at the disposal centre site over time (Figure 3.15, Bioresearches, 2017a). These changes are reflective of the variability in the quality characteristics of the source sediment disposed in the months prior to sampling (Table 3.2 and shown in Figure 3.15 as colour coded ★ symbols). The statistical tests indicate that the concentration of lead varies statistically significantly over time and between sites but the changes over time are different at different sites (Bioresearches, 2017a).

The average concentration of lead has decreased over time between the 10,000 m³ and 150,000 m³ samples from the 500 m, 1000 m, 1500 m, 1750 m and control sites. The decreases were only statistically significant at the 1750 m sites. While statistically significant, the decreases over time at the distant sites do not necessarily indicate the spread of disposal material as the disposal material has varied over time. However, it does indicate that the risk of adverse effects has decreased over time. The lack of an increase in the concentration of lead at the distant sites between the 100,000 m³ and 150,000 m³ samples, when the disposal centre site increased, and the lack of statistically significantly differences between the distant sites and the control sites, provide evidence that the changes in concentration of lead at the distant sites are the result of natural variations in the concentrations of lead.

To allow the statistical tests conducted above samples from each compass point were grouped by radius, this has the potential to mask finer geographical differences, however Figure 3.23 shows each individual sample result graphically along with trends overtime. The Disposal Centre site shows the greatest changes overtime reflective of the changes in disposal material quality, these changes are not displayed consistently in any of the other sample site. The blue trend lines show decreases in the concentration of lead over time for at the Control site and all sample sites except the Disposal Centre site, 500 N and 1500 W. The increases at sites

500 N and 1500 W are minor and not ecologically significant. With the exception of the Disposal Centre site the sample sites showed similar concentrations and trends as shown at the Control site.

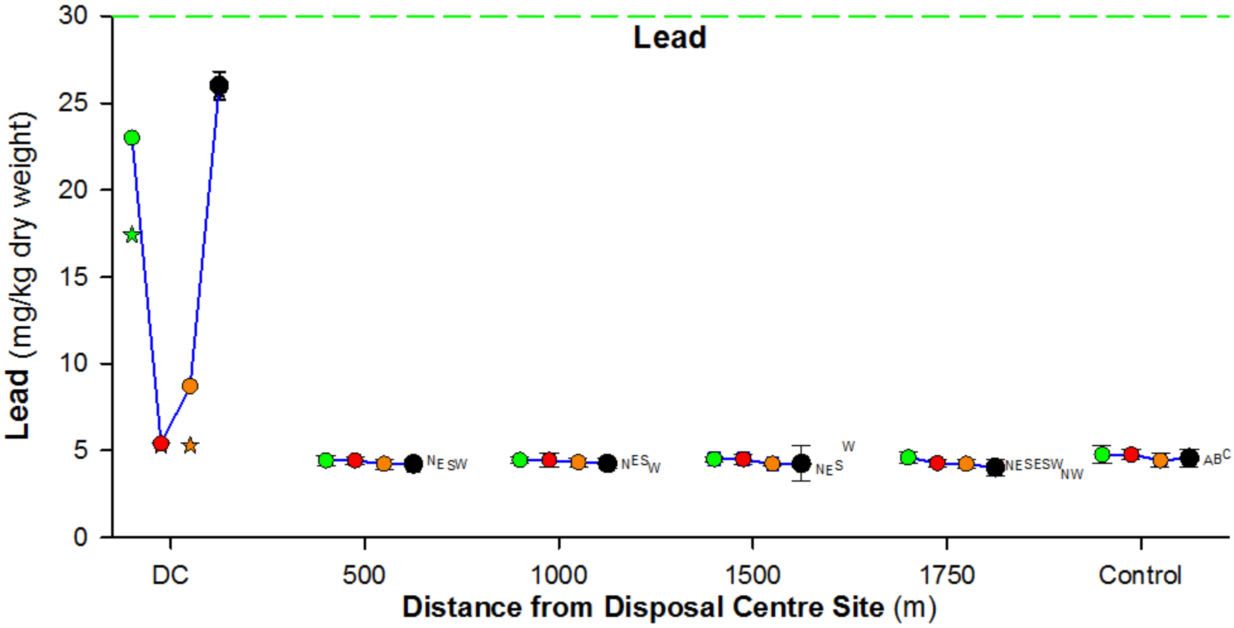


Figure 3.15 Comparison of Total Recoverable Lead with Distance from Disposal Centre Site (DC), after 150,000 m³ Sediment Disposal (N, E, S, W = 150,000 individual sites) (± 95% CI Ɪ and ± $HSI_{0.05}$ **Ɪ**) **and Over Time** (● 10k, ● 50k, ● 100k, ● 150k, ± $HSI_{0.05}$ **Ɪ**). (- - - AC green guideline 30 mg/kg dry weight)

The concentrations of mercury have varied statistically significantly at the disposal centre site over time (Figure 3.16, Bioresearches, 2017a). These changes are reflective of the variability in the quality characteristics of the source sediment disposed in the months prior to sampling (Table 3.2 and shown in Figure 3.16 as colour coded ★ symbols). The statistical tests indicate that the concentration of mercury varies statistically significantly over time and between sites but the changes over time are different at different sites (Bioresearches, 2017a).

The average concentration of mercury has generally remained similar with minor fluctuations between the 10,000 m³ and 150,000 m³ samples at the 500 m, 1000 m, 1500 m, 1750 m sites. A statistically significant fluctuation in the concentration of mercury was recorded at the control site during the 100,000 m³ survey, but there has not been any statistically significant trend of change over time (Figure 3.16, Bioresearches, 2017a). The fluctuations in the concentration of mercury from in and around the disposal area were very small and likely within the natural variation in concentration from the area as indicated by the changes in the control site. There is no indication of mercury rich sediment spreading from the disposal centre site.

To allow the statistical tests conducted above samples from each compass point were grouped by radius, this has the potential to mask finer geographical differences, however Figure 3.24 shows each individual sample result graphically along with trends overtime. The Disposal Centre site shows the greatest changes overtime reflective of the changes in disposal material quality, these changes are not displayed consistently in any of the other sample site. The blue trend lines showed minor increases in the concentration of mercury over time at the Control site and for all sample sites except the Disposal Centre site, 500 E, 500 S, 1000 N, 1500 E, 1500 S, 1750 NE. Figure 3.24 shows a background concentration of mercury in the range of 0.04 to 0.08 mg/kg, however fluctuations are possible as shown by the Control site concentration in August 2015.

Concentrations of mercury recorded at all sites except the Disposal centre site were marginally elevated in April 2015 and August 2015 indicating another environmental factor effecting concentrations or an analytical issue. The changes in the concentration mercury at sites other than the Disposal Centre site were minor and not ecologically significant.

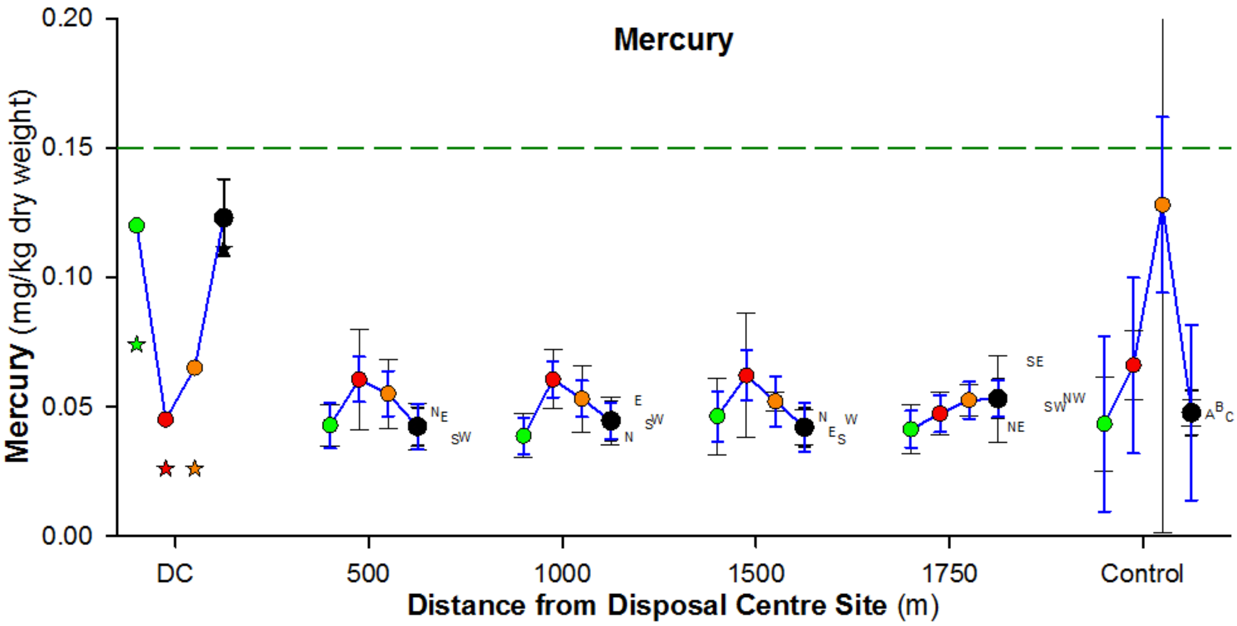


Figure 3.16 Comparison of Total Recoverable Mercury with Distance from Disposal Centre Site (DC), after 150,000 m³ Sediment Disposal (N, E, S, W = 150,000 individual sites) (± 95% CI Ɪ and ± $HSI_{0.05}$ **I**) **and Over Time** (● 10k, ● 50k, ● 100k, ● 150k, ± $HSI_{0.05}$ **I**). (- - - ISQG-Low guideline 0.15 mg/kg dry weight.

The concentrations of nickel have varied statistically significantly at the disposal centre site over time (Figure 3.17, Bioresearches, 2017a). These changes are largely reflective of the variability in the quality characteristics of the source sediment disposed in the months prior to sampling (Table 3.2 and shown in Figure 3.17 as colour coded ★ symbols). The statistical tests indicate that the concentration of nickel varies statistically significantly over time and between sites but the changes over time are different at different sites (Bioresearches, 2017a).

The average concentration of nickel has fluctuated and ultimately increased similarly over time between the 10,000 m³ and 150,000 m³ samples at the 500 m, 1000 m, 1500 m, 1750 m and the control sites. The increases at the 500 m, 1000 m, 1500 m and the control sites were statistically significant, although the very small changes in concentrations of nickel recorded were all within the likely natural background variation in the concentration of nickel as indicated by the changes at the control site.

Within the disposal centre site, nickel concentrations decreased to below the control site concentration following the 10,000 m³ monitoring study. There is little likelihood that the increases, if real, in the nickel concentration from the disposal area sites are the result of the spread of disposal material.

To allow the statistical tests conducted above samples from each compass point were grouped by radius, this has the potential to mask finer geographical differences, however Figure 3.25 shows each individual sample result graphically along with trends overtime. The Disposal Centre site shows the greatest changes overtime reflective of the changes in disposal material quality, these changes are not displayed consistently in any of the other sample site. The blue trend lines show minor increasing or decreasing changes in the concentration of nickel over time, in similar concentration ranges for all sample sites except the Disposal Centre site. The concentration of nickel recorded at 500 W in August 2015 was lower than expected it is unlike the result of earlier disposed sediment which were lower in nickel as shown by the concentration recorded at the Disposal Centre site in April 2015, as this would require the sediment to move up slope. It may be the result of a slightly off target disposal event.

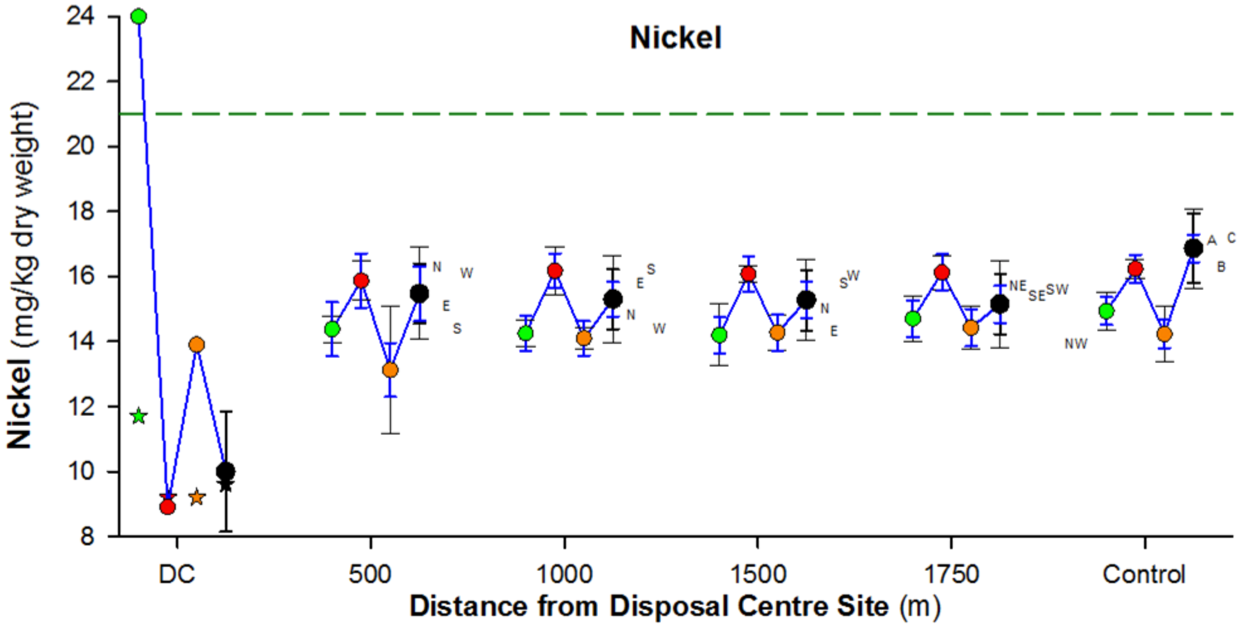


Figure 3.17 Comparison of Total Recoverable Nickel with Distance from Disposal Centre Site (DC), after 150,000 m³ Sediment Disposal (N, E, S, W = 150,000 individual sites) (± 95% CI Ɪ and ± $HSI_{0.05}$ **Ɪ**) **and Over Time** (● 10k, ● 50k, ● 100k, ● 150k, ± $HSI_{0.05}$ **Ɪ**). (- - - ISQG-Low guideline 21 mg/kg dry weight)

The concentrations of zinc have varied statistically significantly at the disposal centre site over time (Figure 3.18, Bioresearches, 2017a). These changes are reflective of the variability in the quality characteristics of the source sediment disposed in the months prior to sampling (Table 3.2 and shown in Figure 3.18 as colour coded ★ symbols). The statistical tests indicate that the concentration of zinc varies statistically significantly over time and between sites but the changes over time are different at different sites (Bioresearches, 2017a).

The average concentration of zinc showed very small, but in some cases statistically significant, fluctuations in concentration between the 10,000 m³, 50,000 m³, 100,000 m³ and 150,000 m³ samples at the 500 m, 1000 m, 1500 m, 1750 m and control sites. The very small changes are likely within the natural variation in concentration of zinc from the area and do not show any indication of spread of disposal material from the disposal centre site.

To allow the statistical tests conducted above samples from each compass point were grouped by radius, this has the potential to mask finer geographical differences, however Figure 3.26 shows each individual sample result graphically along with trends overtime. The Disposal Centre site shows the greatest changes overtime reflective of the changes in disposal material quality, these changes are not displayed consistently in any of the other sample site. The blue trend lines show minor increasing or decreasing changes in the concentration of zinc over time, in similar concentration ranges for all sample sites except the Disposal Centre site. With the exception of the Disposal Centre site the sample sites follow the trends shown at the Control site.

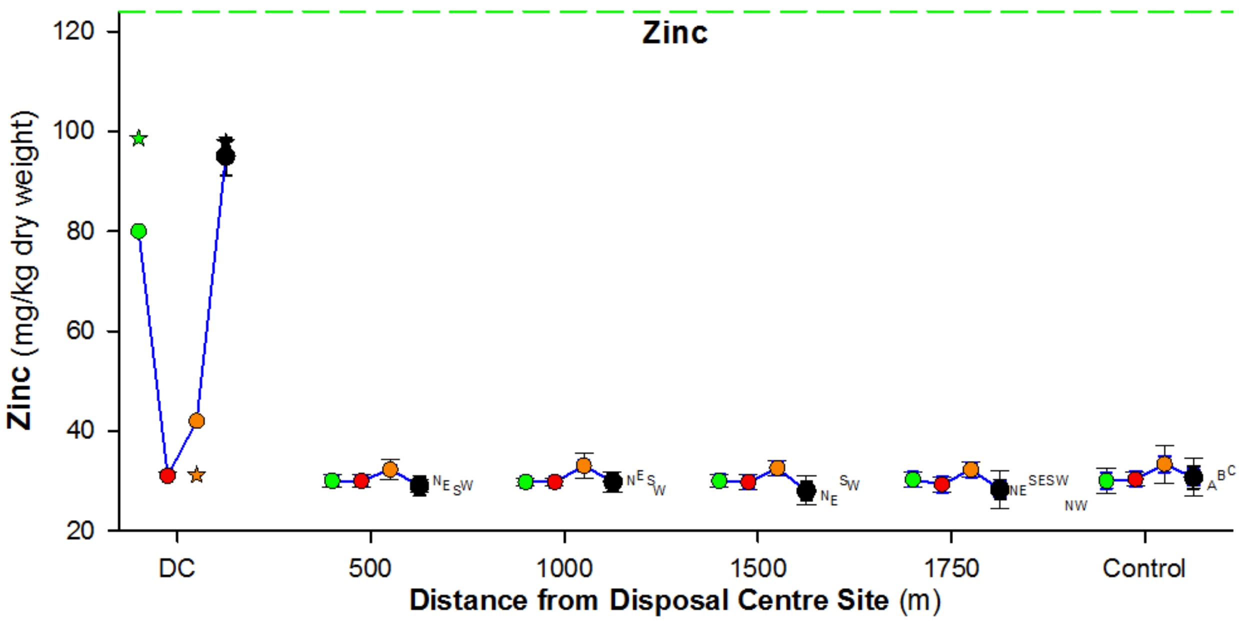


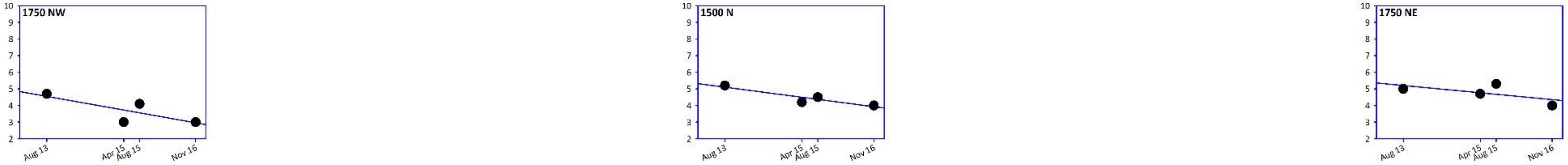
Figure 3.18 Comparison of Total Recoverable Zinc with Distance from Disposal Centre Site (DC), after 150,000 m^3 Sediment Disposal. (N, E, S, W = 150,000 individual sites) (± 95% CI I and ± $HSI_{0.05}$ **I**) **and Over Time** (● 10k, ● 50k, ● 100k, ● 150k, ± $HSI_{0.05}$ **I**). (- - - AC green guideline 124 mg/kg dry weight)

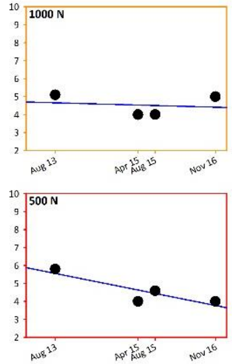
3.4 Water Quality

A variety of standard methodologies were employed during the 2010 pilot disposal period to assess turbidity at the disposal site. These are discussed in University of Waikato (2011c) and included time series turbidity measurements (using two different types of sensors), water sampling for total suspended sediment concentrations, and Acoustic Doppler Current Profiler (ADCP) backscatter data.

The 2010 ambient suspended sediment levels in the upper 10 m of the water column are typically low, less than 20 mg/l. In 2016 during the 150,000 m^3 post disposal monitoring, ambient suspended sediment levels were recorded at 5 m, 10 m, 70 m depths and 1 above the bottom from the disposal centre site. All showed low concentrations of less than 5 mg/l suspended solids.

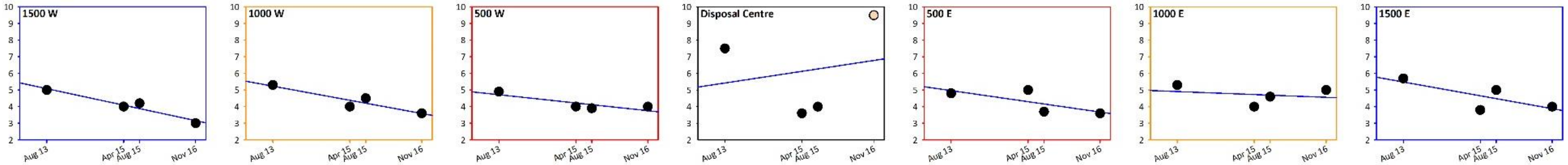
Water chemistry has not been collected from the disposal area, due to the predicted lack of effects based on sediment elutriation results from pre characterisation studies (discussed in section 2 above) and due to the extreme difficulty of sampling the correct unseen sub-surface volume of potentially effected water.

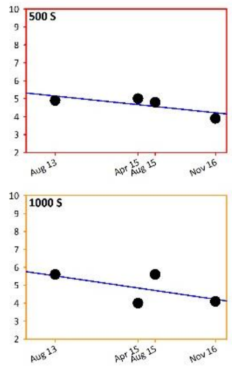


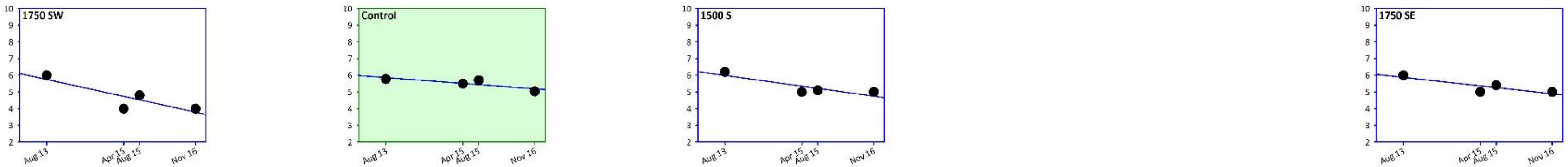


Arsenic (mg/kg dry weight)

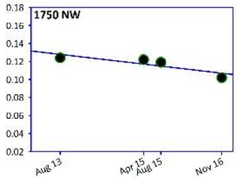
Figure 3.19 Comparison of Total Recoverable Arsenic over Time from individual sample points, showing trends within sample points over time. (● Exceeds the ER-L guideline of 8.2 mg/kg)

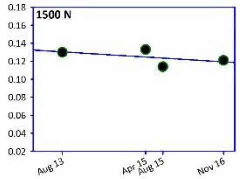


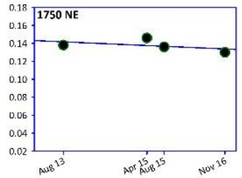


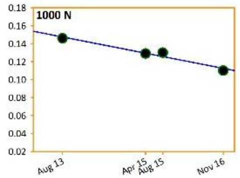


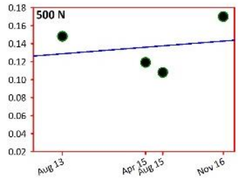
Cadmium (mg/kg dry weight)

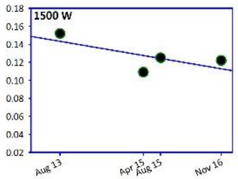


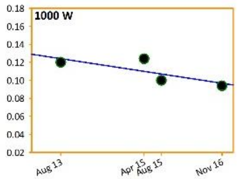


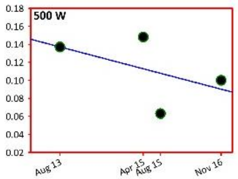


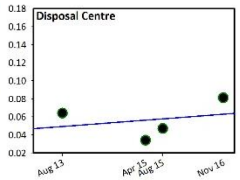


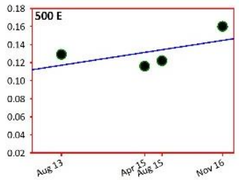


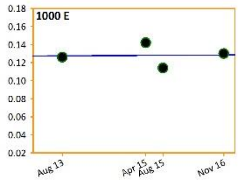


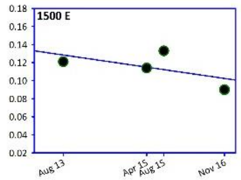


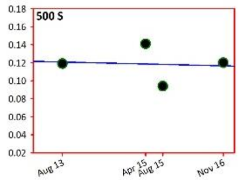


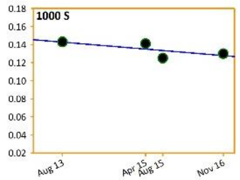


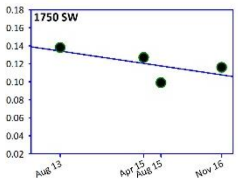


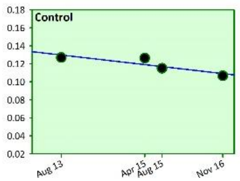


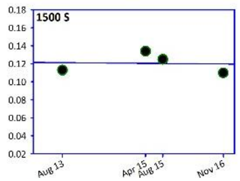












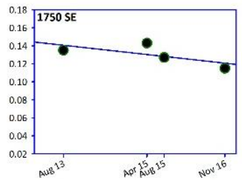


Figure 3.20 Comparison of Total Recoverable Cadmium over Time from individual sample points, showing trends within sample points over time.

Chromium (mg/kg dry weight)

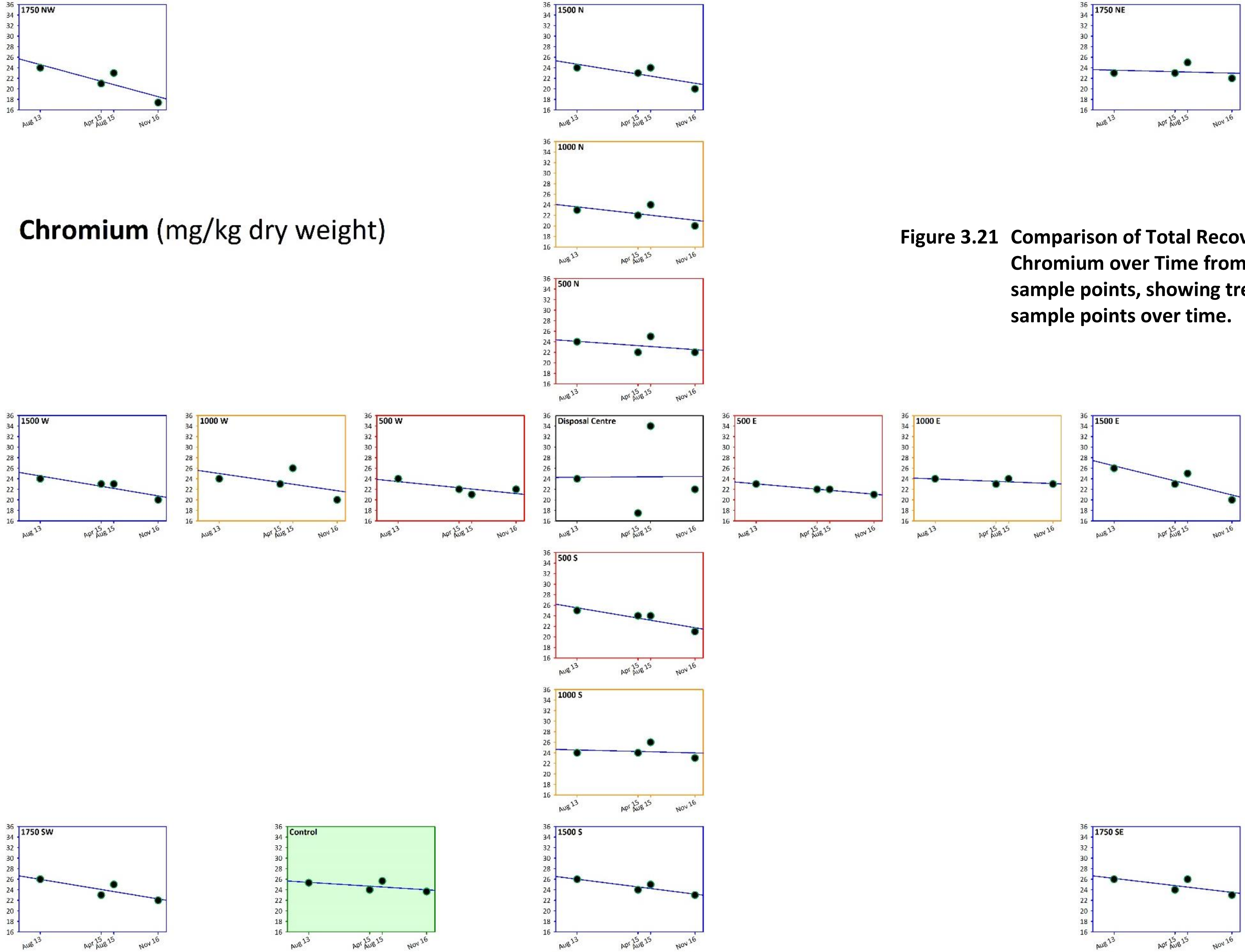


Figure 3.21 Comparison of Total Recoverable Chromium over Time from individual sample points, showing trends within sample points over time.

Copper (mg/kg dry weight)

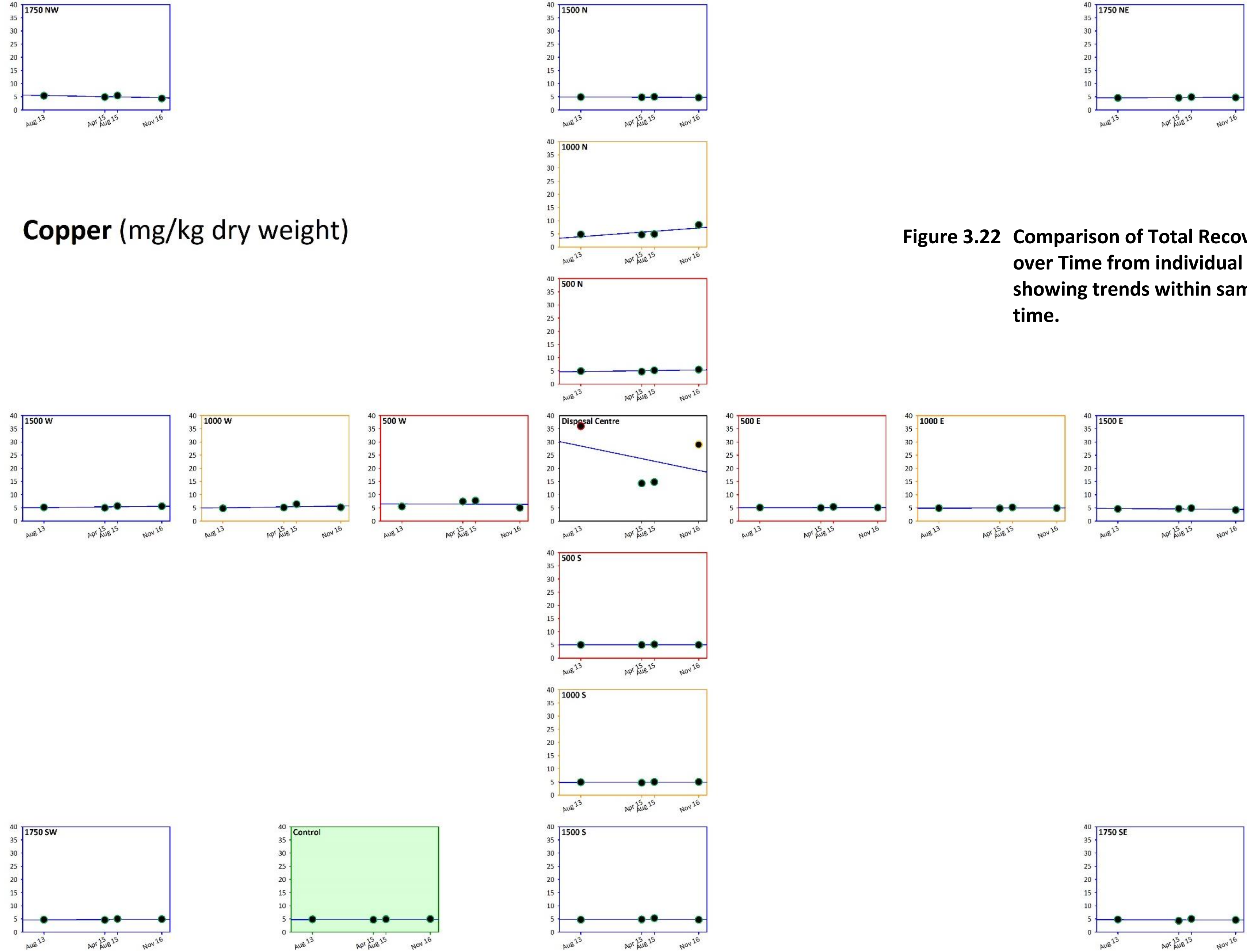


Figure 3.22 Comparison of Total Recoverable Copper over Time from individual sample points, showing trends within sample points over time.

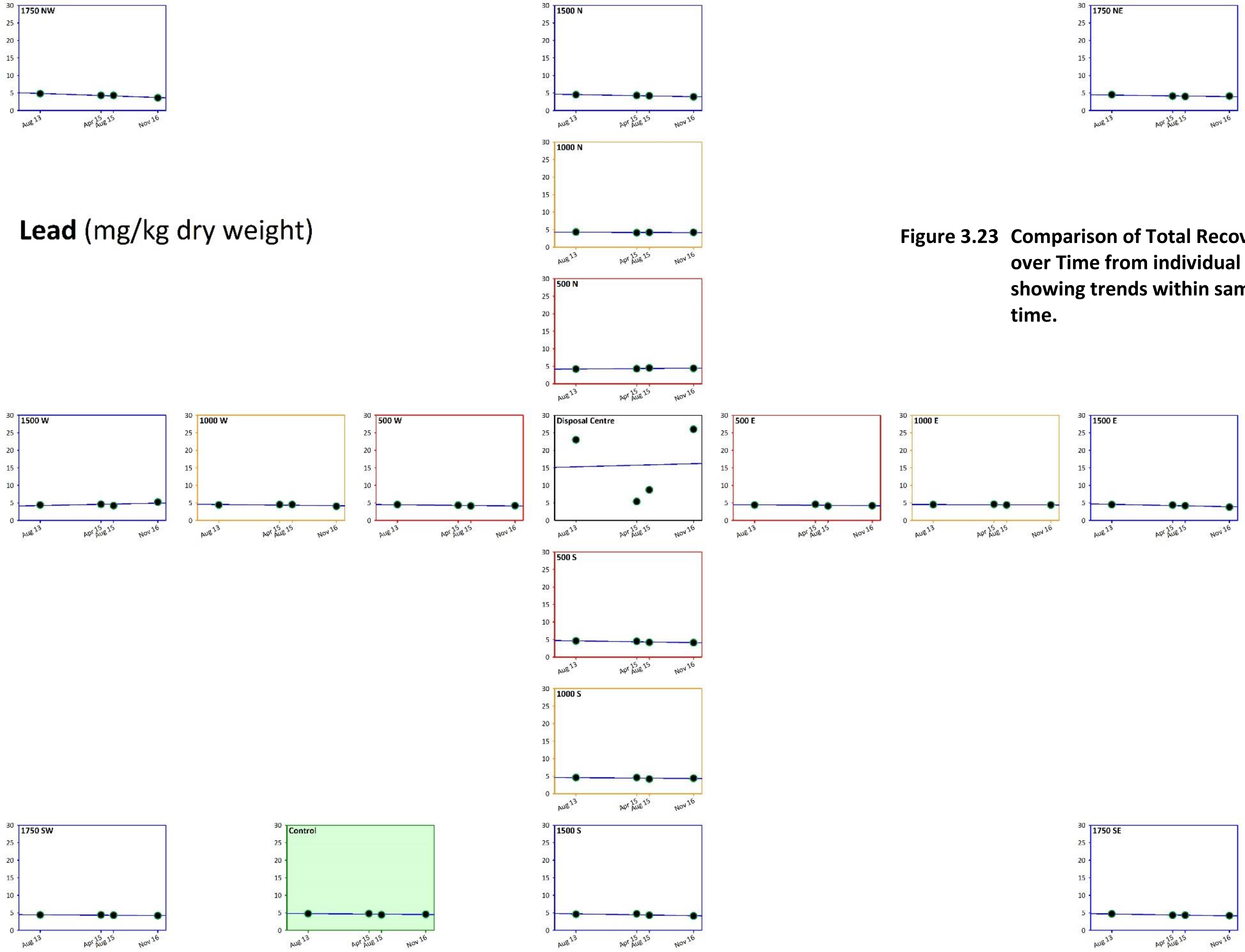


Figure 3.23 Comparison of Total Recoverable Lead over Time from individual sample points, showing trends within sample points over time.

Mercury (mg/kg dry weight)

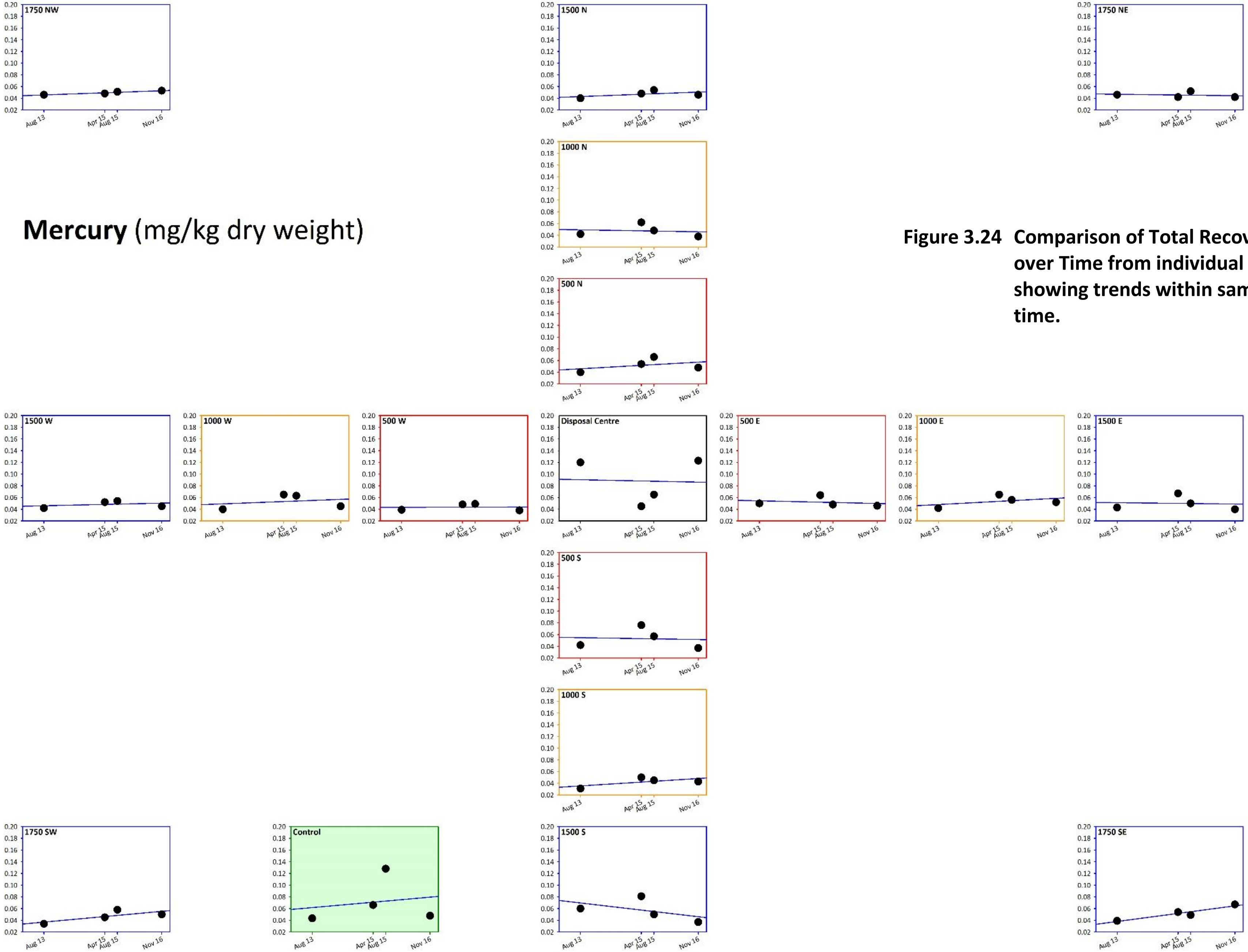


Figure 3.24 Comparison of Total Recoverable Mercury over Time from individual sample points, showing trends within sample points over time.

Nickel (mg/kg dry weight)

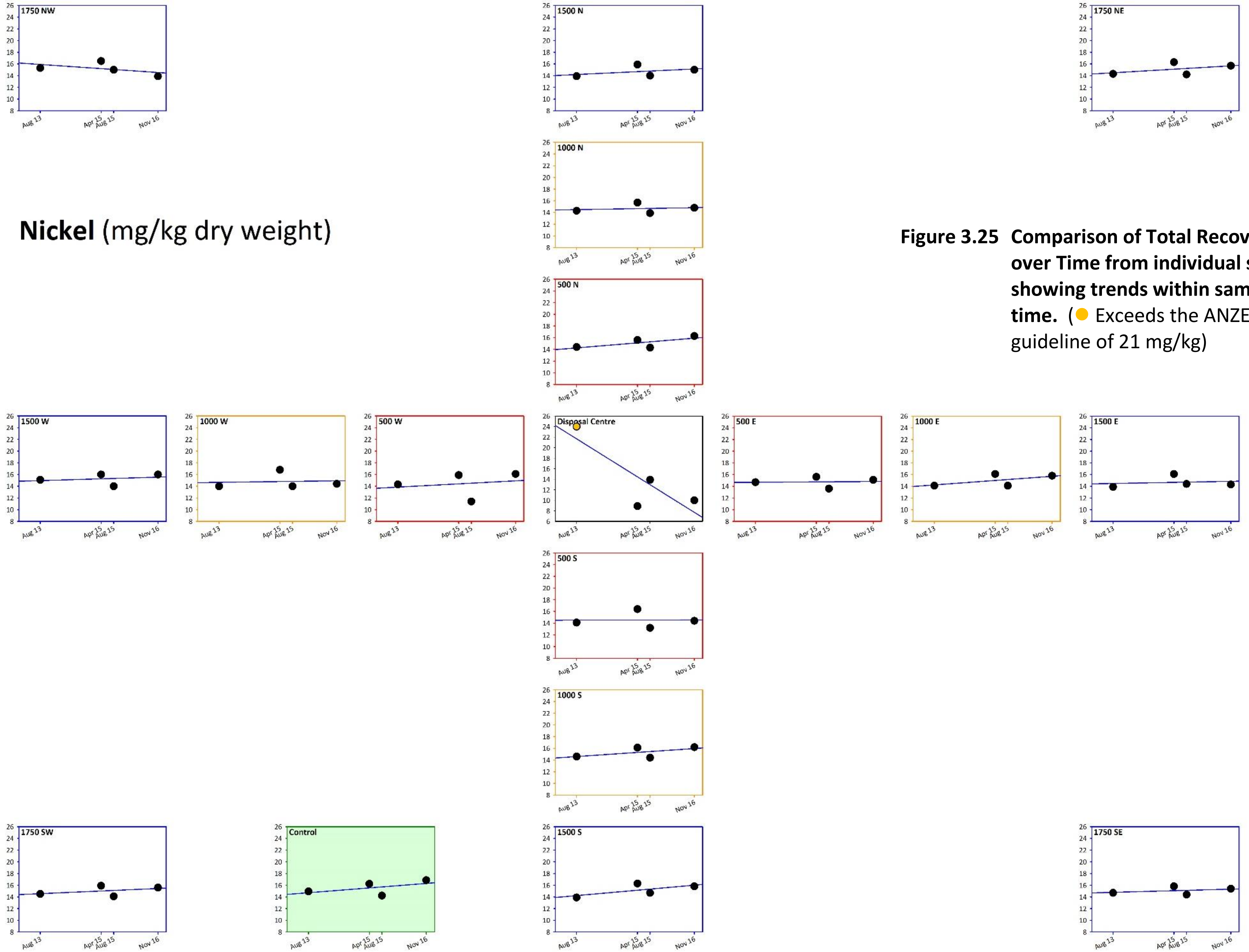


Figure 3.25 Comparison of Total Recoverable Nickel over Time from individual sample points, showing trends within sample points over time. (● Exceeds the ANZECC ISGQ-Low guideline of 21 mg/kg)

Zinc (mg/kg dry weight)

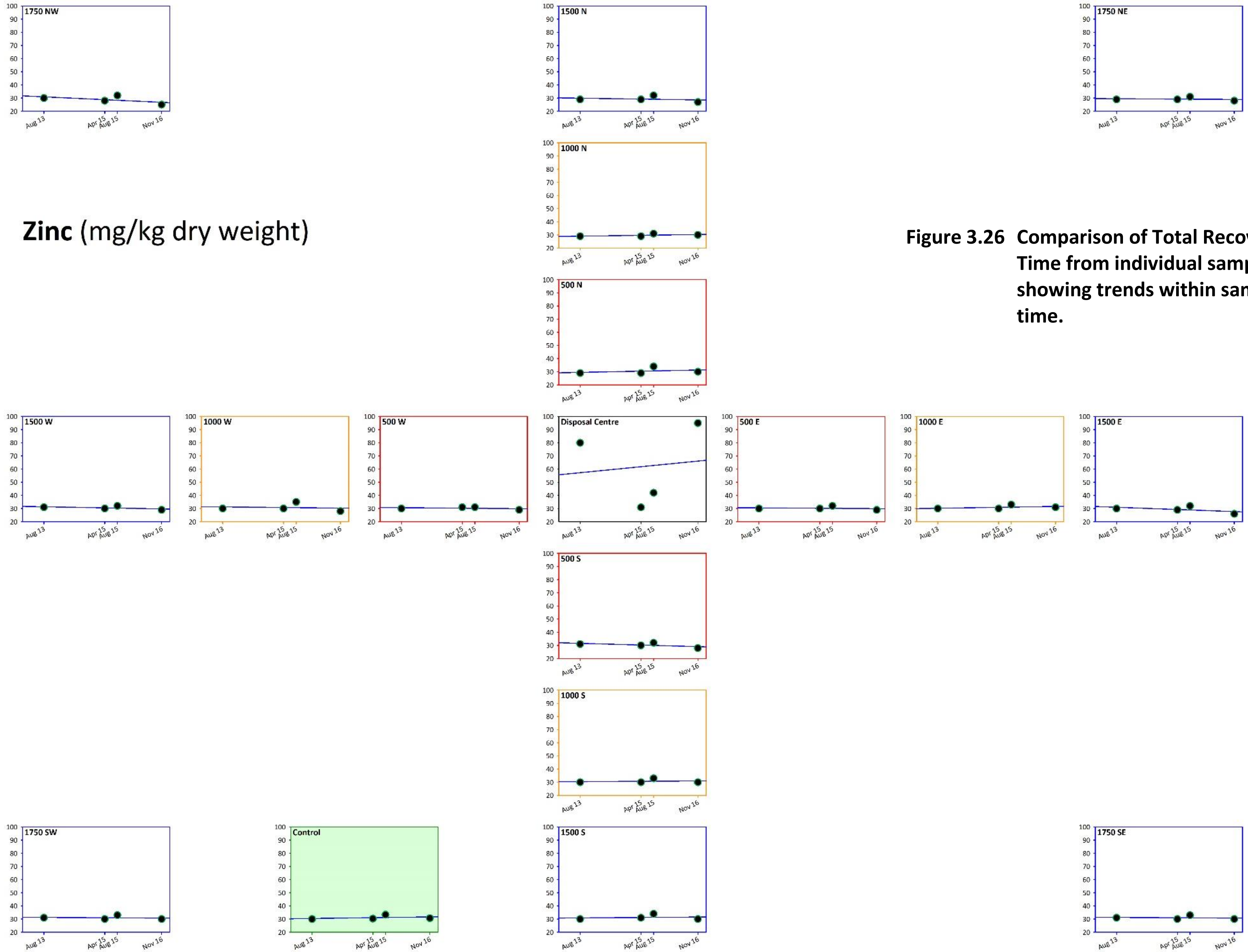


Figure 3.26 Comparison of Total Recoverable Zinc over Time from individual sample points, showing trends within sample points over time.

3.5 Biological Composition and Activity

Within the disposal area the seabed contains biota (benthic biota) that live within and on the surface of the sediment. In the water column above, there are likely to be fish and marine mammals that are transient, i.e. not present all the time and able to move in and out of the disposal area. The monitoring required by the MNZ Permit 568 and EPA consent EEZ900012 included observation and audio recording of marina mammals at the time of disposal events and the sampling of seabed sediment cores for benthic biota at intervals after cumulative trigger disposal volumes. Data collected to date in the disposal area are summarised and compared below.

3.5.1 Benthic Fauna

Prior to the MNZ Permit 568 being granted the proposed disposal area was monitored before and after the test disposal, under MNZ Permit 555. In June 2009 and January 2010, benthic cores were collected by the University of Waikato from locations across the disposal site as well as at nearby control sites (Figure 3.2). In June 2010, following disposal of dredged material, cores were again retrieved at locations shown in Figure 3.2. A single 70 mm diameter core was collected at each position. The samples were extruded and placed in labelled zip lock bags and frozen for long-term storage until further assessment was possible. Taxonomic identification was contracted to Bioresearches. Frozen samples were allowed to defrost in a bath of 10% formalin for 48 hours. The samples were then gently washed with tap water through a 0.5 mm mesh sieve to remove fine sediment. The retained material from each sample was preserved in 70% isopropyl alcohol. Organisms from each sample were then sorted out and placed into a labelled vile of 70% isopropyl alcohol. Taxonomic identification was then undertaken on each sample to the lowest possible level.

Raw data for the pre and post sampling are presented in Appendix 7 as Table 8.18 and Table 8.19. Species/taxa composition of the disposal area, based on samples collected, varies somewhat between the two sampling periods. Out of 49 total species/taxa identified at the disposal area, 21 were present in both the pre and post disposal samples. The majority of organisms collected in each sample were of the phylum Foraminifera. Foraminifera are very small amoeboid protists (in the order of 1 mm), would likely dominate in abundance in any sample from the area. It should be noted that the small sample size (70 mm diameter core, where most organisms would occur in the top 50-100 mm) might introduce a bias towards organisms of a smaller size without significant space requirements. However, the ~20 samples collected over a large area of the site are likely to be sufficiently representative of the types of organisms that are present there.

The MNZ Permit 568 and EPA consent EEZ900012 require monitoring of benthic biota at the control site, the disposal centre site, and a minimum of four sampling sites equally spaced on the boundary of the Disposal Area.

Additional sample sites may be required if contaminants analysed in the sediments at the other sites are;

i. above ANZECC ISQG-Low levels or
ii. shown to be moving from the site, (i.e. if the difference in sediment chemistry between any one sampling site and the control site is more than 50% of the difference between the control and disposal area centre samples).

As per the consent only the five sample sites (DC, 1500N, 1500E, 1500S, 1500W) within and around the disposal area, and the control site, as shown in Figure 3.27, were sampled following the disposal of 10,000 m^3, 50,000 m^3 and 100,000 m^3, but additional samples were also collected at the 500N, 500E, 500S and 500W sites following the disposal of 150,000 m^3.

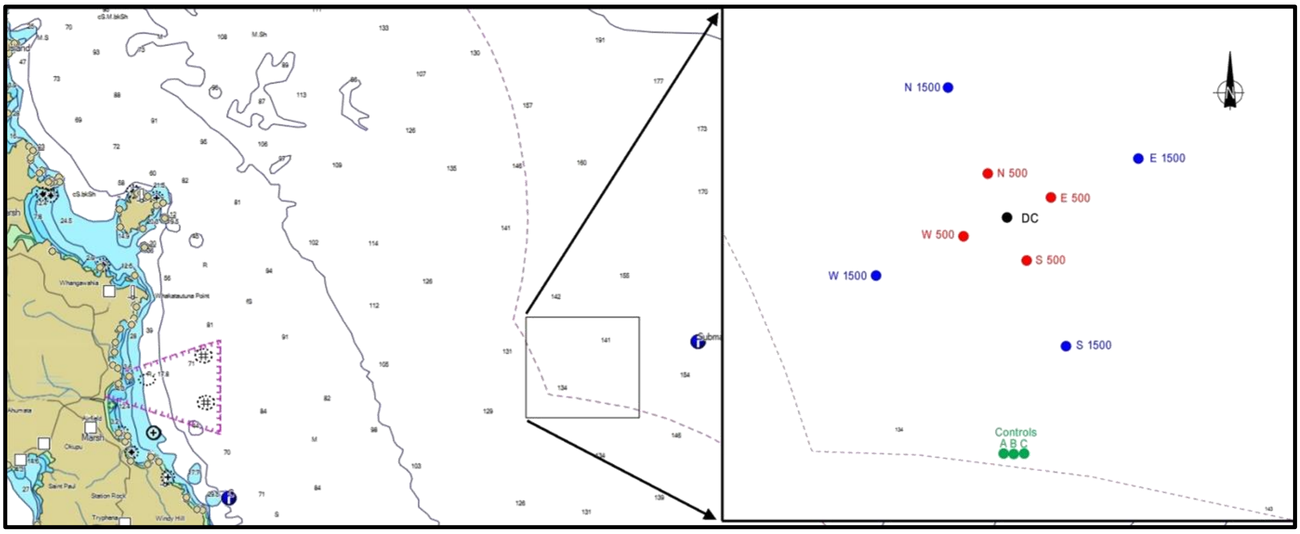


Figure 3.27 Seabed Benthic Biota Sampling Sites.

Sampling equipment varied slightly between sampling events with three replicate samples of four, 70 mm diameter gravity core samples were collected from each site during the 10,000 m^3 monitoring event. During the 50,000 m^3, 100,000 m^3 and 150,000 m^3 three replicate samples of two, 100 mm diameter gravity core samples were collected from each site. Typically the core depth was in the order of 150 mm, no attempt was made to standardise the core depth, other than to use the same equipment and insure cores were at least greater than bioturbation depth plus 25% (100mm depth). The bioturbation depth was determined to be in the order of 80 mm from the photographed sediment cores reported in section 3.3.1 above. The cores within each replicate were combined, labelled and then sieved as soon as practicable by washing each whole sample through 0.5 mm mesh sieves with seawater. All samples were sieved within six hours of collection. The material retained on the sieves was transferred to a polyethylene zip lock bag, and preserved with a 10% glyoxal, 70% ethanol sea water solution, sealed, placed in a second polyethylene zip lock bag and packed into a labelled plastic container for transportation to the laboratory. During the 100,000 m^3 sampling event the use of Rose Bengal stain was trialled to in an attempt to differentiate live from dead foraminifera, however the no benefit was observed with the use of Rose Bengal stain, therefore only intact and uneroded animals were counted.

QA/QC procedures

Routine internal QA/QC procedures involving the extraction and identification of biota from samples was conducted. In order to ensure the quality of sample sorting, a minimum of 10% of the samples (randomly selected) were re-sorted by a second experienced and independent sorter. The percentage sorting efficiency was calculated by:

$$(a /(a + b)) \times 100$$

Where:
a = the number of organisms originally sorted, b = the number of organisms found in re-sort

The minimum acceptable sorting efficiency was set at 95%. If the sorting efficiency was found to be below 95% all samples at that site were required to be resorted. Organisms found in the QA/QC re-sort were added to the original sorted sample for identification and enumeration. QA/QC was also carried out for species identification and enumeration. 10% of the samples from each site were randomly selected, re-identified and re-enumerated. The percentage identification and enumeration efficiency was calculated by:

$$((c - d) / c) \times 100$$

Where:
c = the number of organisms in the re-count, d = the number of errors

The minimum acceptable identification and enumeration efficiency was set at 95%. If the identification and enumeration efficiency was found to be below 95% all samples at that site were required to be re-counted and re-identified.

3.5.1.1 Results

Benthic biota results are summarised by calculation of numbers of taxa, numbers of individual organisms, and Shannon-Wiener diversity index for each replicate at each sampling station. The full results of the benthic biota sampling are presented in Appendix 7 as Table 8.20, Table 8.21, Table 8.22 and Table 8.23, and summarised in Table 3.3 along with the previous pilot study results. The summary statistics are compared graphically over time within sites in Figure 3.28, Figure 3.29 and Figure 3.30.

To comply with the consent the overall hypothesis to be tested was that no effects were present at and beyond the 1500 m boundary after each disposal trigger volume. This includes changes in the numbers of individuals, changes in the numbers of species, changes in diversity and multivariate changes in species composition and abundance. Additional hypotheses were investigated that numbers of individuals, numbers of species, diversity were not changing over time at each individual sample site.

Table 3.3 Total Numbers of Species and Animals - Summary Data (heading colours correspond with symbol colours in the following graphs)

Station	Total Number of Species											
	Average per sample						Per site					
	Pre	Post	10k	50k	100k	150k	Pre	Post	10k	50k	100k	150k
	Jun-09	Jun-10	Aug-13	Apr-15	Aug-15	Nov-16	Jun-10	Jun-10	Aug-13	Apr-15	Aug-15	Nov-16
DC	**11**	**7**	**7.33**	**3.67**	**19.00**	**0.67**	**11**	**7**	**17**	**11**	**36**	**2**
500 N	4.00	9.00				19.00	4	9				37
500 E	5.00	9.00				14.00	5	9				27
500 S	7.00	8.00				16.33	7	8				31
500 W	7.00	6.00				10.33	7	6				18
Average	**5.75**	**8.00**				**14.92**	**5.8**	**8.0**				**28.3**
95% CL	2.39	2.25				5.85	2.4	2.3				12.7
1500 N	7.00	10.00	27.00	23.33	21.00	18.00	7	10	42	41	37	37
1500 E	8.00	6.00	15.67	21.00	15.67	19.00	8	6	34	40	28	37
1500 S	9.00	6.00	18.00	24.00	13.67	18.33	9	6	37	42	25	31
1500 W	8.00	14.00	13.33	18.00	16.70	15.33	8	14	27	34	29	27
Average	**8.00**	**9.00**	**18.50**	**21.58**	**16.76**	**17.67**	**8.0**	**9.0**	**35.0**	**39.3**	**29.8**	**33.0**
95% CL	1.30	6.09	9.51	4.32	4.92	2.56	1.3	6.1	10.0	5.7	8.2	7.8
Control	**6.67**	**6.50**	**18.33**	**22.67**	**19.67**	**19.33**	**11**	**20**	**35**	**37**	**38**	**35**

Station	Total Number of Animals											
	Average per sample						Per square metre					
	Pre	Post	10k	50k	100k	150k	Pre	Post	10k	50k	100k	150k
	Jun-10	Jun-10	Aug-13	Apr-15	Aug-15	Nov-16	Jun-10	Jun-10	Aug-13	Apr-15	Aug-15	Nov-16
DC	**73**	**44**	**14.7**	**70.3**	**297.0**	**0.7**	**18969**	**11433**	**953**	**4478**	**18908**	**42**
500 N	45	98				120.0	11693	25465				7639
500 E	55	65				150.7	14291	16890				9592
500 S	60	96				161.7	15591	24945				10292
500 W	36	33				106.3	9354	8575				6769
Average	**49.0**	**73.0**				**134.7**	**12732.4**	**18968.7**				**8573.0**
95% CL	17.0	48.8				41.2	4414.7	12672.3				2617.9
1500 N	88	43	101.3	876.0	450.3	106.7	22866	11173	6583	55768	28669	6791
1500 E	58	33	35.0	610.0	586.3	195.7	15071	8575	2274	38834	37327	12457
1500 S	20	31	40.3	365.0	246.0	187.3	5197	8055	2620	23237	15661	11926
1500 W	42	69	30.7	332.7	302.0	131.7	10913	17929	1992	21178	19226	8382
Average	**52.0**	**44.0**	**51.8**	**545.9**	**396.2**	**155.4**	**13511.9**	**11433.2**	**3367.3**	**34754.3**	**25220.8**	**9889.0**
95% CL	45.5	27.8	52.9	401.8	243.9	68.6	11830.4	7224.9	3435.7	25578.4	15530.5	4368.6
Control	**16.7**	**10.7**	**40.7**	**347.3**	**353.0**	**159.0**	**4330.7**	**2771.7**	**2642**	**22112**	**22473**	**10122**

Station	Shannon Wiener Diversity Index					
	Pre	Post	10k	50k	100k	150k
	Jun-10	Jun-10	Aug-13	Apr-15	Aug-15	Nov-16
DC	**1.667**	**1.227**	**1.627**	**1.002**	**1.458**	**0.693**
500 N	0.800	1.285				1.501
500 E	0.944	1.416				1.066
500 S	1.312	1.256				1.208
500 W	1.509	1.323				1.375
Average	**1.141**	**1.320**				**1.288**
95% CL	0.520	0.111				0.303
1500 N	1.097	1.552	2.457	1.496	1.592	1.722
1500 E	1.181	1.323	2.293	1.105	1.203	1.594
1500 S	1.843	1.482	2.534	1.413	1.162	1.361
1500 W	1.558	1.741	2.074	1.308	1.461	1.383
Average	**1.420**	**1.525**	**2.340**	**1.331**	**1.355**	**1.515**
95% CL	0.551	0.275	0.324	0.269	0.328	0.276
Control	**1.635**	**1.649**	**2.432**	**1.401**	**1.357**	**1.791**

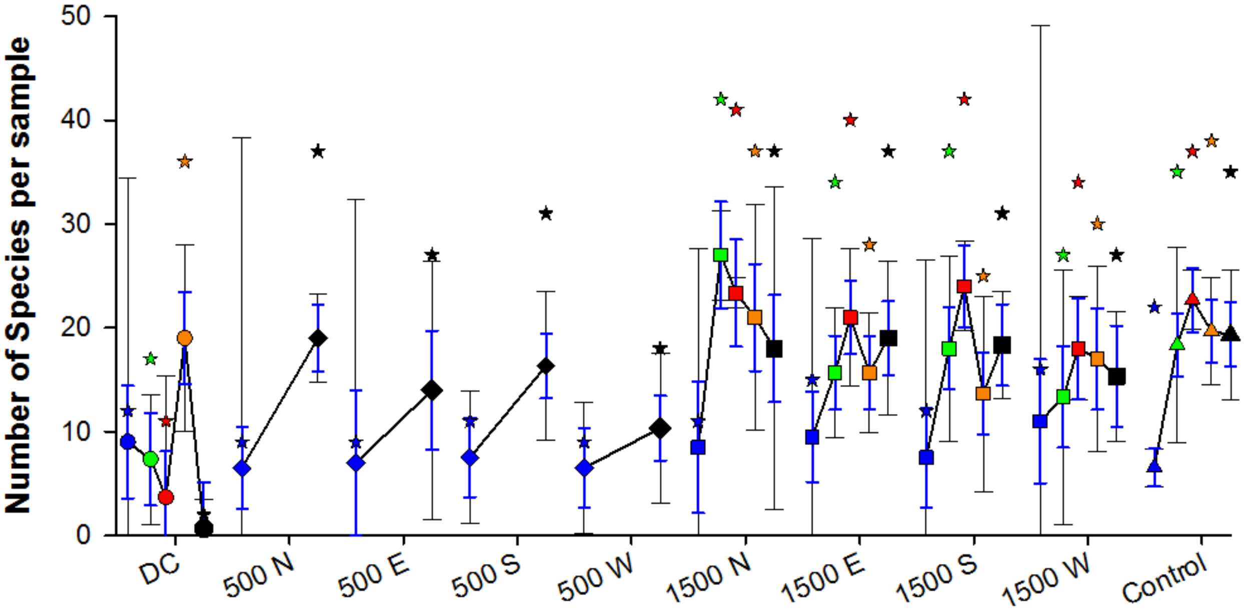


Figure 3.28 Comparison of average Number of Species per sample Over Time (± 95% CI and ± $HSI_{0.05}$, ● pilot, ● 10k, ● 50k, ● 100k, ● 150k, total species per site ★).

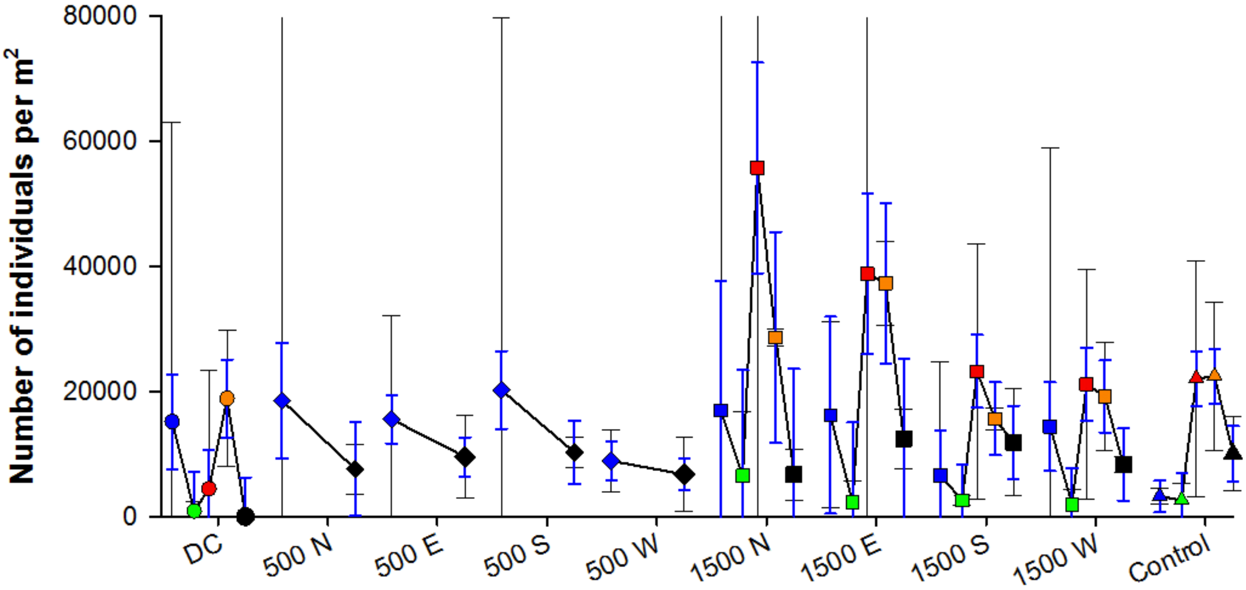


Figure 3.29 Comparison of average Number of Individuals per m² Over Time (± 95% CI and ± $HSI_{0.05}$, ● pilot, ● 10k, ● 50k, ● 100k, ● 150k).

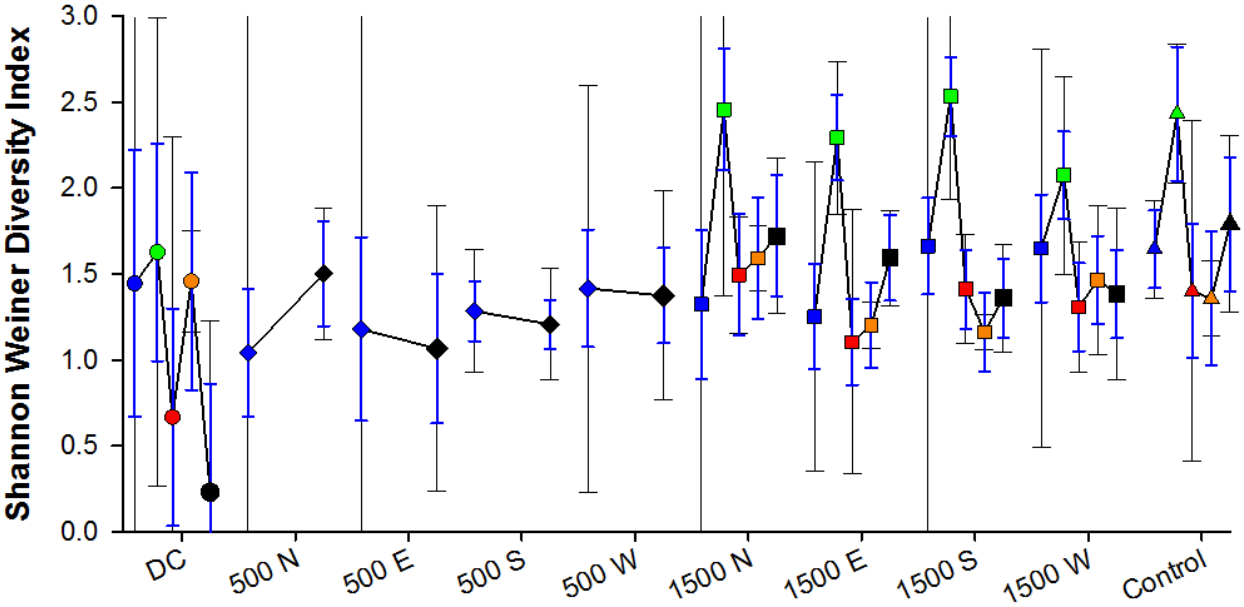


Figure 3.30 Comparison of average Shannon Weiner Diversity Index per sample Over Time (± 95% CI and ± $HSI_{0.05}$, ● pilot, ● 10k, ● 50k, ● 100k, ● 150k).

3.5.1.2 Current Benthic Biota following the 150,000 m^3 Survey

Site DC had a very low diversity (0.7 species per replicate, 2 species in total) and a very low abundance (42 per m^2). This is lower than previously recorded from the disposal centre site however not unexpected as a result of the disposal of dredge spoil at the site. Only two individuals were found, a mysid shrimp (21 per m^2) and a foraminifera *Pyrgo* sp. (21 per m^2).

Site 500 N had a moderate to high diversity (19.0 species per replicate, 37 species in total) and a moderate to high abundance (7,639 per m^2). The biota was numerically dominated by the foraminifera, *Lenticulina* sp. (5,029 per m^2). Of the other species present, in much lower numbers, the foraminifera, *Alabamina* sp. (531 per m^2), *Cibicidoides* sp. (488 per m^2), *Pyrgo* sp. (318 per m^2) and *Quinqueloculina suborbicularis* (149 per m^2) had significant contributions. Species from other taxonomic groups such as polychaete worms, nemerteans, molluscs, amphipods, isopods cumaceans, ostracods, tanaids and ophiuroid starfish were present but at very low numbers.

Site 500 E had a moderate to high diversity (14.0 species per replicate, 27 species in total) and a moderate to high abundance (9,592 per m^2). The biota was numerically dominated by the foraminifera, *Lenticulina* sp. (7,279 per m^2). Of the other species present, in much lower numbers, the foraminifera, *Alabamina* sp. (467 per m^2), *Cibicidoides* sp. (233 per m^2), *Pyrgo* sp. (552 per m^2) and *Quinqueloculina suborbicularis* (255 per m^2) had significant contributions. Species from other taxonomic groups such as polychaete worms, molluscs, amphipods, isopods and tanaids were present but at very low numbers.

Site 500 S had a moderate to high diversity (16.3 species per replicate, 31 species in total) and a high abundance (10,292 per m^2). The biota was numerically dominated by the foraminifera, *Lenticulina* sp. (7,257 per m^2). Of the other species present, in much lower numbers, the foraminifera, *Alabamina* sp. (1,082 per m^2), *Cibicidoides* sp. (594 per m^2), *Pyrgo* sp. (318 per m^2) and *Quinqueloculina suborbicularis* (127 per m^2) had significant contributions. Species from other taxonomic groups such as polychaete worms, sipunculid worms, amphipods, isopods, cumaceans, tanaids and ophiuroid starfish were present but at very low numbers.

Site 500 W had a moderate diversity (10.3 species per replicate, 18 species in total) and a moderate abundance (6,769 per m^2). The biota was numerically dominated by the foraminifera, *Lenticulina* sp. (4,032 per m^2). Of the other species present, in much lower numbers, the foraminifera, *Alabamina* sp. (891 per m^2), *Cibicidoides* sp. (785 per m^2), *Pyrgo* sp. (446 per m^2) and *Quinqueloculina suborbicularis* (127 per m^2) and the polychaete worm, *Lumbrinereis* sp. (127 per m^2) had significant contributions. Species from other taxonomic groups such as polychaete worms, isopods, cumaceans, mysids, ostracods and ophiuroid starfish were present but at very low numbers.

Site 1500 N had a moderate to high diversity (18.0 species per replicate, 37 species in total) and a moderate abundance (6,791 per m^2). The biota was numerically dominated by the foraminifera, *Lenticulina* sp. (3,629 per m^2), with significant contributions from *Cibicidoides* sp. (743 per m^2), *Alabamina* sp. (806 per m^2), *Pyrgo* sp. (361 per m^2) and *Quinqueloculina suborbicularis* (106 per m^2). Species from other taxonomic groups such as polychaete worms, sipunculid worms, amphipods, isopods, cumaceans, mysids, ostracods, ophiuroid starfish and a sponge were present but at very low numbers.

Site 1500 E had a moderate to high diversity (19.0 species per replicate, 37 species in total) and a high abundance (12,457 per m^2). The biota was numerically dominated by the foraminifera, *Lenticulina* sp. (6,133 per m^2), with significant contributions from *Cibicidoides* sp. (2,525 per m^2), *Alabamina* sp. (1,804 per m^2), *Pyrgo* sp. (615 per m^2) and *Quinqueloculina suborbicularis* (255 per m^2). Species from other taxonomic groups such as polychaete worms, amphipods, isopods, cumaceans, ophiuroid starfish and a sponge were present but at very low numbers.

Site 1500 S had a moderate to high diversity (18.3 species per replicate, 31 species in total) and a high abundance (11,926 per m^2). The biota was numerically dominated by the foraminifera, *Lenticulina* sp. (7,979 per m^2), with significant contributions from *Cibicidoides* sp. (997 per m^2), *Alabamina* sp. (700 per m^2), *Pyrgo* sp. (700 per m^2), *Quinqueloculina suborbicularis* (255 per m^2) and *Nummoloculina contraria* (191 per m^2). Species from other taxonomic groups such as polychaete worms, amphipods, ostracods and ophiuroid starfish were present but at very low numbers.

Site 1500 W had a moderate diversity (15.3 species per replicate, 27 species in total) and a moderate abundance (8,382 per m^2). The biota was numerically dominated by the foraminifera, *Lenticulina* sp. (5,411 per m^2), with significant contributions from *Cibicidoides* sp. (912 per m^2), *Alabamina* sp. (488 per m^2), *Pyrgo* sp. (531 per m^2), *Quinqueloculina suborbicularis* (233 per m^2), *Nummoloculina contraria* (127 per m^2) and *Triloculina insignis* (106 per m^2). Species from other taxonomic groups such as polychaete worms, amphipods, isopods, mysids, ostracods and a sponge were present but at very low numbers.

The control site had a moderate diversity (19.3 species per replicate, 35 species in total) and a high abundance (10,122 per m^2). The biota was numerically dominated by the foraminifera, *Lenticulina* sp. (4,944 per m^2), with significant contributions from *Alabamina* sp. (1,146 per m^2), *Pyrgo* sp. (1,316 per m^2), *Cibicidoides* sp. (594 per m^2), *Quinqueloculina suborbicularis* (615 per m^2), *Nummoloculina contraria* (127 per m^2) and *Triloculina insignis* (255 per m^2). Species from other taxonomic groups such as polychaete worms, sipunculid worms, molluscs, amphipods, isopods, cumaceans, mysids, ostracods, anemones, ophiuroid starfish and a sponge were present but at very low numbers.

The numbers of species and individuals increase with distance from the disposal centre site. The average number of species and individuals at the 500 m and 1500 m sites were not statistically significantly different from the control Site, indicating little, if any, effect beyond the immediate disposal centre site, as seen in the sediment chemistry data. The average diversity index increases with distance from the disposal centre site, with the disposal centre site statistically significantly lower compared with all the other sites and the average for the 500 m sites statistically significantly lower than the control site. The average diversity index for the 1500 m sites was not statistically significantly different from the control site.

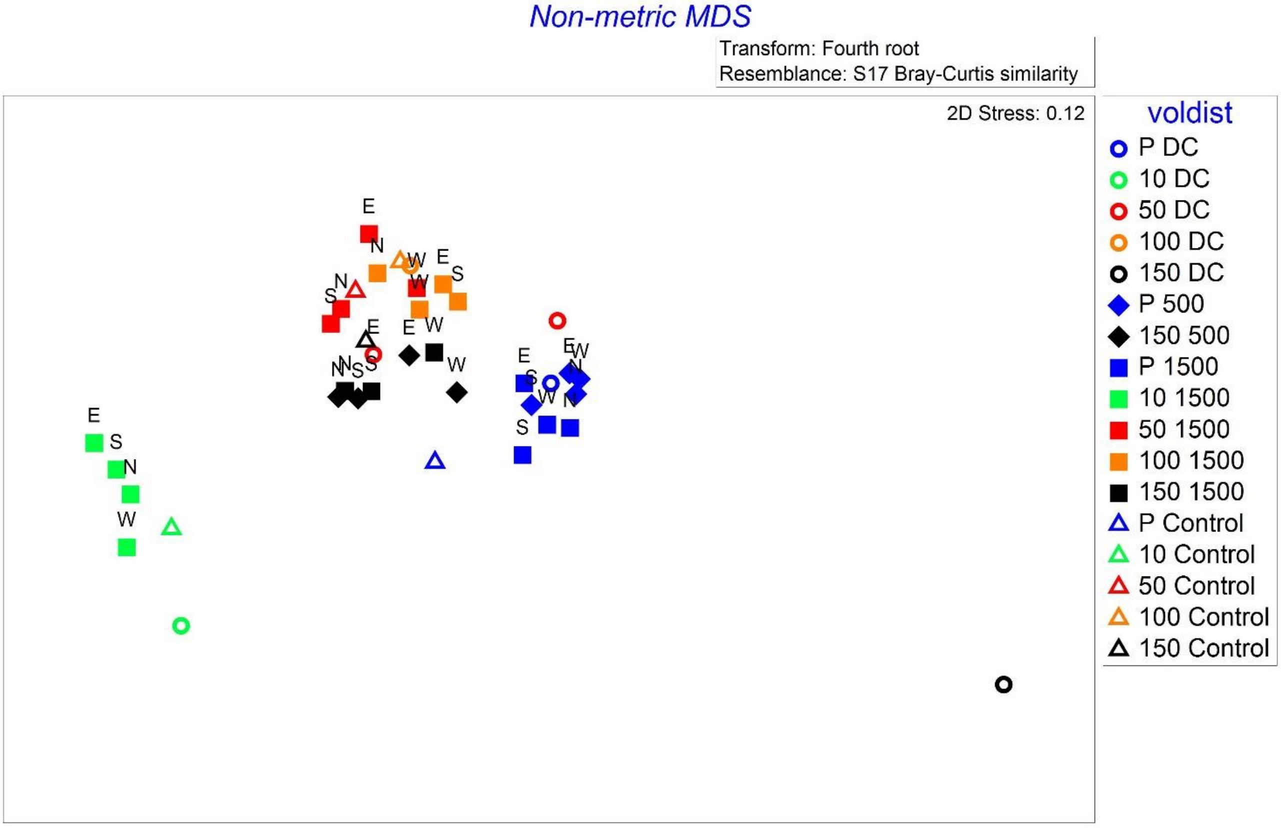
There is no indication the disposal of sediment at the centre of the disposal area has adversely affected benthic biota beyond the disposal area boundary.

No exotic pest species were recorded in the post 150,000 m^3 survey.

The majority of species are present at very low numbers, which limits the statistical analysis, with the exception of foraminifera. When the average numbers of individuals of foraminifera are compared, the numbers increase with distance from the disposal centre site. The average numbers of foraminifera are very similar between the 1500 m sites and the control site. However, the most abundant species of foraminifera (*Lenticulina* sp.) is absent from the disposal centre site but decreases in abundance, by 16%, from the 500 m sites to the control site. Other than the absence of species from the disposal centre site, the disposal sediment is not considered to have had an impact on any individual species recorded.

To further investigate the patterns in the benthic biota data as a whole, the data were subjected to multivariate analysis. Prior to analysis all the benthic biota data collected to date were standardised to numbers per square metre, and the replicate data averaged at each site. This data set was then loaded into the software package Primer 7. The data were then transformed using a fourth root transformation to reduce the effects of the very abundant species. A resemblance matrix was then calculated using the Bray Curtis similarity measure. The resemblance matrix was then analysed using the non-metric multiple dimensional scaling (MDS) to provide 2D and 3D representations of the similarities between samples. The closer together the points for each sample are, the more similar the benthic biota community structure is between the samples. The Primer MDS analysis provides a stress value, which is an indication of how well the plots fit the real data. Stress values <0.05 provide excellent representation with no prospect of misinterpretation, <0.1 corresponds to a good ordination with no real prospect of misleading interpretation, <0.2 still gives a potentially useful 2D picture, though for values in the upper end of this range little reliance should be placed on the detail of the plot. The results of the MDS analysis are shown in Figure 3.31, the symbol and colour patterns have been maintained from the univariate plots above. Both the 2D and 3D graphs show that the data from each survey are closely grouped and in some cases (pre and 10,000 m^3 survey) well separated from other surveys. The 50,000 m^3, 100,000 m^3 and 150,000 m^3 survey data appear to overlap in the 2D graph indicating the community structure is similar. The DC sample point (O) appears to be separated from the other data within the survey for the 10,000 m^3, 50,000 m^3 and 150,000 m^3 surveys. The data are best represented in the 3D plot with its lower stress.

The axis on the plots are not related to any variable and are numberless. Data from the pre and the post 150,000 m^3 surveys have been further investigated by rotation and the results are shown in Figure 3.32 and Figure 3.33. These two sets of data were retained as they both contained more than just DC, 1500 m and control site data.



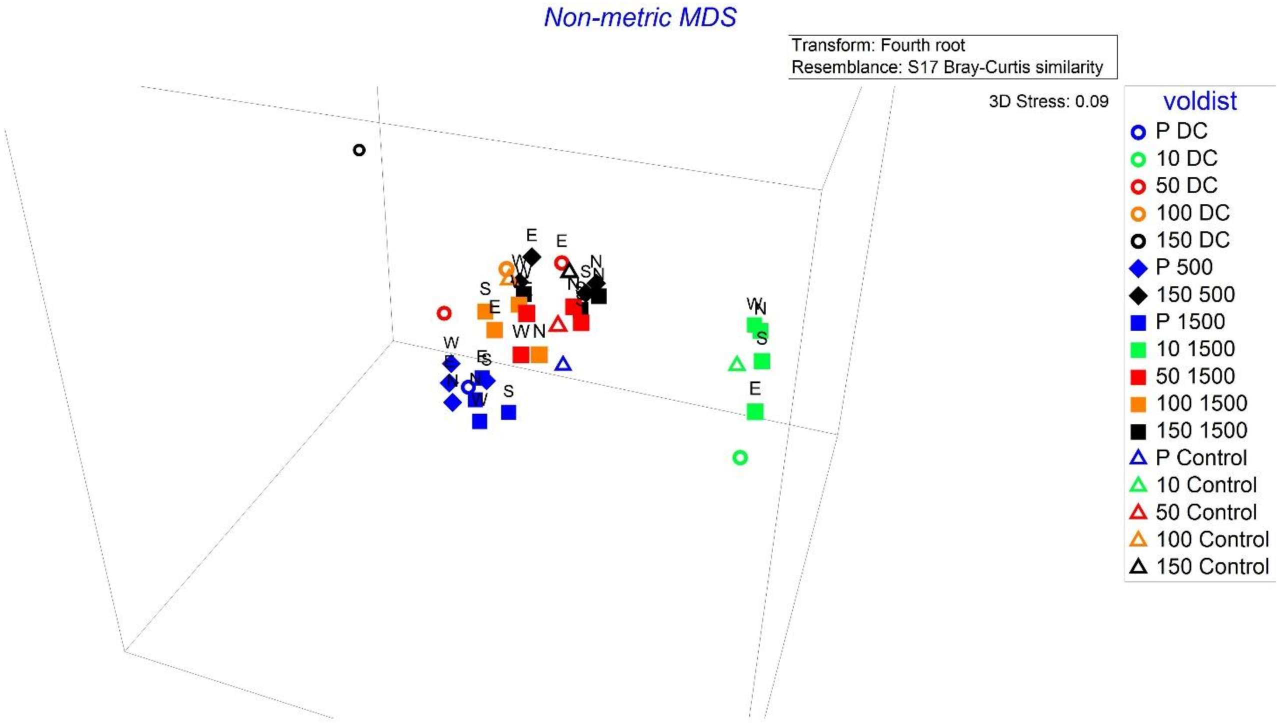


Figure 3.31 MDS plots of site averaged area standardised benthic biota data. (○ DC, ◆ 500 m, ■ 1500 m, △ Control, ● pilot, ● 10k, ● 50k, ● 100k, ● 150k)

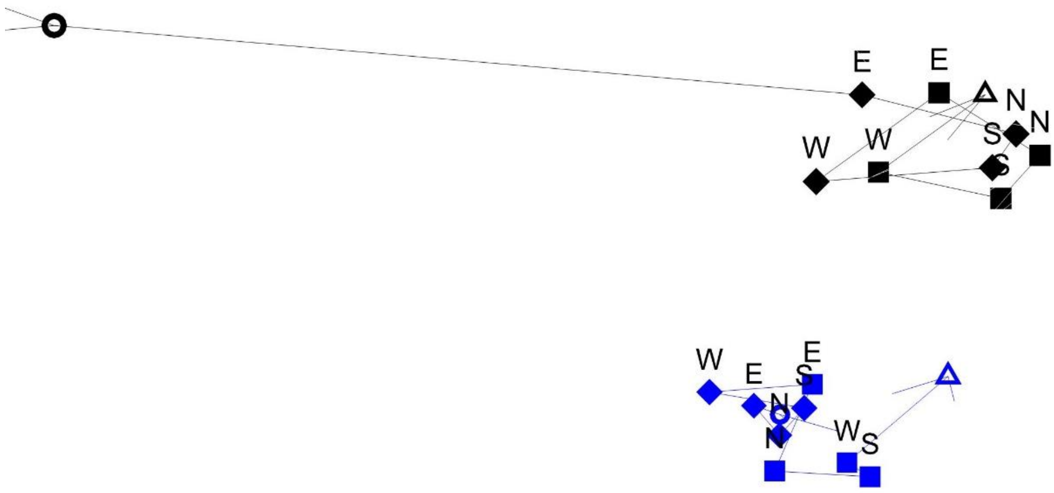


Figure 3.32 MDS plot of site averaged area standardised benthic biota data for the pre disposal and 150,000 m³ post disposal. (○ DC, ◆ 500 m, ■ 1500 m, △ Control, ● pilot, ● 150k)

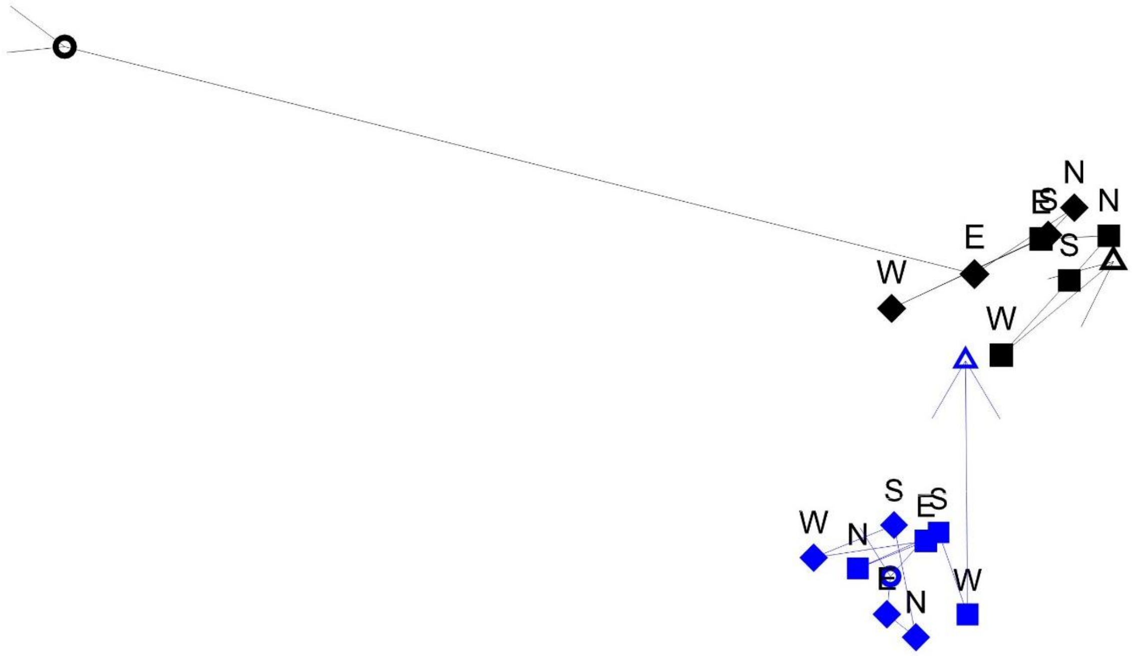


Figure 3.33 MDS plot of site averaged area standardised benthic biota data for the pre disposal and 150,000 m³ post disposal. (○ DC, ◆ 500 m, ■ 1500 m, △ Control, ● pilot, ● 150k)

In Figure 3.32 both the pre disposal data (●) and post 150,000 m³ data (●) shows that the 500 m and 1500 m data are very similar, the difference is in the control and disposal centre site data in relation to the 500 m and 1500 m data. In the pre disposal data, the disposal centre site is more similar to the 500 m and 1500 m data whereas the control data is shown as an outlier. This is somewhat expected as the control sites were located further inshore in shallower water compared to the other sites and the disposal site had not yet received disposal material. Shallower sites are expected to have more wave disturbance and terrigenous inputs and thus a different species composition. In the post 150,000 m³ data, the control data is more similar to the 500 m and 1500 m data whereas the disposal centre site is shown as an outlier. This is reflective of the disposal activity and more suitable control site location. In addition, the post 150,000 m^3 data shows the similarity of biota by compass direction, with 500 W most similar to 1500 W, 500 E most similar to 1500 E while 500 N, 500 S, 1500 N and 1500 S were all similar. This has been interpreted as an effect of depth differences onshore and offshore, and similarity along shore. However, when shown from a different direction (Figure 3.33) there is a pattern of difference between the 500 m and 1500 m sites in the post 150,000 m^3 data. This is potentially an indication of some stress from the disposal activity on the 500 m samples. The MDS does not allow statistical significance testing of the differences but rather allows the patterns in data to be observed. The univariate statistical testing of species diversity indicated some statistically significant differences between the disposal centre site, 500 m, 1500 m and control sites; the plots shown in Figure 3.32 and Figure 3.33 appear to be consistent with this. The differing angle of observation did not separate the 500 m and 1500 m sample points for the pre disposal data.

3.5.1.3 Changes in Benthic Biota Over Time

Due to differences in the methodologies and site locations, the pilot trial benthic biota data and the post-permitting benthic biota data are not directly comparable. The abundance of both the pre disposal data and the post disposal data have been normalised to area to allow some comparison between the data sets but any conclusions should be interpreted with some caution. Species numbers cannot so easily be normalised therefore the numbers as reported per study have been compared, similarly for the diversity index.

At the disposal centre site, numbers of species, individuals and diversity index have declined statistically significantly following disposal as expected (Figure 3.28, Figure 3.29, Figure 3.30, Bioresearches, 2017a). The disposal centre site has had continued interment disposal of a cumulative 150,000 m^3 of material over a period of three years. The almost constant burial and reburial of biota has predictably resulted in a significantly reduced community of benthic biota. The higher numbers recorded during the 50,000 m^3 study was likely the result of longer periods between disposal events, while those recorded during the 100,000 m^3 study are likely a result of variation in the location of the disposal centre sampling site; samples were not able to be collected from the disposal centre location but the closest possible location of 150 m east was used.

At the control site, the numbers of species increased statistically significantly between the pre disposal and 10,000 m^3 post disposal surveys. But the number of species post disposal has not varied statistically significantly between consecutive surveys. The differences between the pre and post disposal numbers of species is likely the result of the different survey methods with the relatively small sample size and none replication in the pre disposal sampling resulting in an under estimation of biota present. The number of individuals increased statistically significantly between the 10,000 m^3 and 50,000 m^3 post disposal surveys and is likely the result of the way in which the foraminifera were enumerated. The numbers between the 50,000 m^3 and 100,000 m^3 post disposal surveys did not change statistically significantly, however the numbers halved between the 100,000 m^3 and 150,000 m^3 post disposal surveys. Assuming the changes in numbers are real and not the result of enumeration variation, this indicates that the numbers of individual varies statistically significantly naturally over time. This not unusual in that species composition and abundance can and does vary seasonally. The timing of sampling varies seasonally, and cannot be standardised under the current consent, as sampling is timed to occur after a trigger volume not a time period. The data available are not suitable to test for seasonality. The large increase in abundance between the 10,000 m^3 and 50,000 m^3 post disposal surveys resulted in a statistically significant decrease in the diversity index. There were no statistically significant differences in diversity indices between the 50,000 m^3, 100,000 m^3 and 150,000 m^3 surveys.

At the 1500 m sites the numbers of species increased between the pre and 10,000 m^3 post surveys, again, likely the result of the different survey methods and locations between pre and post disposal. The four post disposal surveys have shown little statistically significant variation within sites. At 1500N the numbers of species were statistically significantly lower in the 150,000 m^3 survey compared to the 10,000 m^3 survey. At 1500S the numbers of species were statistically significantly higher during the 50,000 m^3 survey than the 100,000 m^3 surveys, and in general followed the pattern of changes at the control site.

Like the control site, the numbers of individuals decreased at all the 1500 m sites the between the pre and 10,000 m^3 surveys, increased between the 10,000 m^3 and 50,000 m^3 surveys and, like the control site, this is likely due to the way in which the foraminifera were enumerated. The numbers of individuals decreased statistically significantly between the 50,000 m^3 and 100,000 m^3 surveys at the 1500N site. This was the result of a 50% reduction in the numbers of the six most abundant foraminifera species (*Lenticulina* sp., *Elphidium* sp., *Cibicidoides* sp., *Alabamina* sp., *Pyrgo* sp. and *Quinqueloculina suborbicularis*). The cause of the reduction is unknown but there is no evidence it is related to sediment quality effects of disposed sediments. The numbers of individuals decreased at all 1500 m sites between the 100,000 m^3 and 150,000 m^3 surveys, as did the numbers at the control site. The similarity of the variation between sampling events at the 1500 m sites and the control site indicates the factors controlling the species abundance at these sites is similar or the same. If the control site is unaffected by the disposal material, as it should be by design, the 1500 m sites are also unaffected by disposal material as they vary in a similar way. Similarly, the diversity index values vary at the 1500 m sites in a similar way to the control site indicating that any statistically significant differences are natural or related to minor variations in the sampling methods and not the disposal material.

Limited data is present for the 500 m sites with just the pre disposal and post 150,000 m^3 disposal samples collected. As previously mentioned, the pre disposal samples were small and may have under estimated the numbers of species. Therefore, the increases in number of species shown in Figure 3.28 between all 500 m the pre disposal (◆) and post 150,000 m^3 disposal (◆) surveys, may not be as pronounced. The decreases in number of individuals per square meter recorded between all the 500 m sites between the pre disposal and post 150,000 m^3 disposal surveys were not statistically significant. Similarly, the differences in diversity index values at the 500 m sites between the pre disposal and post 150,000 m^3 disposal surveys were not statistically significant, with the 500N increasing slightly and the other 500 m sites decreasing slightly. The benthic biota data from the 500 m sites is insufficient to determine any long term trends over time but the most recent data does not indicate any significant adverse effects.

The MDS plots shown in Figure 3.31 indicate the pre disposal samples were separate from the post 10,000 m^3 samples, while the samples from the post 50,000 m^3, 100,000 m^3 and 150,000 m^3 surveys were more similar to each other and separate from the other two survey groups.

Based on the assessments above, it is concluded that no effect as a result of the disposal activity has occurred at or beyond the 1500 m disposal boundary during or following the disposal of the 150,000 m^3 of sediment between November 2012 and November 2016.

3.5.2 Mammals

Marine mammals, such as whales and dolphins, use the northeast region of New Zealand as part of a migratory path and/or feeding and nursery grounds. Disposal operations such as the presence of a vessel and the periodic addition of a large quantity of sediment to the water column may disrupt their natural behaviours by forcing the animals off their normal migratory path. However, studies have shown that the presence of these animals in the vicinity of the site is not common.

Using a pair of hydrophones, McDonald (2006) attempted to identify and quantify baleen whale songs east of Great Barrier Island. The hydrophones were deployed 600 m apart and 5 km east of Great Barrier Island in 70 m of water. A year (1997) of acoustical data recorded by these hydrophones was analysed to examine seasonal variation in migration patterns for baleen whales. Table 3.4 includes the findings of this year long study.

Table 3.4 Findings of a baleen whale song study off the northeast coast of New Zealand. (Source: McDonald, 2006)

Baleen whale	Number of songs recorded	Season	Location	Misc
Bryde's whale *Balaenoptera edeni brydei*	> 140 (2 types)	Year round and seasonally	Inshore and offshore (outside the continental shelf)	Possibly, some individuals are travelling inshore seasonally and some individuals are staying offshore
Humpback whale *Megaptera novaeangliae*	65	February through September	Not specified	Possible north bound migration of males
Fin whale *Balaenoptera physalus*	26	June through September	Offshore (outside continental shelf)	
Blue whale *Balaenoptera musculus intermedia*	10	Most May through July	Offshore (outside continental shelf)	

Studies of dolphins in New Zealand have determined that the common dolphin, *Delphinus delphis* is commonly found north of the Subtropical Convergence (approximately 42°S) (Gaskin, 1968 and Neumann, *et al*., 2002). One study in particular determined that the common dolphin regularly moves from the Hauraki Gulf to areas of the Coromandel coastline and back (Neumann, *et al.,* 2002). During the post 100,000 m^3 disposal survey, a small pod of approximately six common dolphins were observed within the disposal area.

A study of Bottlenose dolphins, *Tursiops truncatus* in the Hauraki Gulf (Dwyer, 2014, Dwyer, *et al.*, 2014, Dwyer, *et al.*, 2016,) showed a hot spot on the western side of Great Barrier Island with Bottlenose dolphins recorded on 19 of 20 survey months (Dwyer, 2014, Dwyer *et al.,* 2014, Dwyer *et al.,* 2016). Large groups of more than 50 individuals were reported in the Colville Channel. The study showed dolphins were more likely encountered in deeper waters in summer and shallower water in winter. It is possible that during these movements, the animals may visit areas very close to the proposed site (Dwyer, 2014, Dwyer *et al.,* 2014, Dwyer *et al.,* 2016).

Visser (2000) determined that out of a population of approximately 115 orcas in New Zealand waters, the highest number of sightings were in the northeast coast region. The majority of the sightings were in nearshore areas (Visser, 2000). Therefore, it is not likely that New Zealand orcas, *Orcinus orca* will be present except perhaps for transient passage at the proposed site or in surrounding waters.

On the survey cruise of November, 2007, one whale was observed travelling south near the site. Its path was east of Great Barrier Island and approximately 500 m west of the disposal area. To the untrained eye, it was guessed to be a humpback whale. Additionally, several groups of common dolphins were observed, but they were travelling in waters west of Great Barrier Island and within the Hauraki Gulf. Based on previous studies and field observations from a survey taken on November 30, 2007, it is possible that Bryde's whales, Humpback whales, Blue whales and common dolphins may transit the region of the proposed disposal site, but there are no indications that the area is being used as a nursery ground by any of these species.

In July 2017 a Blue whale was spotted traveling south in the Hauraki Gulf, its presence inside the gulf is unusual, but indicative of their transit through or past the region during the winter months.

Prior to each barge disposal of material, a 30 minute hydrophone recording has been made. All but one of these recordings have been just background noise. On one occasion a sound assumed from a marine mammal was heard, the barge crew then recorded for an additional 30 minutes in which no mammal noises were heard, unfortunately the second recording was over the previous one with mammal sounds. Therefore with recording lost it is not possible to identify the species heard.

3.5.3 Fin fish

Very few pelagic surveys have been undertaken in the region of the NDA. As part of a marine reserve assessment approximately 20 km northwest of the NDA, a study done by Sivaguru and Grace (2002) included identification of fin fish recorded by a ROV/video survey. At the eastern most and deepest video site, only two fish were observed, a sea perch and one unidentified species (Table 3.5). The habitat in the NDA is somewhat different to that observed to the north, with only soft muddy sediment present in the NDA. The lack of sea floor habitat conducive to feeding, suggests that bottom feeding fin fish are unlikely to inhabit the muddy bottom at the disposal area. No surveys of midwater pelagic fish have been conducted. Observation of depth sounder during the post disposal benthic sampling studies showed no or very few fish present. However, fish were observed on the sounder in November 2007 during the pre-disposal surveys.

Table 3.5 Fin fish identified from the easternmost site of the DOC commissioned survey using ROV/video. (Source: Sivaguru and Grace, 2002**)**

Depth	120 m	
Site characteristics	Scattered silt-covered boulders on muddy sediment bottom	
Taxa	**Species name (if available)**	**Common name (if available)**
Osteichthyes (Fishes)	*Heliocolenus percoides*	Jock Stewart or Sea Perch
		unidentified fish species

Despite the lack of specific data on the composition and abundance of fishes present in the disposal area, pelagic fish are expected to use the area. During summer and autumn especially, warm water currents from the north bring many pelagic species such as tunas and marlin closer to shore in the waters of the northeast coast (Francis *et al*., 1999).

In general, there are not expected to be a significant number of fin fish as bottom feeders at the proposed site. Reef fish will stay closer to shore where reef habitats are more prevalent and large pelagic species may migrate in during warmer seasons, but these occurrences are likely to be rare and mostly seasonal, but as detected by the echo sounder, schools of fish do rarely pass by in the water column of the disposal area.

4. EVALUATION OF POTENTIAL IMPACTS

4.1 Contaminant Leaching

Leaching is the process of releasing contaminants in the sediments to the surrounding water. As outline in section 2.1 and in the "New Zealand Guidelines for Sea Disposal of Waste" (MSANZ, 1999) dredge sediments are screened based on total sediment quality. If contaminant concentrations exceeded the guideline values in Table 2.1 then additional testing in the form of elutriate testing was conducted. The elutriate test simulates the release of contaminants from a waste during and after disposal. Release can occur by physical processes (e.g. directly from sediment pore water) or by a variety of chemical changes (e.g. the oxidation of metal sulphides and the release of contaminants adsorbed to particles or organic matter).

Pre characterisation testing of the dredge material included elutriate testing, at all source sites to some extent. At Sandspit marina sediments from five sites were subjected to elutriation analysis for arsenic and nickel. The results showed that both arsenic and nickel were released in the process but the concentrations allowing for initial dilution were well below the ANZECC marine water quality triggers or the USEPA chronic continuous exposure criterion. Other metals were not tested as they were below the ANZECC ISQG Low trigger values.

At Hobsonville Point marina seven sediment samples were subjected to elutriation analysis for ammoniacal-nitrogen and metals, and five samples were subjected to elutriation analysis for tributyl tin. The results showed that as expected ammoniacal-nitrogen was released from some sites, arsenic was released from all but one site and copper was only released from two sites. The concentrations of ammoniacal-nitrogen and copper exceeded the ANZECC marine water quality triggers at one site each. However after allowing for an estimated initial dilution of 10 times the concentrations were below the ANZECC marine water quality triggers. No detectable concentrations of tributyl tin were released.

At Hobsonville marina one samples was subjected to elutriation analysis for arsenic and tributyl tin in 2014, and two samples were subjected to elutriation analysis for arsenic and metals in 2016. In 2014 no detectable concentrations of arsenic or tributyl tin were released. In 2016 no detectable concentrations of metals were released, however arsenic was released from both samples. The concentration of arsenic did not exceed the USEPA chronic continuous exposure criterion, indicating no adverse effects were likely.

At Halfmoon Bay marina eight sites were subjected to elutriation analysis for metals (copper, lead, mercury, nickel, zinc), four samples were tested for tributyl tin and two samples were tested for arsenic. No detectable concentrations of lead, mercury or tributyl tin were released, however arsenic was released from both samples, copper was released at one site, nickel at two sites and zinc at two sites. The concentration of arsenic released did not exceed the USEPA chronic continuous exposure criterion, indicating no adverse effects were likely. The concentrations of nickel and zinc released did not exceed the ANZECC 95% marine water quality at either site, however the concentration of copper exceeded the ANZECC 95% marine water quality trigger at one site. However after allowing for an estimated initial dilution of 10 times the concentrations were below the ANZECC marine water quality triggers.

At Pine Harbour marina four composite samples were subjected to elutriation analysis for arsenic and metals in 2011 and 2015, from three composite samples in 2012. The concentration of arsenic showed it was generally released from the Pine Harbour marina sediments with all but one sample showing detectable concentrations. The concentration of arsenic released did not exceed the USEPA chronic continuous exposure criterion, indicating no adverse effects were likely. The concentrations cadmium showed cadmium was generally not released from the sediment, however two samples in 2012 recorded marginally elevated concentrations indicating release of cadmium. All elutriate concentrations of cadmium were below the ANZECC 95% marine water quality trigger, indicating no adverse effects were likely. The concentrations copper showed copper was not released from the sediment. The concentrations nickel showed nickel was generally not released from the sediment, however two samples in 2012 showed some nickel was released. In 2012 the concentration of nickel was greater than the ANZECC 95% marine water quality trigger at all three sites, however the initial marina dilution water was also similarly elevated in nickel. No detectable concentrations of chromium, lead or mercury were released. After allowing for an estimated initial dilution of 10 times the concentrations were below the ANZECC marine water quality triggers.

Based on the elutriation testing conducted pre dredging contaminants are not likely to be released into the water column at the disposal site at concentrations high enough to cause adverse effects to biota.

Following disposal and deposition on the seafloor, dredged materials that are contaminated or even slightly contaminated with various heavy metals, pesticides, polychlorinated biphenyls, and petroleum hydrocarbons, could still leach contaminants from the spoil mound if conditions change. Normally, significant leaching requires a pore water pressure (a pressure gradient from the spoil mound to the overlying surface water). Typically, a distinctive pressure gradient is only established when the mound is very large and solid. To date, at the Northern Disposal Area, only a low mound of sediment has result from the deposition of the dredged material, so that pore water pressure and, therefore, leaching of heavy metals into the overlying water column, will be minimal. The continued use of the site as a disposal area as proposed will not result in a significantly higher mound. Accordingly, we do not expect a high pore water pressure to induce leaching on the sea floor.

4.2 Disposal Mound

Following the disposal of 150,000 m^3 dredge spoil, and based on the information available from seabed cores and bathometric studies, the footprint of the disposal mound is elongated west to east, and located within approximately 375 m east and west of the disposal area centre and 250 m north and south. The thickness of disposal material increases towards the disposal centre site, where the seabed is approximately 1.25 m above the original seabed level, based on multiple survey data.

The shape and slope of the mound and hence available volumetric capacity are discussed in Beca, 2018.

With the increased area of the mound, the addition of material at the disposal point will only result in very thin layers of material at greater distances from the disposal point. It is likely that the benthic biota at the more distant sites (500 m and 1000 m) will show effects, but these effects will remain on the currently measured gradient, from up to 100% reduction at the disposal point to significantly less at the 500 m and 1000 m sites, and no effect at the 1500 m sites. Under this scenario it is likely that a level of recovery will be occurring at the more distant sites and the biota will reach an equilibrium community structure based on the disturbance and recovery occurring.

4.3 Benthic Fauna Mortality and Recovery Rates

The monitoring of the benthic biota at the disposal centre site has shown benthic fauna at the disposal centre site have been affected by the disposal operations, with significant mortality of individuals inhabiting the sediments, most likely as a result of smothering and insufficient recolonization time between successive disposal events. Likewise, the individuals inhabiting the dredged sediments have not survived at the disposal site, most likely due to the change in depth and physical disturbance of dredging and then being buried in the barge of dredge material with limited water space if any.

The geographical extent of the high mortality is not known, but is limited to less than 500 m from the disposal central site as significant decreases in abundance of biota were not detected at the 500 m sites. Based on the information available from seabed cores and bathometric studies, the footprint of the disposal mound is elongated west to east, and located within approximately 375 m east and west of the disposal area centre and 250 m north and south. The current consent does not require the assessment of biota recovery, or is it possible given the lack of time between the frequent disposal events, therefore detailed assessment of the biota changes at and around the Disposal Centre site has not been conducted.

The NDA differs from other monitored disposal areas in New Zealand currently in operation or in the recent past, in that its depth is significantly greater. Other sites (Otago, Lyttelton, Tauranga and Auckland) range in depth from approximately 7 – 30 m.

Environments that are shallow generally experience relatively frequent wave-, wind-, and current-induced disturbances and are typically inhabited by low-diversity, benthic assemblages that are dominated by biota that are fast-growing, small, opportunistic. These species can readily re-establish themselves under conditions of high frequency disturbances (Dauer 1984; Clarke & Miller-Way 1992, Ray & Clarke 1999). These communities are naturally held in early successional stages and are therefore able to recover more rapidly than communities in more stable environments (Newell et al. 1998; Bolam & Rees 2003). The disposal sites at Auckland, Tauranga, Lyttelton and Otago being relatively shallow and open coasts fall into this category, however the NDA does not. The NDA seabed at 140 m depth is not affected by normal or even extreme normal wave conditions, a minimum sustained wave height of 14 m would be required to produce the near-bed velocities needed to entrain deposited material (Flaim, 2012). Thus the biological communities present in the NDA were and are at a later stage of succession and once disturbed likely to take longer to recover to a similar state.

Comparison of rates of biota recovery with other disposal sites in New Zealand is not directly valid. However in general the processes of recolonisation and recovery will begin as soon as spoil deposition begins. The depth of sediment and frequency of new material are key factors in determining the effects to biota (Gibbs & Hewitt 2004, Erftemeijer *et al*. 2012). In addition, the response after burial differs between species. In shallow nearshore habitats, if burial depth is less than a few centimetres, then more mobile species will likely migrate through the sediment and survive while less mobile species will perish. Mobile biota at the disposal site are not common, based on the benthic biota data obtained to date. Hence the data shows mass mortality. Rapid deposition of thick layers of dredged material at a site will cause mortality of almost all the underlying benthos, with the exception of a few active species of macroinvertebrates, which are adapted to living within dynamic sedimentary conditions (Smith and Rule, 2001). Repopulation of the disposed sediments will, for the majority of species, occur via settlement of planktonic larval stages that are likely to have originated many kilometres away. Mobile benthic invertebrate species are uncommon in the disposal area and immigration from immediately adjacent areas is expected to be low.

Once sediment disposal has ceased, benthic communities are expected to recover to pre disposal levels, but the time it will take is not able to be stated with any precision as recovery rates are not known for this environment in New Zealand. In the shallower environments of the Ports of Otago disposal area, it has been shown that recovery can be in the order of 6 months (James, *et al.,* 2009). International literature also suggests that muddy sediments have slower recovery rates than sand habitats (Dernie, *et al*., 2003). If the sediment characteristics, such as grain size and chemistry, differ from the surrounding habitats then recolonization is likely to be slower. The specific recovery rate of invertebrate benthic communities in an unstressed habitat has been estimated to take between 1 and 4 years (Bolam and Rees, 2003). Interestingly, Bolam and Rees (2003), found that communities in more stressed environments only took approximately 9 months to recover. Classic community disturbance literature demonstrates that macro faunal communities in environmentally stressed environments are more naturally resilient (Bolam and Rees, 2003). Since the natural biota of the NDA was in an undisturbed state the recovery back to this state is predicted to take longer than shallow disposal areas such as Otago.

The ongoing disposal at the NDA and other disposal areas will result in a gradation of effects radiating away from the disposal point out to and beyond the influence of disposal material. The effects will depend on the frequency, thickness of deposits, the biota present and their abilities to survive burial by sediments. The effects will therefore be different for different species. The result for a stable disposal volume and frequency will be an equilibrium of limited species and numbers in the centre, with a changing species composition and abundance with distance from the centre, finally becoming no different from the background biota.

4.4 Potential for Spread of Invasive Species

The invasive species detected at the source sites are summarised in section 2.6. The general ecology of these invasive species is summarised in Appendix 1. None of these invasive species are expected to survive on the seabed in the NDA. To date none of these invasive species have been recorded in the benthic biota monitoring from the NDA as presented in Appendix 7. Unfortunately the threat of invasive species is not limited to the survival of animals at the NDA. By their nature invasive species are highly capable of spreading and colonising new suitable habitats, this is achieved either by rafting of individuals or by natural spawning and dispersion of planktonic larvae. The degree to which invasive species can do this is variable between species, hence each species is discussed separately below. In addition knowledge of the likelihood of water movements resulting in the transport of material to coastal areas adjacent to the NDA is required, which needs to consider multiple time frames and seasonal conditions. Based on existing information MetOcean Solutions was able to provide a model of the trajectory of water bodies including neutrally buoyant plankton (MetOcean, 2018) predicting the likelihood of a waterbody from the NDA reaching the adjacent coast.

Rafting of individuals or groups of individuals is generally considered unlikely in that this would require floatable material on which species could raft. Since the source material is all sediment of material dredged from the sea bed these is not likely to be any floatable material disposed on which invasive species could raft. Dispersion of planktonic larvae from the point of disposal or from spillage in route generally provides the greatest potential threat of spreading unwanted invasive species to areas not previously colonised.

4.4.1 Mediterranean Fan Worm (*Sabella spallanzanii*)

Mediterranean fanworm is a large, tube-dwelling worm. The tubes are leathery, flexible and are generally found on hard sub-tidal structures, but can also be buried up to 10cm deep in soft substrates in shallow (0 – 30m) water. Mediterranean fanworms are found throughout the Waitematā harbour. They were present at all sources sites except Sand Spit Marina. The pre dredging characterisation studies indicated they were only located on the hard marina structures and none were recorded from within the soft sediments to be dredged. Therefore the risks of fan worm being present in the dredged material is considered low. However there is still a risk that fan worms could be present in dredge sediments not sampled or that fan worms could be dislodged from the hard marina structures by the dredging activity and included in the dredged material.

It is very unlikely that Mediterranean fanworms will survive on the seabed at the NDA.

Assuming the worst in that one or more mature undamaged fan worms (those bigger than 120mm) of each sex were included in a barge load then there is a risk they could spawn producing fertilised planktonic larvae. However this is complicated as the male Mediterranean fanworm release sperm into the water to be captured by the females. Fertilisation takes place inside the female worm's tube, where the egg is released. Hence not only do one of each sex need to be included, they need to be close by to allow sperm transfer. The likelihood of undamaged fan worms being included is low, as for the worms to be included they need to be dislodged from the marina structures by a digger bucket or arm, which in all likelihood would result in significant damage. Given the low expectation of undamaged worms being included, it is also unlike they will be present in the barge in close proximity to each other. It is more likely that they will be buried and isolated by subsequent dredge material. Females are ready to spawn over a prolonged autumn-winter period (May to September), thus outside this time period spawning is significantly less likely. However mature female worms can produce more than 50,000 eggs during a spawning event and the larvae drift in the water column for approximately 14 days. At this point the larvae must settle in suitable environment and start the process of metamorphosis into a feeding juveniles.

The trajectory modelling data suggests that there is a moderate (20 to 40%) probability that planktonic larvae released on to the surface at the NDA would reach the shoreline along the coast of Great Barrier Island and Eastern Coromandel Peninsular within 2 days over the spawning months. However the majority of disposal material falls as a mass to the seabed with very little (3-5 %) material entrained as a surface or mid water plume. It is therefore considered that the mid water depth model numbers are the most relevant. Based on the mid water data it is predicted that water potentially containing planktonic larvae from the NDA will only reach the adjacent shoreline in a minimum of 12 to 15 days, less than 0.5 % of the time during the spawning period. Thus with the limited unquantified risk of inclusion in the barge, limited likelihood of successful spawning and the low chances of larvae reaching the coast within 14 days, there is only a negligible chance that Mediterranean fanworm could be spread to Great Barrier Island and Eastern Coromandel Peninsular via the disposal of dredge spoil at the NDA.

To date all the known reports of Mediterranean fanworm incursions have been shown to be the result of newly arrived vessels from invested areas. This is considered to be a vector of spread of greater risk than dispersal of Mediterranean fanworm larvae from the NDA.

There have been a number of research projects looking at the potential to kill fan worms attached to boat hulls, these have shown the use of chlorine has been successful although difficult to implement. The distribution of fan worms has also shown they do not survive well in freshwater. All of these studies target the worms not the larvae, it is likely that the larvae are slightly more vulnerable than worms to treatments however there is no science to corroborate this.

4.4.2 Asian paddle carb (*Charybdis japonica*)

The Asian paddle crab, *Charybdis japonica* is a large paddle crab that was first discovered in New Zealand, in Waitematā Harbour in September 2000. They native to the north-west Pacific, including coastal regions of China, Malaysia, Korea, Taiwan and Japan. Asian paddle crabs are known to be present in the Whangarei, Waitematā and Tauranga harbours, Waikare Inlet in Northland and Matakana Estuary north of Auckland. They inhabit intertidal to subtidal estuarine habitats and in New Zealand and are found on a number of different substrate types from fine muds to reefs. They were present at the Sand Spit and Half Moon Bay Marina sources sites. The pre dredging characterisation studies indicated they were located within the soft sediments to be dredged. Therefore it is highly likely they will have been present in the dredged material. While paddle crabs have the ability to bury themselves in the substrate, it is unlikely they will be able to return to the sediment surface if buried by more than 10 -20 cm of dredged the sediments in the disposal barge. Assuming they survive the dredging process and are released alive in the dredge disposal process, it is very unlikely that they will survive on the seabed at the NDA.

Assuming the worst in that one or more mature undamaged female fertilised paddle crabs were included in a barge load and that they were not buried, then there is a risk they could spawn producing fertilised planktonic larvae. Males are not necessarily required to be present in the barge as females can store sperm for later fertilisation. Adult Asian paddle crabs can produce hundreds of thousands of offspring over multiple events in the spawning season of November to March. Their planktonic larvae are relatively long-lived taking three to four weeks to metamorphose into juvenile crabs. The majority of disposal material falls as a mass to the seabed with very little (3-5 %) material entrained as a surface or mid water plume. It is therefore considered that the mid water depth trajectory modelling numbers are the most relevant. Based on the mid water data it is predicted that water potentially containing planktonic larvae from the NDA will only reach the adjacent shoreline in a minimum of 13 to 16 days, approximately 0.5 % of the time during the spawning period. Based on figures 4.1, 4.2, 4.3, 4.11 and 4.12 in MetOcean, 2018 it is shown that water flow is generally south along shore in November switching to northerly for January to March. At 4 weeks the mid water depth figure 4.11 shows that water from the NDA in November will only reach the shoreline south of Whitianga less than 0.5 % of the time. The offshore islands east of the Coromandel Peninsular may experiences a very slightly higher probability of up to 10% of the disposal events resulting in water reaching their shorelines. At 4 weeks the mid water depth figure 4.12 shows the highest probability of up to 10% of the disposal events resulting in water reaching the shoreline of Cuvier Island and eastern Great Barrier Island in December. Between January and March there is a less the 0.5 % chance of water from a disposal event reaching the shoreline at the north eastern end of Great Barrier Island within 4 weeks. Thus with the limited unquantified risk of inclusion in the barge, limited likelihood of successful spawning and the low chances of larvae reaching the coast within 4 weeks, there is a negligible chance that larvae from the Asian paddle crab could be spread to Great Barrier Island and Eastern Coromandel Peninsular via the disposal of dredge spoil at the NDA.

With Asian paddle crabs not being recorded at all source sites it may be possible to restrict the timing of the dredging and disposal of material likely to contain Asian paddle crabs to periods outside there spawn season, thus preventing the potential spread of Asian paddle crab larvae.

4.4.3 Australian drop tunicate *(Eudistoma elongatum)*

The Australian droplet tunicate is an ascidian native to Australia, which looks like clusters of white or cream coloured tubes or "sausages" and forms large colonies that attach to hard substrates. It is generally found in muddy bottomed tidal habitats and on man-made structures such as wharf piles and aquaculture equipment, below low tide. Australian droplet tunicates were first reported in New Zealand in early 2005 in Northland, but it was not originally regarded as a pest, given its low density and the fact it appeared to die off in winter. Eudistoma elongatum has been reported present in Opua, Kerikeri, Russell and the Waikare Inlet in the Bay of Islands, Whangarei Harbour, Matakana Estuary, Mahurangi Harbour, Waiheke Island, Tauranga Harbour (historically), and Picton (historically). To date they have only been recorded as present at the Sand Spit Marina sources sites. The pre dredging characterisation studies indicated they were located within the soft sediments to be dredged. Therefore it is highly likely they will have been present in the dredged material. Assuming Australian droplet tunicate survive the dredging process and are released alive in the dredge disposal process, it is very unlikely that they will survive on the seabed at the NDA.

This species is a prolific breeder, reproducing for at least nine months of the year, from October through to June. The larvae are free-swimming for approximately six hours before they begin to settle on surfaces. Based on the mid water data it is predicted that water potentially containing planktonic larvae from the NDA will only reach the adjacent shoreline in a minimum of 13 to 16 days, approximately 0.5 % of the time during the spawning period. Given the planktonic larvae stage only lasts approximately 6 hours the chances of larvae surviving until they reach shoreline is nil. Hence there is no threat of spreading this species as a result of disposal.

4.4.4 Clubbed sea squirt (*Styela clava*)

Styela sea squirts have a long, club-shaped body on a short, tough stalk. The clubbed sea squirt has been found from the low intertidal zone to water about 40m depth. It grows on rocks, shell fragments and a wide range of artificial surfaces such as pylons, buoys, mussel lines, wharves and jetties. In New Zealand, it has a preference for sheltered sites but overseas also is found in semi-protected waters on more exposed coasts. The clubbed sea squirt was first identified in 2002 and is now widely established throughout parts of New Zealand. It is not feasible to eradicate *Styela clava* in New Zealand due to its wide spread distribution and the fact that it has been present in New Zealand for some years. Clubbed sea squirts are found in a number of locations in the Hauraki Gulf, including Mahurangi harbour, Whangaparaoa, east coast bays, Waitematā harbour, Tamaki estuary, Waiheke Island firth of Thames and Coromandel harbour. They were present at the Half Moon Bay Marina and have been recorded at Sand Spit and Pine Harbour marina sources sites. The pre dredging characterisation studies indicated they were only located on the hard marina structures and none were recorded from within the soft sediments to be dredged. Therefore the risks of clubbed sea squirts being present in the dredged material is considered low. However there is still a risk that clubbed sea squirts could be present in dredge sediments not sampled or that clubbed sea squirts could be dislodged from the hard marina structures by the dredging activity and included in the dredged material.

It is very unlikely that clubbed sea squirts will survive on the seabed at the NDA, as it is outside their prefer habitat depth range.

Styela clava can breed in water temperatures above 15° C and salinities above 25-26 ppt. Like all sea squirts, they hermaphroditic, but its male and female gonads mature at different times so it is not self-fertile. In north eastern New Zealand, *Styela clava* spawns between spring to early autumn, with a spawning peak February to early April, releasing both eggs and sperm into the water. Eggs and larvae are planktonic for no more than 1-2 days before settling to the bottom, attaching and metamorphosing. Based on the mid water data it is predicted that water potentially containing planktonic larvae from the NDA will only reach the adjacent shoreline in a minimum of 12 to 16 days, approximately 0.5 % of the time during the spawning period. Given the planktonic larvae stage only lasts 1 – 2 days the chances of larvae surviving until they reach shoreline is nil. Hence there is no threat of spreading this species as a result of disposal.

4.4.5 Encrusting Bryozoan *(Watersipora subtorquata)*

Watersipora subtorquata is a loosely encrusting bryozoan capable of forming single or multiple layer colonies. It has been present in New Zealand since at least 1982 and is now present in most ports from Opua to Bluff. It grows on vessel hulls, pilings, pontoons and can also be found attached to rocks and seaweeds. They form substantial colonies on these surfaces, typically around the low water mark.

The risks of this bryozoan being present in the dredged material is considered low. However there is still a risk that it could be dislodged from the hard marina structures by the dredging activity and included in the dredged material. *Watersipora subtorquata* will not survive on the seabed at the NDA, as it is outside their prefer habitat depth range and there are no hard substrates present to colonise.

The main vector of spread of *Watersipora subtorquata* is transport on vessel hulls, port to port. *Watersipora subtorquata* has a short less than one day, planktonic larval stage before settling. Therefore based on the mid water trajectory model data it is predicted that water potentially containing planktonic larvae from the NDA will only reach the adjacent shoreline in a minimum of 12 to 16 days, approximately 0.5 % of the time, hence the chances of larvae surviving until they reach shoreline is nil. There is no threat of spreading this species as a result of disposal at the NDA. In addition its long term presences in New Zealand has resulted in it already being present in most areas.

4.4.6 Asian date mussel (*Arcuatula senhousia*)

Arcuatula senhousia is a small mussel, with a smooth, thin shell that is olive green to brown with dark radial lines or zigzag markings. *Arcuatula senhousia* has been found from the intertidal to a depth of 20 m and on soft or hard substrata. It prefers to settle in groups on soft substrata, but is capable of fouling wharf pilings and man-made structures. It is a highly adaptive species, and is able to tolerate low salinities. It has been present in New Zealand since at least 1978 and has spread to a range of estuaries in north-east New Zealand, from Parengarenga Harbour to East Cape. They were present at the Hobsonville Marina, have been recorded at Sand Spit and Pine Harbour marina sources sites in the past and all other source sites are with the know established range. The pre dredging characterisation studies indicated they were located within the soft sediments to be dredged. Therefore it is highly likely they will have been present in the dredged material.

It is very unlikely that the Asian date mussel will survive on the seabed at the NDA, as it is outside their prefer habitat depth range.

A. senhousia spawns from the end of summer to late autumn. It is a broadcast spawner, with fertilization occurring in the water column. The eggs are large and the larvae emerge from these eggs and drift in the water currents for 14 to 55 days. Both the fertilised eggs and the developing larvae are planktonic.

Based on the mid water trajectory model data it is predicted that water potentially containing planktonic larvae from the NDA will only reach the adjacent shoreline in a minimum of 12 to 16 days, approximately 0.5 % of the time. Based on the potentially much longer planktonic larval dispersal phase, there is high possibility of larvae surviving until they reach a shoreline. However the Asian date mussel is already well-established in Auckland and Coromandel regions and thus their distribution range will not be extended due to the disposal of dredge material at the NDA.

4.4.7 Pacific oyster (*Crassostrea gigas*)

The Pacific oyster, is an important aquaculture species throughout the world, including New Zealand. It has a white elongated shell, with an average size of 150-200 mm. *Crassostrea gigas* is an estuarine species, but can also be found in intertidal and subtidal zones. They prefer to attach to hard or rocky surfaces in shallow or sheltered waters up to 40 m deep, but have been known to attach to muddy or sandy areas when the preferred habitat is scarce. They were introduced to New Zealand in the 1960s. They are now a dominant structural component of fouling assemblages and intertidal shorelines in northern harbours of New Zealand and the upper South Island.

There is little risk of spreading this species, as it is well established in north eastern New Zealand.

4.4.8 Window shell (*Theora lubrica*)

Theora lubrica is a small bivalve with an almost transparent shell. They were introduced to the New Zealand in the early 1970s probably in ballast water from its home in Japan. It has since spread to most other ports in the country and rapidly colonises disturbed and muddy habitats. *Theora lubrica* typically lives in muddy sediments from the low tide mark to 50 m, however it has been found at 100 m.

There is little risk of spreading this species, as it is well established in north eastern New Zealand.

4.5 Fin Fish, Birds and Mammal disruption

During each disposal event, the majority of sediment is expected to fall directly to the seabed in a column. A small plume of fine sediment is expected to occur for a short period down current from the disposal point. Plume monitoring studies undertaken by the University of Waikato showed this plume did not extend beyond the disposal area boundary. The disposal of a barge load of material directly on top of mammals or fish is likely to have adverse effects to the individual animals involved. The current consent (EEZ900012) controls are in place to prevent disposal of material if mammals are present in the area. The presence of fine sediment plumes will potentially impact on fish present in the water column. However, the plumes are short lived and the fish and mammals are mobile and able to avoid the plumes. Given the low numbers and intermittent presence of these species, the risk of impacts to these species are likely to be low.

Increased turbidity as a result of disposal of material has the potential to reduce light levels and thus potential for primary production by phytoplankton for a period after disposal until the plume has dispersed. However since the majority of disposal events has occurred during the night due to operational constraints, the effect of reduced light is negated.

The reduction in benthic biota in the seabed around the disposal centre site is confined to a relatively small area making the potential impact on the benthic feeding habitat of fish relatively small.

The intermittent activity of disposal operations would create noise disturbance for fin fish and marine mammals in the vicinity. No breeding activity of fish of mammals is known to occur in the disposal area therefore the short duration of the disposal activity, and the likelihood that the individuals will divert to avoid contact, will prevent any significant risk.

Any effects to sea birds will be indirect but localised to the disposal area. There is a small potential for these effects to take the form of reduced food species. The remote from shore location of the NDA means all of the sea birds temporarily present in the disposal area are able to cover a large geographic range thus the slim potential reduction of prey in a small area is not likely to adversely affect any of bird species.

4.6 Effects on Human Health

The environmental effects observed to date do not present a risk to human health. The effects have been relatively minor and there is little or no linkage between the disposal site seabed and human health contact. The only potential for human health contact is by fish feeding on the seabed at the disposal site being caught and consumed. The low numbers of fish present and the remote location of the site combine to make the risk of human health contact almost zero.

4.7 Biological Diversity and Integrity of Species, Ecosystems, and Processes

The continental shelf extends out to 60 km from Great Barrier Island. Sea floor relief of the shelf is relatively uniform, except for small areas of basement outcrop and isolated rock pinnacles, which occur 16 km south and 20 km north west of the disposal area. The Northern Disposal Area ranges in depth from approximately 130 m to 140 m and was characterised by sandy muddy sediments. Beyond the shelf edge, a band of coarser muddy sand extends in a NW direction along the upper slope, down to 300–500 m depth. There are limited sediment and biological samples around this region. NIWA's marine database for this region, suggests Scleractinia (solitary stony coral) may be present. Scleractinia corals are typically associated more with elevated features such as seamounts or ridges. Scleractinia have not been recorded in the study area as part of either the predisposal studies or the post disposal monitoring studies.

Biodiversity within and beyond the disposal area has not been impacted by the disposal activity to date. No sensitive species or ecosystems have been encountered in the disposal area or are expected to occur in the nearby environment.

4.8 Vulnerable Ecosystems and the Habitats of Threatened Species

On the continental shelf in this region it has been reported that Scleractinia (solitary stony coral) may be present. New Zealand has a diverse fauna of 127 stony coral species, 110 of which are azooxanthellate, (i.e., lacking symbiotic algae). Azooxanthellates/ahermatypes are sometimes called 'deepwater corals' or 'solitary corals' and are usually small and slower growing, and do not form reefs. An entire coral, may consist of a single individual or a colony of many individuals. The skeleton of an individual polyp has a cup-shaped opening that is typically round or oval as in New Zealand's cold-water corals. During 2010, an amendment of Schedule 7A of the Wildlife Act (1953) widened the range of corals afforded protection to include "all deepwater hard corals (all species in the orders Antipatharia, Gorgonacea, Scleractinia, and Family Stylasteridae)". Scleractinia corals are typically found in water depths greater than 200 m, often associated more with elevated features such as seamounts or ridges. Despite this a few species have habitat ranges that could occur in the NDA. The Stoney corals *Caryophyllia quadragenaria*, *Kionotrochus suteri* and *Monomyces rubrum* (Figure 4.1) have been recorded north of the NDA in depths similar to the NDA (Brook, 1982, Sivaguru *et al*, 2004, Lee *et al*, 2015). Scleractinia would be adversely effected by burial by sediment as they are sedentary. However Scleractinia either alive or dead have not been recorded in the study area as part of either the predisposal studies (University of Waikato, 2011e) or the post disposal monitoring studies (Bioresearches, 2013a, 2015, 2015a, 2017a). Therefore until they are shown to be present they are considered unaffected.

A B C

Figure 4.1 Stoney Corals, A = *Caryophyllia quadragenaria*, B = *Kionotrochus suteri* and C = *Monomyces rubrum*

The continental shelf in region east of Great Barrier Island is used by a number of whale species including Bryde's whale, Humpback whale, Fin whale and Blue whale. Of these species only the Bryde's whale is present year round. The other species are only seasonal as they pass through the area on migration to and from breeding grounds. The activity of disposal may create some noise for very short periods of time and also the act of disposal will create a risk of falling material. Whales are more than able to avoid these very small risks and disposal management protocols call for the observation and lessening for marine mammals to further reduce the risk of contact. Three species of the dolphin family are also likely to occur in the NDA, orca, bottlenose dolphin, and common dolphin. Common dolphin have been observed in the NDA attracted to the boat during sampling for the 100,000 m^3 monitoring survey. Bottlenose dolphin and Orca are likely to move through the area from time to time. Like whales the dolphin are able to avoid contact with the disposal activity. No mammals are permanently resident in the NDA. More details on the marine mammals are discussed above in section 3.5.2.

No endangered fish or birds are known to be present or use the NDA.

The disposal area is typical of large areas of the continental shelf in region of New Zealand. Studies to date have shown that the disposal area does not contain any known vulnerable ecosystems or habitats of threatened species. Transitory species such as whales and dolphins are not considered to be affected by the disposition of material on the seabed, but are likely to avoid noise of the disposal activity for the very short periods of the disposal events. The area is not known to be used for breading activity by marine mammals.

5. SUMMARY

The post disposal monitoring studies to date have confirmed the impacts predicted in the initial impact assessment, and confirmed that the site is suitable for marine sediment disposal operations. The environmental effects observed do not present a risk to human health, as the effects are relatively minor and there is little or no linkage between the disposal site seabed and human health contact. The pre characterisation and post disposal monitoring studies to date have been sufficient to detect changes. During the course of these studies no endanger or protected species were recorded in the benthic biota.

The initial impact assessment suggested three years of detailed monitoring in order to accurately determine what, if any, long term impacts the disposal operation is having on the environment, and that this be limited to approximately 50,000 m^3 of dredged material per year. With the proposed increase in annual disposal volume, some refinements to the monitoring studies are out lined below.

The monitoring conducted has confirmed that:

- **Water quality** in the surrounding area is not adversely effected, turbid waters resulting from the disposal plume are not persisting for an extended period of time after a disposal of dredged material has occurred and do not extend beyond the disposal area boundary.
- **Chemical content** of sediment beyond the disposal area boundary does not show any significant increase in heavy metal concentrations, where adverse effects on benthic organisms are likely to occur. The concentration of contaminants recorded in pre dredged material is strongly reflected in the concentrations recorded at the disposal centre site, and no significant spread of contaminated sediment has occurred.
- **Formation of a spoil mound**: The consented monitoring (condition 6.e.) has failed to provide sufficient detail to adequately assess the mound size, shape and thickness. However the monitoring has confirmed that the formation of a large and tall mound has not occurred. To date, the mound is estimated be approximately 1.25 m high and covers an area of less than 29 hectares.
- **Movement of the spoil mound**: To date, the monitoring shows that the spoil mound is centred on the disposal point, elongated slightly west to east. This elongation is likely the result of the direction of travel of the barge and thus the result of variation in the point of disposal, not the movement of material on the seabed. The disposal material has not been shown to be present beyond 500 m from the disposal point.
- **Impacts on surrounding areas**: The monitoring to date confirms that loads are hitting the target area and the sediment quality and benthic biota populations have not been affected beyond 500 m.

The recovery rate of benthic biota has not been assessed as disposal is still occurring.

With the initial pilot study and this larger volume assessment now complete with no significant adverse effects beyond the disposal area, there is evidence to support the approval of disposing larger annual volumes. Given that the pre characterisation of dredge material remains, the same and limiting the acceptability of disposal material to that currently disposed. The main factor in defining what volume is acceptable is the size, shape and rate of change of the spoil mound, and the sizes of the disposal area. Ideally, the footprint of the mound should remain as small as possible to limit the extent of effects. The data to date does not show any migration of the mound, however, this not to say that this will not occur once significantly greater volumes are disposed of. The disposal area as set, will have a limit as to how much sediment can be disposed before either the mound becomes too high and wide spread or adverse effects are detected on or near the boundary of the disposal area. At this point, this volume is still undefinable. In order to maximise to volume without making the mound to high, resulting in side slumping, a disposal site of within 500 m of the disposal centre site is proposed. Rather than random dumping within the larger disposal site, it is proposed to maintain a 100 m target radius around a disposal point, and vary the location of the disposal point base on 250,000 m^3 cumulative volumes as shown in the Table 5.1, this is shown graphically in Figure 5.1 along with sediment quality sampling points.

250,000 m^3 per annum has been suggested as a maximum volume that will be needed in the future based on an increased number of dredging source sites and expanding projects. Assuming the shape and slope of the disposal mound remain similar, it is expected that the mound will initially expand at a similar rate to that observed to date, but as the size of the mound increases, the rate of increase in size and height will decrease. With the increased area of the mound, the addition of material at the disposal point will likely result in very thin layers of material at greater distances from the disposal point. It is likely that the benthic biota at the more distant sites (500 m and 1000 m) will show effects, but these effects will be on the gradient as currently detected, from up to 100% reduction at the disposal point to significantly less at the 500 m and 1000 m and no effect at the 1500 m sites. Under the rotating disposal point scenario, it is highly likely a level of recovery will occur at the more distant sites further away from the disposal point.

Any monitoring studies will have to be adaptive given the uncertainty of information on the shape and size of the mound and its predicted growth.

Table 5.1 Locations of Potential Variable Disposal Points

Volume range (m^3)	Operational Disposal Point	Latitude (WGS 84)	Longitude (WGS 84)
0 – 250,000	DS	36° 12.3403' S	175° 48.002' E
250,000 – 500,000	W200	36° 12.388' S	175° 47.880' E
500,000 – 750,000	N200	36° 12.244' S	175° 47.945' E
750,000 – 1,000,000	E200	36° 12.299' S	175° 48.123' E
1,000,000 – 1,250,000	S200	36° 12.441' S	175° 48.055' E
1,250,000 – 1,500,000	W400	36° 12.432' S	175° 47.759' E
1,500,000 – 1,750,000	NW400	36° 12.271' S	175° 47.750' E
1,750,000 – 2,000,000	N400	36° 12.146' S	175° 47.890' E
2,000,000 – 2,250,000	NE400	36° 12.148' S	175° 48.091' E
2,250,000 – 2,500,000	E400	36° 12.253' S	175° 48.246' E
2,500,000 – 2,750,000	SE400	36° 12.423' S	175° 48.249' E
2,750,000 – 3,000,000	S400	36° 12.539' S	175° 48.109' E
3,000,000 – 3,250,000	SW400	36° 12.553' S	175° 47.904' E

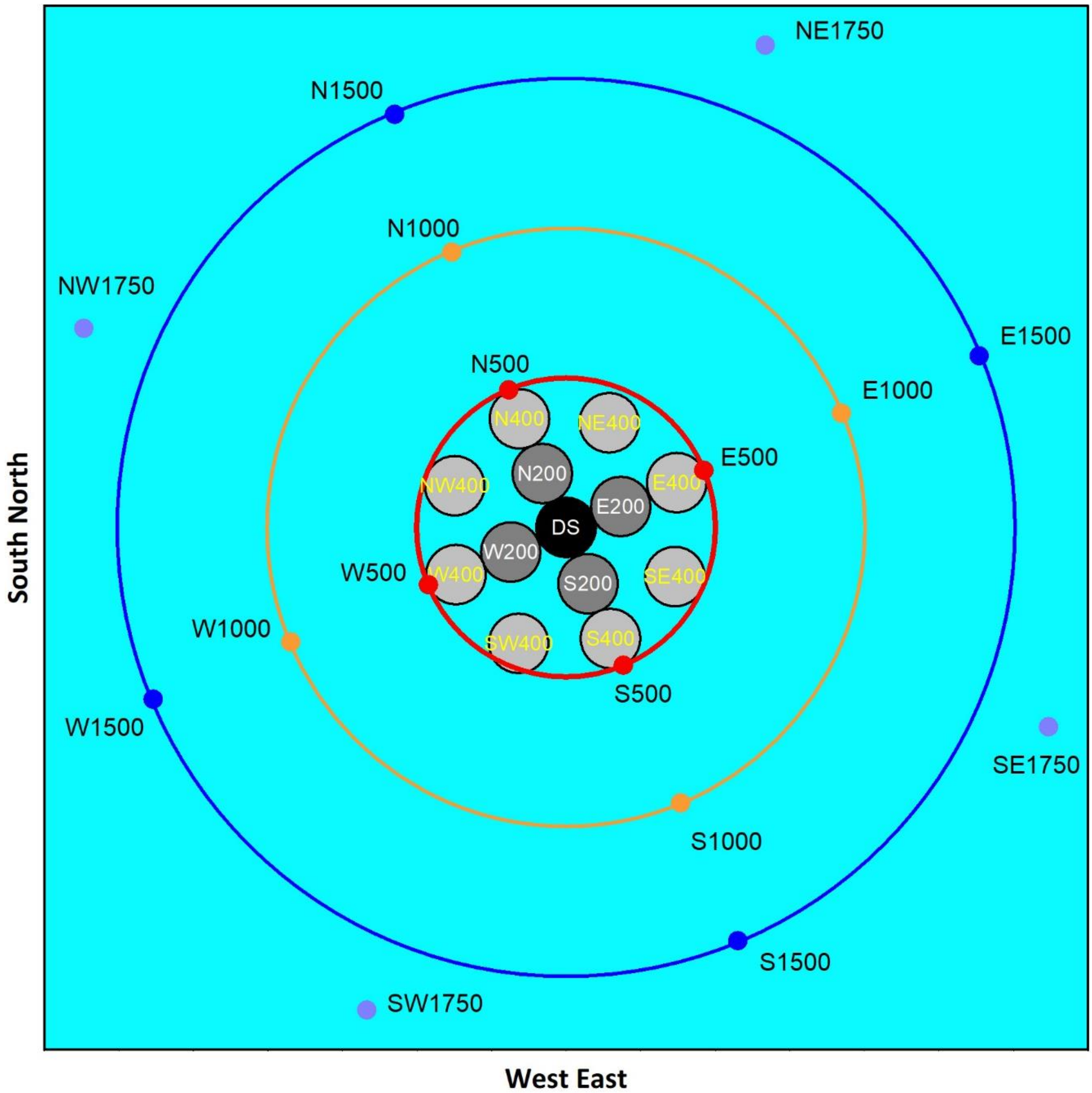


Figure 5.1 Location of Disposal points and Sediment quality monitoring points.
(Grey circles show 100m radius targets) note control site not shown.

6. MONITORING

The current post disposal monitoring studies have been triggered by cumulative disposal volume targets. At each disposal monitoring event, the sediment chemistry and particle size is assessed at a minimum of 13 sites within the disposal area, and at a control site and four sites 250 m outside the disposal area between the within area radii. Sample sites within the disposal area are arranged in four radii from the disposal centre site that correspond to long shore, onshore and offshore; samples are collected at 0, 500, 1000, 1500 m from the centre site. Sample site locations are shown in Figure 3.3.

- **Core samples** are collected in clear tubes that allow the layers in the sediment to be photographed and these layers to be quantified.
- **Contaminants** (metals and TPH) and sediment particle size are tested from the top 5cm of seabed sediment in a single replicate sample from each site. Each replicate sample consists of two 70 mm diameter cores.
- **Benthic biota** is required to be sampled at a sub set of the sediment quality sites. As a minimum this included the disposal centre site, the four 1500 m radii sites and the control site. At each site, three replicate samples were required, in most cases each replicate sample has consisted of two 100 mm cores. Additional samples are required if sediment chemistry at a site was greater than the ANZECC ISQG low guideline or if the difference in chemistry between the site and the control was greater than 50% of difference between the control and the disposal centre site.

A bathymetric study was also undertaken using multi-beam acoustic backscatter and/or side-scan sonar to determine changes in the seafloor level at the best possible practical level of accuracy.

Sampling was initially required and conducted after cumulative totals of 10,000 m^3 and 50,000 m^3 and then repeated at following each additional 50,000 m^3.

With an increased annual maximum volume of 250,000 m^3 the following monitoring studies are suggested;

Bathometric survey

A bathymetric study will be undertaken using multi-beam acoustic backscatter and/or side-scan sonar to determine changes in the seafloor level at the best possible practical level of accuracy. This should be conducted following cumulative totals of 125,000 m^3.

In addition to acoustic studies, which have limited accuracy, direct measurements of the thickness of layers of sediments on the seabed will be made with core samples. Single 70 mm diameter core samples will be collected at 100 m intervals along axes from the disposal centre site until no disposal sediment is observed and then at intervals of 500 m from the disposal centre site. The axes will be aligned in onshore (W 245.5°) offshore (E 65.5°) and along shore (N 335.5°, S 155.5°) directions. Beyond 500 m from the disposal centre site an additional axes will be added midway between the above axes (NE 20.5°, SE 110.5°, SW 200.5° and NW 290.5°). This should be conducted following cumulative totals of 125,000 m^3.

Sediment quality

Two 70 mm diameter cores will be collected at the disposal centre site and at 500 m intervals along axes from the disposal centre site out to 1500 m. The axes will be aligned in onshore (W 245.5°) offshore (E 65.5°) and along shore (N 335.5°, S 155.5°) directions. Additional samples will be collected from axes mid-way between the above axes (NE 20.5°, SE 110.5°, SW 200.5° and NW 290.5°) at 1750 m from the disposal centre site and at three controls located 100 m apart, 2500 m south of the disposal centre site. The top 50 mm of each core will be combined to provide a single replicate sample for sediment quality. Sediment quality testing will include metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc) and particle size. If the pre dredging characterisation studies suggest significant concentrations of other contaminants such as TPH, PAHs, TBT or antifouling compounds are likely to be present, then these contaminants should be added to the post disposal monitoring testing. This should be conducted following cumulative totals of 125,000 m^3.

Benthic Biota

Benthic biota sampling will be sampled at the control, disposal centre and 1500 m sites on axes aligned in onshore (W 245.5°) offshore (E 65.5°) and along shore (N 335.5°, S 155.5°). Additional sites will be sampled at 500 m intervals along the axes from the disposal centre site to the 1500 m sites, once the presence of disposal material has been detected within 250 m of the sample site. Three replicate samples, consisting of at least two 100 m diameter cores, will be collected at each site. Sampling will be conducted in spring (September, October, November). However provided the previous sediment quality survey does not require additional benthic biota sample sites not sampled in the previous sampling event, the sampling could be deferred to spring the following year, if less than 50,000 m^3 has been disposed in the year preceding 1 September and the forecast disposal volume for the year from 1 September is less than 100,000 m^3. However, sampling should be conducted at no greater than two yearly intervals. If sediment thickness cores have not been conducted in the preceding six months these should be conducted concurrently.

The study is limited to sampling a very small area of seabed for each sample. Larger mobile surface biota is likely to be poorly represented in the samples collected to date. Therefore, the use of video and/or photographic sampling should be trialled with the aim of detecting larger mobile species not current detected.

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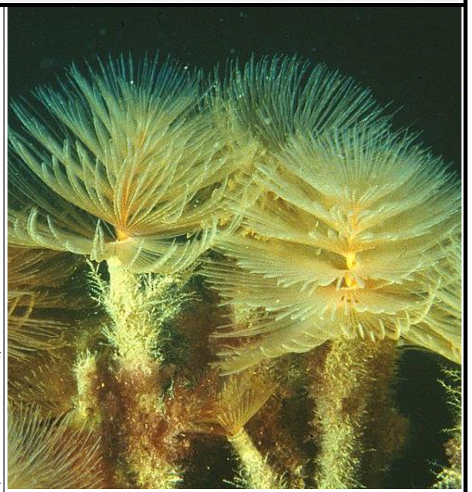
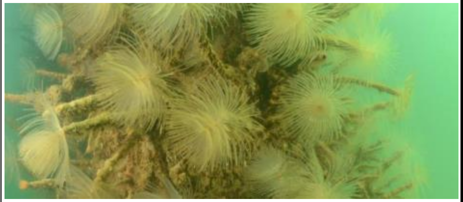
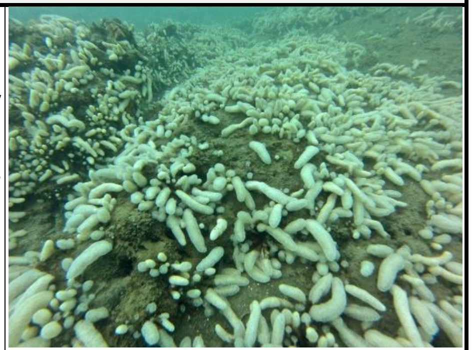
8. APPENDICES

Appendix 1 Invasive Species

Scientific name (common name)	Description and Habitat	Feeding Guild	Impacts	Management	Photo
Polychaete					
Sabellidae *Sabella spallanzanii* (Mediterranean Fan Worm)	Mediterranean fanworm is a large, tube-dwelling worm. It is the largest fanworm in New Zealand with its body measuring up to 20mm wide and 800mm long. It has a prominent crown of feeding tentacles that extend out of the tube and can be 150mm wide. The crown is often banded orange, purple or white. The tubes are leathery, flexible and muddy-looking and are generally found on hard sub-tidal structures, but can also be buried up to 10cm deep in soft substrates. Mediterranean fanworm can live in most artificial and natural habitats in the marine environment but it will not tolerate freshwater. It prefers sheltered, nutrient-enriched waters and is generally found in shallow subtidal areas in depths from 1 to 30m. It attaches to a range of solid surfaces including artificial materials (rocks, concrete, wood, steel), and benthic organisms (ascidians, mussels, oysters). But it can also be found on soft substrates, generally attached to a small buried fragment of shell or rock. It is a common fouling species on moored vessels, movement of these vessels between ports is generally how the species is spread. It is native to shallow waters in the northeastern Atlantic Ocean and the Mediterranean Sea. It first appeared in New Zealand in May 2008 and is regarded as unwanted organism in New Zealand. It has become established in Lyttelton Port, the wider Waitematā Harbour/inner Hauraki Gulf in Auckland and in Whangarei Harbour. There are ongoing elimination programmes underway in a number of locations including Coromandel, Tauranga, Gisborne and Nelson harbours and also Picton and Tutukaka marinas.	fanworms are filter feeders	The Mediterranean fanworm forms dense colonies that could affect native species by competing for food and space. Recent studies have indicated impacts on the establishment of new generations of some species, and on nutrient flow. The presence of dense colonies of this species could also change the underwater scenery of an area, potentially impacting on dive tourism activities. While they have not yet been recorded to have had significant impacts on fisheries in New Zealand, they could become a nuisance to recreational and commercial fishers by clogging dredges and fouling other fishing gear when in high densities. This fanworm has been detected on some mussel farms in the Hauraki Gulf and Coromandel region recently. Because mussels and fanworms are filter feeders, the productivity of mussels may be affected if the fanworm infestations become high.	Non-Indigenous Species Unwanted Organism[2] Under management No person shall knowingly transport any material or equipment that may contain or harbour a marine sustained control pest without first undertaking suitable measures to ensure all marine sustained control pests are removed or rendered non-viable. Fan worms are not expected to survive at the disposal site but there is a small risk of spread of fan worms along the transport route due to loss of material from the barge. Fan worms larger than 120 mm are considered to be mature and capable of spawning, which occurs in May to September. The larvae are planktonic for approximately 2-3 weeks prior to settling. Thus there is the potential for fan worms to spawn at the disposal site and spread larvae at certain times of the year. They prefer to settle in areas sheltered from direct wave action.	 

[2] An unwanted organism is any organism that is capable of causing harm to natural or physical resources or human health.

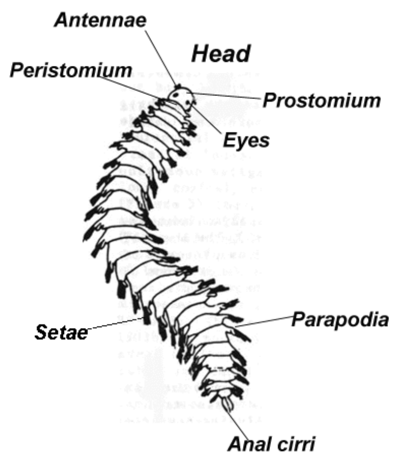
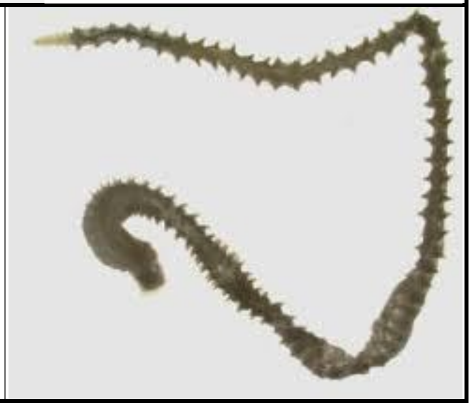
Scientific name (common name)	Description and Habitat	Feeding Guild	Impacts	Management	Photo
Bryozoan					
Watersipora arcuata	*Watersipora subtorquata* is a loosely encrusting bryozoan capable of forming single or multiple layer colonies. The colonies are usually dark red-brown, with a black centre and a thin, bright red margin. The native range of the species is unknown, but is thought to include the wider Caribbean and South Atlantic. It also occurs in the north-western Pacific, Torres Strait and north-eastern and southern Australia. *W. subtorquata* has been present in New Zealand since at least 1982 and is now present in most ports from Opua to Bluff. *W. subtorquata* is an important marine fouling species in ports and harbours. It occurs on vessel hulls, pilings, pontoons and can also be found attached to rocks and seaweeds. They form substantial colonies on these surfaces, typically around the low water mark. *W. subtorquata* is resistant to a range of antifouling toxins and it can therefore spread rapidly on vessel hulls.	filter feeders	It is a nuisance fouler of both vessel hulls and aquaculture operations	Non-Indigenous Species Preventative measures are the only current practical means controlling *W. subtorquata* populations. The main vector of spread is transport on vessel hulls. It has a short less than one day, planktonic larval stage before settling. Therefore spread via natural dispersion is slow.	
Crustacea					
Charybdis japonica, (Asian paddle carb)	*Charybdis japonica* is a large paddle crab that was first discovered in New Zealand, in Waitematā Harbour in September 2000. It is native to the north-west Pacific, including coastal regions of China, Malaysia, Korea, Taiwan and Japan. Carapace colouration is variable, but can include a yellow-brown marbled shell or a dark shell with blue and red flashes on the ventral surfaces and legs. Adult crabs occupy a range of habitats in sub-tidal coastal areas and estuaries up to 15 m depth.	Aggressive predator	As a key estuarine predator, *C. japonica* is likely to have significant impacts on native estuarine benthic assemblages, particularly small bivalves. It could be highly detrimental to shellfish aquaculture, and can carry diseases that affect crab, lobster, shrimp and prawn fisheries.	Non-Indigenous Species Unwanted Organism Under management No person shall knowingly transport any material or equipment that may contain or harbour a marine sustained control pest without first undertaking suitable measures to ensure all marine sustained control pests are removed or rendered non-viable. Adult Asian paddle crabs can produce hundreds of thousands of offspring and it is thought that reproduction is limited to seawater temperatures of over 20 °C. Larvae are relatively long-lived and can survive for three to four weeks potentially facilitating spread to new areas. Thus there is potential spread of this species from the dump site if spawning has occurred en route.	

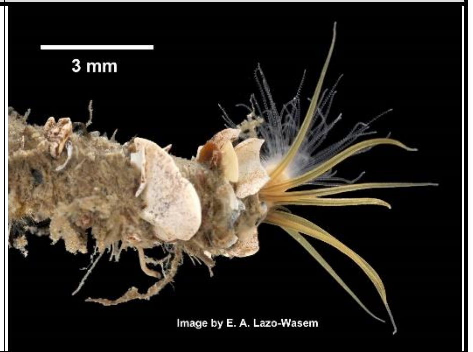
Scientific name (common name)	Description and Habitat	Feeding Guild	Impacts	Management	Photo
Ascidiacea					
Eudistoma elongatum (Australian drop tunicate)	The Australian droplet tunicate looks like clusters of white or cream coloured tubes or “sausages”. The Australian droplet tunicate is an ascidian native to Australia, which forms large colonies that attach to hard substrates. It is generally found in muddy bottomed tidal habitats and on man-made structures such as wharf piles and aquaculture equipment. It is generally submerged just below the waterline, but can often be seen at low tide. The size of the Australian droplet tunicate in New Zealand is influenced by seawater temperatures, with it decreasing in size over the winter months, but rapidly re-growing to its full size once summer arrives. It was first reported in New Zealand in early 2005, but was not originally regarded as a pest, given its low density and the fact it appeared to die off in winter. In the summer of 2007-2008 it became more prolific in a number of locations in Northland and has continued to reappear over the summer months.	Filter feeder	The Australian droplet tunicate competes with native species for both space and food. It has a rapid growth rate, can inhabit a wide range of habitats, and can reach high abundances. It is also possible that it can ingest and kill the eggs and larvae of native species. When present in high densities the Australian droplet tunicate has the potential to have significant impacts on habitats and species. They foul boats, aquaculture installations and other marine structures.	Non-Indigenous Species Unwanted Organism Under management No person shall knowingly transport any material or equipment that may contain or harbour a marine sustained control pest without first undertaking suitable measures to ensure all marine sustained control pests are removed or rendered non-viable. This species is a prolific breeder, reproducing for at least nine months of the year, from October through to June. The larvae are free-swimming for approximately six hours before they begin to settle on surfaces. Reproductive output decreases after high rainfall and in the early winter months due to the colony size also decreasing.	
Styela clava (Clubbed sea squirt)	*Styela* sea squirts have a long, club-shaped body on a short, tough stalk. Its surface is tough, leathery, rumpled, and knobbly, ranging in colour from brownish-white. The *Styela* sea squirt has been found from the low intertidal zone to water about 40m deep, but is most common at depths of less than 25m. In addition to growing on rocks, shell fragments and other organisms (e.g. oysters) it can also grow on a wide range of artificial surfaces such as pylons, buoys, mussel lines, wharves and jetties. In New Zealand, it has a preference for sheltered sites but overseas also is found in semi-protected waters on more exposed coasts.	filter feeder	The *Styela* sea squirt is able to colonise a variety of hard surfaces and tolerate wide ranges of salinity and temperature. It is also a highly efficient filter feeder, straining food particles from the water. These features make it a strong competitor and it is capable of forming monospecific stands and potentially out-competing native species.	Non-Indigenous Species Unwanted Organism Under management No person shall knowingly transport any material or equipment that may contain or harbour a marine sustained control pest without first undertaking suitable measures to ensure all marine sustained control pests are removed or rendered non-viable. Animals release eggs and sperm into the water and the larvae are free-swimming for a 12-24h period before settling on suitable surfaces and metamorphosing into sessile adults. Spawning is believed to occur in waters above 15°C	

Scientific name (common name)	Description and Habitat	Feeding Guild	Impacts	Management	Photo
Mollusca					
Arcuatula senhousia (Asian date mussel)	*Arcuatula senhousia* is a small mussel, it has a smooth, thin shell that is olive green to brown with dark radial lines or zigzag markings. A well-developed byssus is used to construct a cocoon which protects the shell. This cocoon is made up of byssal threads and sediment. *Arcuatula senhousia* has been found from the intertidal to a depth of 20 m and on soft or hard substrata. It prefers to settle in groups on soft substrata, but is capable of fouling wharf pilings and man-made structures. It is a highly adaptive species, and is able to tolerate low salinities. *Arcuatula senhousia* is native to the Japan and north China Seas. It has been present in New Zealand since at least 1978 and has spread to a range of estuaries in north-east New Zealand, from the East Cape to Parengarenga Harbour.	Filter feeder	*Arcuatula senhousia* can dominate benthic communities and potentially exclude native species. The byssal mats formed by the mussel restrict the growth of some species of seagrass, increases sediment deposition and retention, and can thereby alter the abundance and composition of infaunal assemblages.	Non-Indigenous Species Unwanted Organism Under management No person shall knowingly transport any material or equipment that may contain or harbour a marine sustained control pest without first undertaking suitable measures to ensure all marine sustained control pests are removed or rendered non-viable.	
Crassostrea gigas (Pacific oyster)	The Pacific oyster, is an important aquaculture species throughout the world, including New Zealand. It has a white elongated shell, with an average size of 150-200 mm. *Crassostrea gigas* is an estuarine species, but can also be found in intertidal and subtidal zones. They prefer to attach to hard or rocky surfaces in shallow or sheltered waters up to 40 m deep, but have been known to attach to muddy or sandy areas when the preferred habitat is scarce. *Crassostrea gigas* is native to the Japan and China Seas and the north-west Pacific, it was introduced to New Zealand in the 1960s.	Filter feeder	Little is known about the impacts of this species in New Zealand, but it is now a dominant structural component of fouling assemblages and intertidal shorelines in northern harbours of New Zealand and the upper South Island. *C. gigas* is now the basis of New Zealand's oyster aquaculture industry, having displaced the native rock oyster, *Saccostrea glomerata*.	Non-Indigenous Species There is little risk of spreading this species, as it is well established in north eastern New Zealand.	
Theora lubrica bivalve	*Theora lubrica* is a small bivalve with an almost transparent shell. The shell is very thin, elongated and has fine concentric ridges. *Theora lubrica* is native to the Japan and China Seas. It was been introduced to the New Zealand in the early 1970s. *Theora lubrica* typically lives in muddy sediments from the low tide mark to 50 m, however it has been found at 100 m.	selective deposit feeder	In many localities, *T. lubrica* is an indicator species for eutrophic and anoxic areas.	Non-Indigenous Species There is little risk of spreading this species, as it is well established in north eastern New Zealand.	

Appendix 2 Common Disposal Site Taxa Ecology

This appendix contains detailed information when available about most commonly occurring taxa in disposal site monitoring studies.

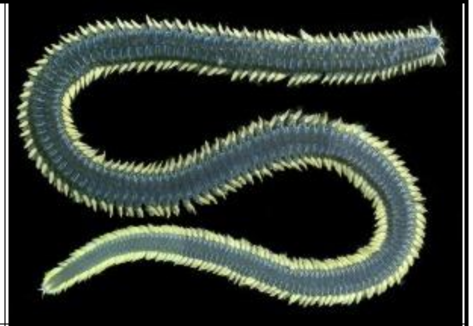
Scientific name (common name)	Description and Habitat	Feeding Guild	Indicator Status	Suitability as indicator for expected sedimentation effects	Photo
Polychaetes Due to their great morphological diversity, polychaete worms can be hard to recognise to the untrained eye. One of the most apparent features of polychaete worms are the paired paddle like lobed appendages on either side of their body segments known collectively as parapodia. Each parapod is used for locomotion and has a number of bristles or 'setae' (also called chaetae) protruding from it. In tube dwelling polychaetes, these features are reduced as they are less mobile. Setae run the length of the body and act to grip, maintain position or aid locomotion depending on the species of worm. Typically, polychaetes have a well-developed head (prostomium) which has 2 to 4 pairs of eyes that sense light and dark, a pair of sensory antennae, a pair of tentacle like feelers (palps) and a mouth. The form of the mouth depends greatly on the diet of the species since this group of worms includes predators, herbivores, filter feeders, scavengers, and parasites. Most free living polychaetes possess a pair of internal jaws that can be quickly pushed outward to grab at food. Filter feeding species have sensitive ciliated tentacles that capture food in the water column. Often just behind the head are a set of external gills that have a feathery appearance, however some species breathe directly through the body wall so do not have these structures. The peristomium is the name given to the first body segment directly behind the head. Life cycle Reproduction in polychaetes can be either sexual or asexual. Asexual reproduction occurs through fragmentation or budding. In sexual reproduction, fertilised eggs hatch in to larvae which grow in the water column for a period of time prior to settling on the sea floor.					
Nephtyidae *Aglaophamus* spp.	*Aglaophamus* spp. are large (up to 170 mm in length) muscular, vigorous, free-burrowing nephtyid worms. They are usually white or cream in colour. *Aglaophamus macroura* is mainly found on the intertidal sand flats in harbours (but does occur offshore also), whereas *Aglaophamus verrilli* is found in the subtidal region in fine to muddy sands. They are found New Zealand wide.	They are secondary predators in sediment-dwelling organism communities and a food source for birds and fish.	At present little is known about the biology of *Aglaophamus* spp. or their sensitivity to sediment mud content. However, they generally prefer sandy habitats over muddy ones. Increases in sediment mud content are likely to result in a decline in *Aglaophamus* spp. abundance.	Yes, if mud content increases.	

Scientific name (common name)	Description and Habitat	Feeding Guild	Indicator Status	Suitability as indicator for expected sedimentation effects	Photo
Ampharetidae	Most are smallish deposit feeders which frequently live in small tubes they build from mud or similar substrate, or burrow in the sand.	deposit feeders	At present little is known about the biology of Ampharetids.	unknown	
Capitellidae *Heteromastus filiformis*	Capitellid worms are long, thin and fragile worms. They have no head appendages or other distinguishable characteristics. Adults can grow up to 50mm long. Capitellids prefer a muddy sand habitat in estuaries and harbours where they can burrow deeply into the sediment up to about 10 cm. They are tolerant of and sometimes flourish in organically-enriched environments.	Capitellids are subsurface deposit feeders and bioturbators. They are prey for fish and birds.	Capitellids tolerate a sediment mud content of up to 95%, with an optimum range of 10-40%. Therefore they are usually found in moderately muddy habitats. Capitellid abundance is often high in organically enriched estuarine sediments. Where sediments change from a sandy to muddier type habitat and/or become organically enriched, the abundance of capitellids is expected to increase. However, where sediment mud content exceeds their optimum range (>40%), capitellids are expected to decrease in abundance.	Yes if mud content increases above 40% the decreases in abundance are expected. If organic content increases then increases in abundance are expected.	
Cirratulidae	Cirratulids are sedentary, cylindrical burrowers, notable for a profusion of simple elongate filaments along the body. The head is conical or wedge-shaped. Intertidal to continental shelf depths throughout New Zealand.	Cirratulids are deposit feeders	At present little is known about the biology of Cirratulids.	unknown	

Scientific name (common name)	Description and Habitat	Feeding Guild	Indicator Status	Suitability as indicator for expected sedimentation effects	Photo
Hesionidae	Hesionids are found in crevices and amongst the plant and animal growths on hard substrata, with some species occurring commensally on echinoderms and with other larger tube-dwelling worms. They are never very large (< 40 mm) and are rather fragile. Lower intertidal and subtidal to deep sea throughout New Zealand.	Hesionids are active carnivorous worms	At present little is known about the biology of Hesionids.	unknown	
Lumbrineridae *Lumbrineris* sp.	Lumbrinerids are found burrowing in soft substrata. They are muscular, elongate, cylindrical worms. They range in size up to 200 mm in length, though usually smaller. Intertidal and subtidal across the continental shelf throughout New Zealand.	Lumbrinerids are probably mostly carnivores.	At present little is known about the biology of Lumbrinerids.	unknown	
Eunicidae *Marphysa* sp.	Eunicids are large, muscular worms, occurring amongst encrusting growths and in crevices, but rarely in soft sediments unless also under rocks. They have strong complex jaws. Eunicids are large worms at around 5-10 cm long but can be more than 50 cm long and of finger thickness. Eunicids are capable of mass spawning synchronised with the lunar cycle. Found throughout New Zealand in the intertidal, and subtidal to continental shelf depths.	Eunicids are carnivores or scavengers	At present little is known about the biology of Eunicids.	unknown	

Scientific name (common name)	Description and Habitat	Feeding Guild	Indicator Status	Suitability as indicator for expected sedimentation effects	Photo
Maldanidae	Bamboo worms are large, blunt-ended, cylindrical worms and feed as bulk consumers of sediment using a balloon-like proboscis. They live below the surface in flimsy sediment tubes. Many species are small, but can be up to 150 mm in length by 7 mm width.	Subsurface deposit-feeding and bioturbators	At present little is known about the biology of Maldanids, however they have been linked with low organic inputs.	unknown	
Orbiniidae *Orbinia* sp.	Orbiniids are long, slender, sand-dwelling worms, they have a small pointed head without eyes. Adult can grow to 100 mm long but are less than 2 mm in width. Lives throughout the sediment preferring sandy habitats. Orbiniids occur throughout New Zealand. Most of the species occur from mid-intertidal levels to shallow subtidal on semi-protected shores. Few species occur in deeper water.	Orbiniids are unselective sub-surface deposit feeders and bioturbators	*Orbinia papillosa* tolerates a sediment mud content up to 40%, with an optimum range of 5-10%. Therefore, it is usually found in sandy habitats. *Orbinia papillosa* has been shown to be slightly sensitive to zinc contamination. Where sediments becomes muddier (exceeding the optimum range) and/or polluted (particularly with zinc), the abundance of *Orbinia papillosa* is likely to decline.	Yes *Orbinia papillosa* is a good indicator species as mud and zinc concentrations increase abundance declines.	

Scientific name (common name)	Description and Habitat	Feeding Guild	Indicator Status	Suitability as indicator for expected sedimentation effects	Photo
Paraonidae	Paraonidae is a family of thin slender burrowing worms. Adults can grow in size to 40mm in length and a width of 1mm but are usually much smaller. They prefer living in muddy sands over a range of habitats from intertidal flats in estuaries and harbours to the deep sea. Found New Zealand wide	Paraonids are mainly subsurface deposit feeders.	At present the tolerance to sediment mud content and optimum range for paranoids as a group is unknown. However, they generally prefer habitats with some mud (muddy sands). Therefore, where estuarine sediments change from a sandy to muddier type habitat the abundance of paranoids is expected to increase. However, where the sediment mud content becomes very high, paraonids are expected to decrease in abundance.	Yes paranoids are good indicators of mud content changes.	
Paraonidae *Aricidea* spp.	*Aricidea* spp. can be distinguished from other paraonids by a small thread-like antennae protruding from the top of the head. They burrow to a depth of about 15cm and are usually found in habitats that have a slightly greater proportion of sand than mud (e.g. muddy sands). Found New Zealand wide.	*Aricidea* spp. are sub-surface deposit feeders and bioturbators	*Aricidea* spp. tolerate a sediment mud content up to 70%, with an optimum range of 35-40%. Where sediments change from a sandy to muddier type habitat the abundance of *Aricidea* spp. is expected to increase. *Aricidea* spp. have also shown sensitivity to lead and zinc contamination. Therefore when sediments become more polluted (particularly with lead or zinc) and/or where sediment mud content exceeds their optimum range (35-40%), *Aricidea* spp. are expected to decrease in abundance	Yes if mud content increases above 40% then decreases abundance are possible. However if mud content exceeds 40%, and lead and zinc concentrations are elevated the abundance is likely to decline.	

Scientific name (common name)	Description and Habitat	Feeding Guild	Indicator Status	Suitability as indicator for expected sedimentation effects	Photo
Phyllodocidae	The Phyllodocids are a colourful family of long, slender worms that live out on the surface of soft substrata. They occur from intertidal to deep sea throughout New Zealand.	very active carnivorous worms	At present little is known about the biology of Phyllodocids.	unknown	
Onuphidae *Rhamphobrachium* sp.	Onuphids are large predatory worms, which live in tubes lined with a secretion of variable thickness and toughness, and often covered with some adhering particles from the substratum. They are mostly subtidal either burrowing or surface-dwelling mostly on soft substrata. Adults grow to 100 mm long and 8 mm wide or larger. They are found throughout New Zealand, from lower intertidal and subtidal to deep sea.	Onuphids are carnivorous or scavenging worms	Physical disturbance has been shown to increase numbers of Onuphids.	At present little is known about the biology of Onuphids, and there response to changes in the environment.	
Sabellidae *Euchone* spp. (Fan or feather duster worms)	Found in soft sediment habitats New Zealand wide. *Euchone* spp. are small (<20mm length) sabellid or fan worms. They are often found encased in a sandy tube, protruding above the sediment surface with the fan-like tentacles exposed.	They are suspension-feeders	At present, the tolerance of *Euchone* spp. to sediment mud content is unknown. *Euchone* spp. are known to be sensitive to copper and zinc contamination. Where sediments becomes polluted (particularly with copper or zinc), the abundance of *Euchone* spp. is expected to decline.	Yes, if the concentration of copper and zinc increases.	

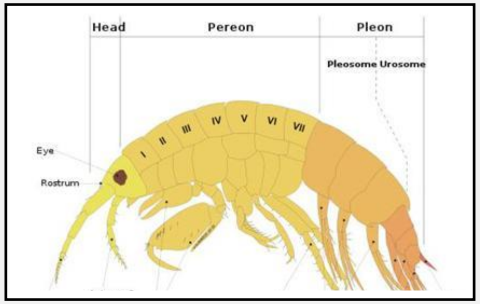
Scientific name (common name)	Description and Habitat	Feeding Guild	Indicator Status	Suitability as indicator for expected sedimentation effects	Photo
Spionidae *Aonides trifida*	*Aonides trifida* is a small (<100mm) thin active spionid worm (smaller than a related spionid species, *Prionospio aucklandica*), with a pointed head and two pairs of eyes. Burrows in fine intertidal and subtidal sands (Prefers low mud content) to 10 cm sediment depth. Found New Zealand wide.	*Aonides trifida* is a surface deposit feeder and bioturbator and a prey for fish and birds.	*Aonides trifida* tolerates a sediment mud content up to 80%, but has an optimum range of 0-5%. Accordingly, *Aonides trifida* is most abundant in sandy habitats. *Aonides trifida* is also sensitive to copper contamination. Where the sediment becomes muddier (exceeding its optimum range) and/or polluted (particularly with copper), the abundance of *Aonides trifida* is likely to decline.	Yes, if mud content increases and copper concentration is elevated	
Spionidae *Prionospio aucklandica*	*Prionospio aucklandica* is a spionid worm, which is slightly larger than the related spionid species *Aonides trifida*. *Prionospio aucklandica* has two pairs of eyes with a rounded head, and three pairs of feather-like gills. They prefer living in moderately to very muddy habitats and is common in the lower intertidal regions of estuaries and harbours, living within the sediment and burrowing to a depth of about 10 cm. Found New Zealand wide.	*Prionospio aucklandica* is a surface deposit-feeder	*Prionospio aucklandica* tolerates a sediment mud content of up to 95%, with an optimum range of 20-70%. It is usually found in moderately to very muddy habitats, but is less abundant in extremely muddy areas (>70% mud). *Prionospio aucklandica* is also sensitive to copper contamination.	Yes if mud content increases then increases in abundance are possible. However if mud content exceeds 70%, and copper concentrations are elevated the abundance is likely to decline.	
Syllidae *Sphaerosyllis* sp.	Syllids are slender, colourful small to medium-sized polychaete worms that range in size from 2–3 mm to 14 cm. They are found from the intertidal to the deep sea, but are especially abundant in shallow water throughout New Zealand. They are found in a range of habitats, rock and sandy substrates, and on other biota, but *Sphaerosyllis* prefers sandy sediments.	They are generalist feeders.	At present little is known about the biology of Syllids. *Sphaerosyllis* sp. has been found to tolerate sediment mud content up to 40%, with an optimum range of 25-30% mud.	Yes if mud content increases from less than 40%.	
Nemertea	Ribbon or Proboscis Worms, mostly solitary, predatory, free-living animals.	predatory	Nemertea tolerate have been found to tolerate sediment mud content up to 95%, with an optimum range of 55-60% mud. They are intolerant of anoxic conditions.	Yes if mud content increases from less than 60%, or if anoxic conditions occur.	

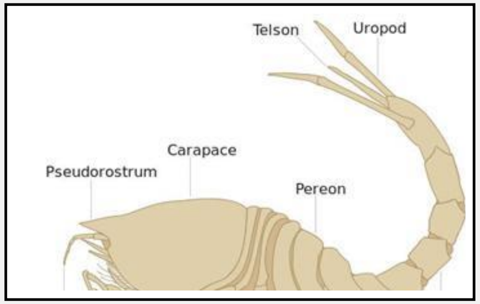
Scientific name (common name)	Description and Habitat	Feeding Guild	Indicator Status	Suitability as indicator for expected sedimentation effects	Photo
Sipuncula	Sipunculid worms or peanut worms is a small group species of bilaterally symmetrical, unsegmented marine worms.	Deposit feeders	At present little is known about the biology.	unknown	
Mollusca					
Nucula sp. (Nut shell)	*Nucula hartvigiana* is a small to moderately large shellfish (6-8 mm in length) with an ovate inflated shape. They prefer muddy sand to sandy mud habitats (intertidal and subtidal to a depth of 20 m) in unpolluted environments. They are found New Zealand wide	*Nucula* sp. are highly mobile deposit feeder.	*Nucula hartvigiana* tolerates a sediment mud content up to 60%, with an optimum range of 0-5%. Therefore it prefers more sandy habitats. *Nucula hartvigiana* is also sensitive to organic enrichment and copper contamination.	Yes, where the sediment mud content increases (exceeding its optimum range) and/or becomes organically enriched or polluted with copper, the abundance of *Nucula hartvigiana* is likely to decline.	
Antalis nana (Tusk shell)	Tusk shells live in seafloor sediment offshore. Most adult scaphopods live their lives entirely buried within the substrate. A number of minute tentacles around the foot, sift through the sediment and latch onto bits of food, which they then convey to the mouth. The mouth has a grinding radula that breaks the bit into smaller pieces for digestion. They have separate sexes, and external fertilisation. Once fertilised, the eggs hatch into a free-living planktivorous trochophore larva, which develops into a veliger larva.	They feed primarily on foraminifera, however some supplement this with vegetable matter	At present little is known about the biology.	unknown	

Scientific name (common name)	Description and Habitat	Feeding Guild	Indicator Status	Suitability as indicator for expected sedimentation effects	Photo

Crustaceans

The segmented exoskeleton (shell) of a crustacean is generally divided into three main regions: head, chest (thorax or pereon) and abdomen (pleon). In some cases (for instance, crabs) the plates of the head and thorax are fused together to create a single shell which covers most of the animal's back (carapace). The carapace may also have a forward projection between the eyes known as the rostrum. Crustacean shells are particularly strong due to their inclusion of calcium carbonate. Each body segment often bears a pair of appendages (limb like structures) which have different functions. On the head these include sensory feelers (antennae) and mouthpart structures (maxillae and mandibles). Bristle like hairs known as 'setae or chaetae' are often present in the mouthparts of crustaceans and on their feeding legs (maxillipeds). These are used to catch and trap food particles and detect changes in their environment. The thorax has a mixture of specialised walking legs (pereiopods), feeding legs (maxillipeds), these appendages also create water currents to keep oxygen flow past their gills for breathing. The abdomen often has paired swimming appendages (pleopods) and a tail like structure on the last body segment known as a telson.





Life cycle

The majority of crustaceans have separate sexes and reproduce sexually. Some species like barnacles are hermaphrodites (having both male and female reproductive organs). Many crustaceans release fertilised eggs in to the water column where they develop as larvae before settling on an appropriate substrate. Others carry eggs on their pleopod legs or create a brood pouch to carry them in. As crustaceans have a hard outer skeleton, they must moult at certain stages in their development (a process known as ecdysis) in order to grow.

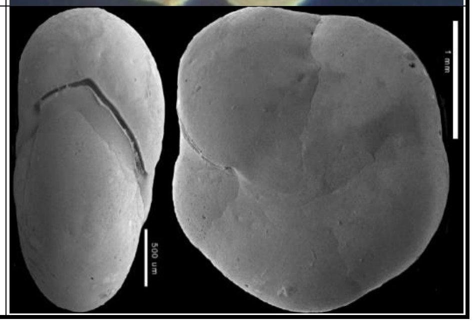
Amphipods

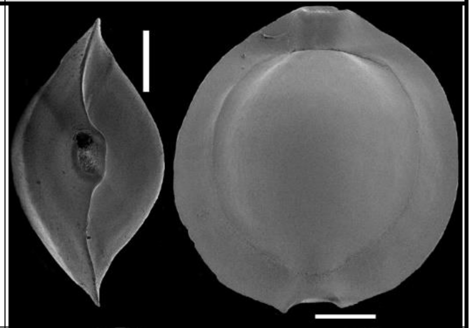
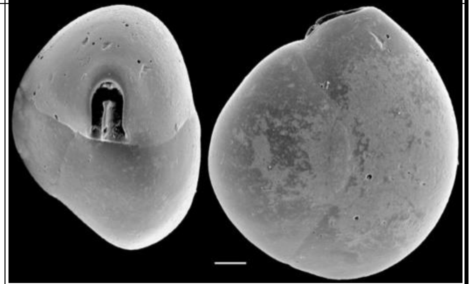
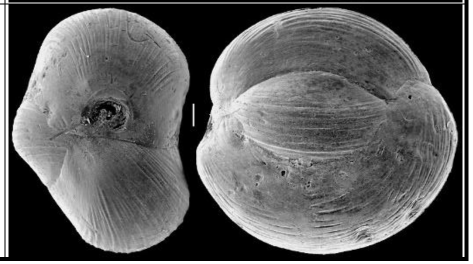
Scientific name (common name)	Description and Habitat	Feeding Guild	Indicator Status	Suitability as indicator for expected sedimentation effects	Photo
Ampeliscidae	They are benthic, found at the bottom of seas and oceans. They are distributed worldwide, and are often abundant in areas with fine sediments. They live in infaunal tubes, constructed from "amphipod silk" and sediment.	species that are both suspension feeders and surface deposit feeders	At present little is known about the biology of New Zealand species. Published literature has established that amphipods are sensitive to polluted sediments, with a general decrease of amphipod abundance and diversity when pollution increases, however sensitivity changes between species.	unknown	
Amphilochidae	They are benthic and living within the sediment.	subsurface deposit feeders	At present little is known about the biology of New Zealand species. Published literature has established that amphipods are sensitive to polluted sediments, with a general decrease of amphipod abundance and diversity when pollution increases, however sensitivity changes between species.	unknown	

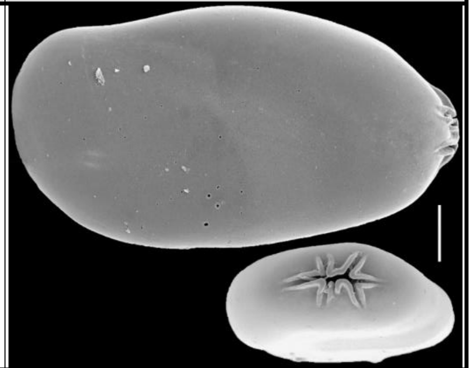
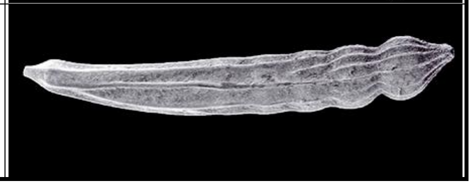
Scientific name (common name)	Description and Habitat	Feeding Guild	Indicator Status	Suitability as indicator for expected sedimentation effects	Photo
Liljeborgia sp.	They are benthic	unknown	At present little is known about the biology of New Zealand species. Published literature has established that amphipods are sensitive to polluted sediments, with a general decrease of amphipod abundance and diversity when pollution increases, however sensitivity changes between species.	unknown	
Lysianassidae	They are benthic and living within the sediment.	Species from this group are either subsurface deposit feeders or opportunistic predatory scavenger feeders	At present little is known about the biology of New Zealand species. Published literature has established that amphipods are sensitive to polluted sediments, with a general decrease of amphipod abundance and diversity when pollution increases, however sensitivity changes between species.	unknown	
Phoxocephalidae	Occur from intertidal (shallow) to deeper environments (50 m depth). Burrow into the sediment. Prefer muddy sand habitats and are sensitive to pollution. They are found New Zealand wide.	Phoxocephalidae are small amphipods which are surface deposit feeders and bioturbators. They are prey for fish and birds.	The preferred mud content is unknown for most phoxocephalids; however, phoxocephalid amphipods are known to be intolerant to very high mud content. They are usually found in muddy sands. Phoxocephalid amphipods cannot tolerate pollution. One species has been shown to be sensitive to lead contamination.	Yes, if the sediment becomes muddier and/or polluted the abundance of phoxocephalids is likely to decline.	

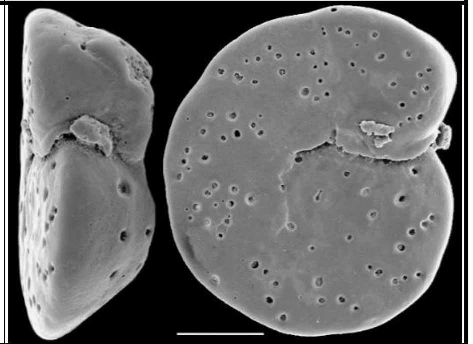
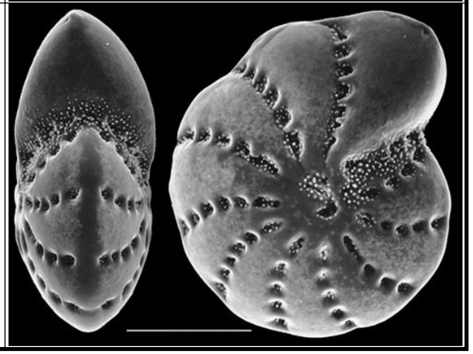
Scientific name (common name)	Description and Habitat	Feeding Guild	Indicator Status	Suitability as indicator for expected sedimentation effects	Photo
Urothoidae	Members of the family are found worldwide. Burrow into the sediment.	mainly detritivores and interface grazers, though some are also facultative filter feeders	At present little is known about the biology of New Zealand species. Published literature has established that amphipods are sensitive to polluted sediments, with a general decrease of amphipod abundance and diversity when pollution increases, however sensitivity changes between species.		
Isopoda					
Asellota *Munna* sp.	Asellota are a highly variable group of Isopoda with many species in freshwater and marine shallow-water environments. Most very small benthic or epibenthic blind animals with a body size of a few millimetres, which are difficult to identify at the species level. They have no planktonic larvae stage.	Some species have been shown to feed on foraminifera	At present little is known about the biology of New Zealand species.	Unknown	
Cymothoida *Paranthura flagellata*	They are found New Zealand wide.		At present little is known about the biology of New Zealand species.	Unknown	
Cumacean (Cumacean shrimp or hooded shrimp)	Generally small, transparent and non-descript crustaceans. They are burrowers, reworking or bioturbating the sediment surface. Prefer fine to muddy sand and are sensitive to pollution. They are found New Zealand wide.	Cumaceans feed mainly on microorganisms and organic material from the sediment. Species that live in the mud filter their food, while species that live in sand browse individual grains of sand. Some have adapted for predation on foraminifera and small crustaceans	*Colurostylis lemurum* tolerates a sediment mud content of up to 60%, with an optimum range of 0-5%. Therefore they are usually found in sandy habitats. *Colurostylis lemurum* is also sensitive to lead contamination and other pollution.	Yes, where the sediment mud content increases (exceeding its optimum range) and/or becomes more polluted the abundance of *Colurostylis lemurum* is likely to decline.	

Scientific name (common name)	Description and Habitat	Feeding Guild	Indicator Status	Suitability as indicator for expected sedimentation effects	Photo
Mysid (opossum shrimps)	Small, shrimp-like crustaceans found worldwide in both shallow and deep marine waters where they can be benthic or pelagic, but most are found close to, crawling on or burrowing into the mud or sand. Opossum shrimps stems from the presence of a brood pouch or "marsupium" in females. The larvae are reared in this pouch and are not free-swimming.	Mysids are filter feeders, omnivores that feed on algae, detritus and zooplankton.	They are sensitive to water pollution, so are sometimes used as bio indicators to monitor water quality	unknown	
Ostracod (seed shrimp)	They are small crustaceans, typically around 1 mm in size, their bodies are flattened from side to side and protected by a bivalve-like, chitinous or calcareous shell. Marine ostracods can be part of the zooplankton or most commonly part of the benthos, living on or inside the upper layer of the sea floor.	They have a wide range of diets, and the group includes carnivores, herbivores, scavengers and filter feeders	unknown	unknown	
Tanaidacea	Tanaids are small, shrimp-like creatures normally ranging in adult size from 2 to 5 mm. Most are marine, from estuaries to deep water, dwelling on or near the bottom.	They are generally filter feeders, but some species are predatory.	unknown	unknown	
Ophiuroidea *Amphiura* sp. (Brittle starfish)	Mobile species found on soft muddy or sandy substrates from estuarine to deep sea.	Ophiuroids are generally scavengers or detritivores.	unknown	unknown	

Scientific name (common name)	Description and Habitat	Feeding Guild	Indicator Status	Suitability as indicator for expected sedimentation effects	Photo
Demospongiae sponge - sandy, flask-shaped		Filter feeders	unknown	unknown	
Foraminifera Foraminifera are single-celled organisms with shells. The shells are commonly divided into chambers that are added during growth, though the simplest forms are open tubes or hollow spheres. Fully grown they are usually less than 1 mm in size. Foraminifera are found in all marine environments, from the intertidal to the deepest ocean trenches, and from the tropics to the poles. Very little is known about how most species of foraminifera live. The few species that have been studied show a wide range of behaviours, diet, and life cycles. Individuals of some species live only a few weeks, while other species live many years. Some benthic species burrow actively, though slowly, through sediment at speeds up to 1cm per hour, while others attach themselves to the surface of rocks or marine plants. They eat foods ranging from dissolved organic molecules, bacteria, diatoms and other single-celled algae, to small animals such as copepods. They catch their food with a network of thin pseudopodia that extend from one or more apertures in the shell. Benthic foraminifera also use their pseudopodia for locomotion. Foraminifera are abundant enough to be an important part of the marine food chain, and their predators include marine snails, sand dollars and small fish.					
Lituolida *Ammodiscus* sp.			unknown	unknown	
Miliodida *Nummuloculina contraria*			unknown	unknown	

Scientific name (common name)	Description and Habitat	Feeding Guild	Indicator Status	Suitability as indicator for expected sedimentation effects	Photo
Miliodida *Pyrgo* sp.			unknown	unknown	
Miliodida *Quinqueloculina suborbicularis*			unknown	unknown	
Miliodida *Triloculina insignis*			unknown	unknown	

Scientific name (common name)	Description and Habitat	Feeding Guild	Indicator Status	Suitability as indicator for expected sedimentation effects	Photo
Lagenida *Astacolus* sp.			unknown	unknown	
Lagenida *Lenticulina* sp.			unknown	unknown	
Lagenida *Nodosaria vertebralis*			unknown	unknown	

Scientific name (common name)	Description and Habitat	Feeding Guild	Indicator Status	Suitability as indicator for expected sedimentation effects	Photo
Rotaliida *Cibicidoides* sp.			unknown	unknown	
Rotaliida *Alabamina* sp.			unknown	unknown	
Rotaliida *Elphidium* sp.			unknown	unknown	

Appendix 3 Sediment Gravity Core Photographs post 150,000 m^3 Survey.

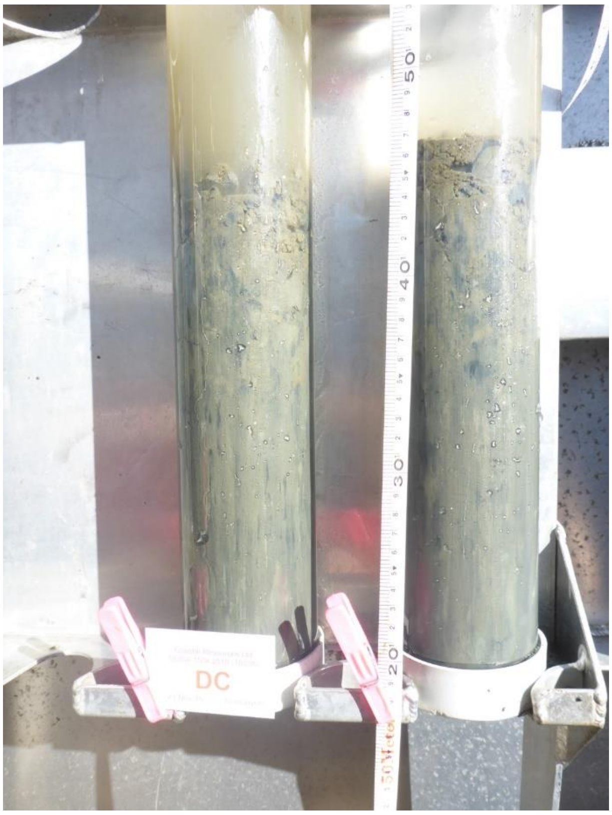


Figure 8.1 Sediment Gravity Cores – Disposal Centre Site, 23 November 2016

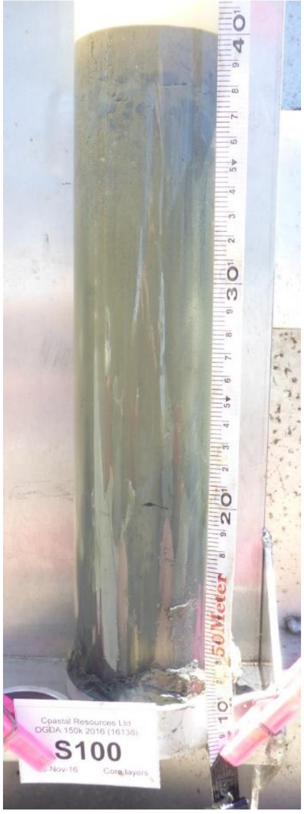


Figure 8.3 Sediment Gravity Cores – S 100, 23 November 2016

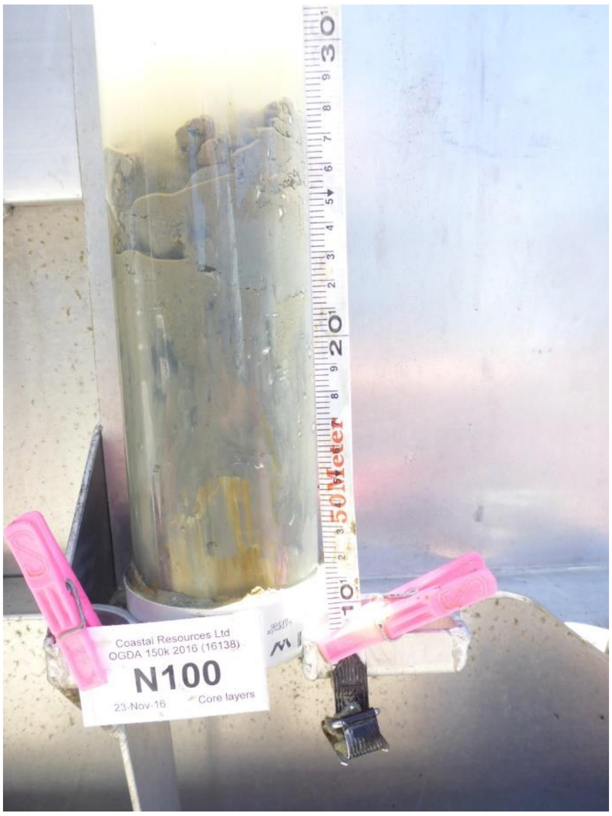


Figure 8.2 Sediment Gravity Cores – N 100, 23 November 2016

Figure 8.4 Sediment Gravity Cores – N 250, 23 November 2016

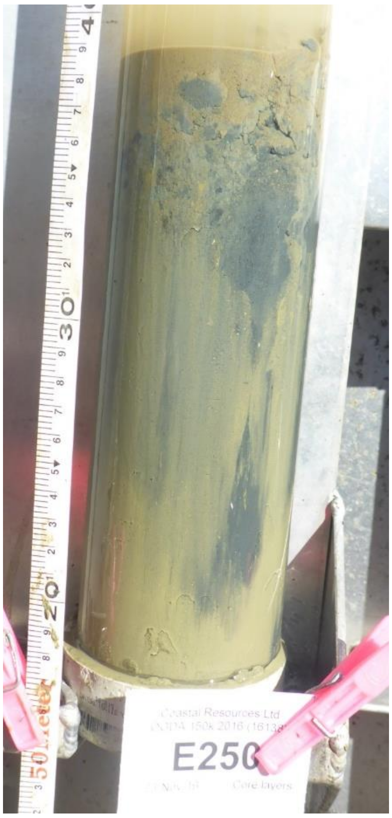


Figure 8.5 Sediment Gravity Cores – E 250, 23 November 2016

Figure 8.7 Sediment Gravity Cores – W 250, 23 November 2016

Figure 8.6 Sediment Gravity Cores – S 250, 23 November 2016

Figure 8.8 Sediment Gravity Cores – N 375, 23 November 2016

Figure 8.9 Sediment Gravity Cores – S 375, 23 November 2016

Figure 8.10 Sediment Gravity Cores – N 500, 23 November 2016

Figure 8.11 Sediment Gravity Cores – E 500, 23 November 2016

Figure 8.12 Sediment Gravity Cores – S 500, 23 November 2016

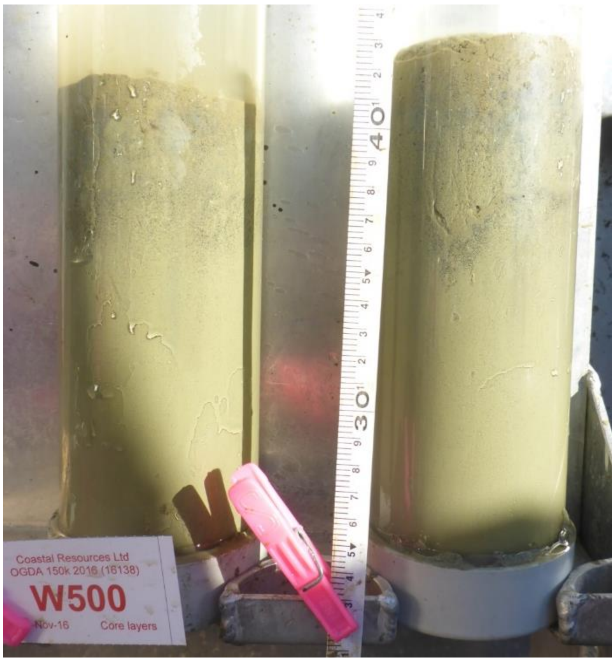


Figure 8.13 Sediment Gravity Cores – W 500, 23 November 2016

Figure 8.15 Sediment Gravity Cores – E 1000, 23 November 2016

Figure 8.14 Sediment Gravity Cores – N 1000, 23 November 2016

Figure 8.16 Sediment Gravity Cores – S 1000, 23 November 2016

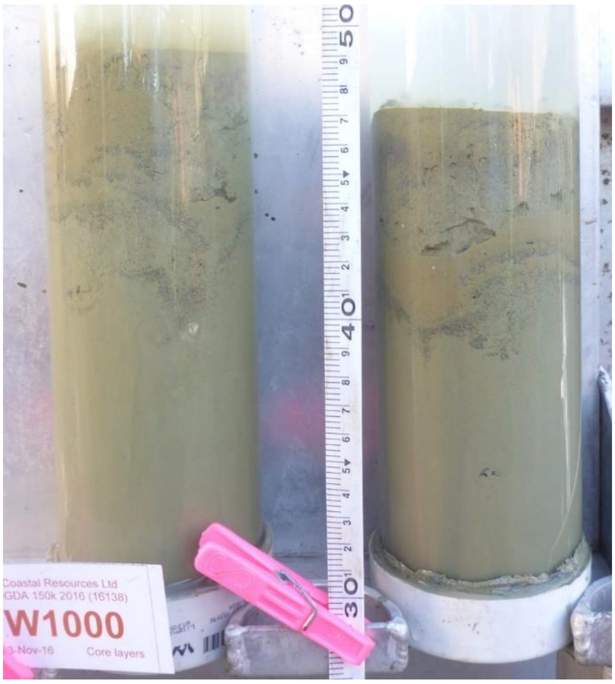


Figure 8.17 Sediment Gravity Cores – W 1000, 23 November 2016

Figure 8.18 Sediment Gravity Cores – N 1500, 23 November 2016

Figure 8.19 Sediment Gravity Cores – E 1500, 23 November 2016

Figure 8.20 Sediment Gravity Cores – S 1500, 23 November 2016

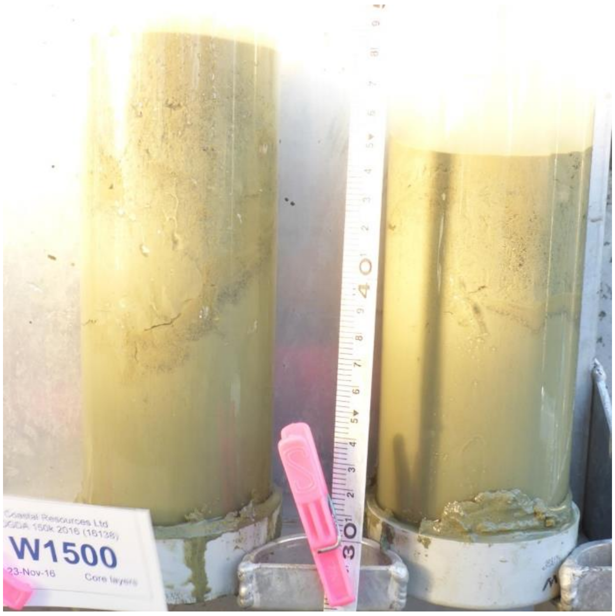


Figure 8.21 Sediment Gravity Cores – W 1500, 23 November 2016

Figure 8.22 Sediment Gravity Cores – NE 1750, 23 November 2016

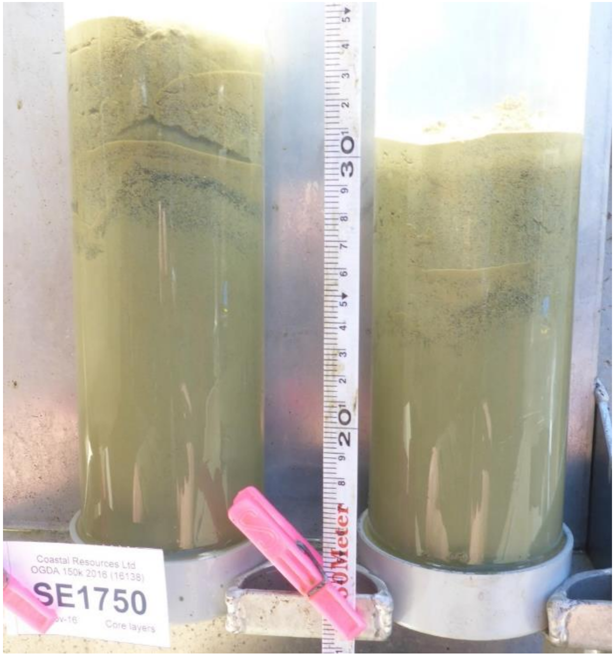


Figure 8.23 Sediment Gravity Cores – SE 1750, 23 November 2016

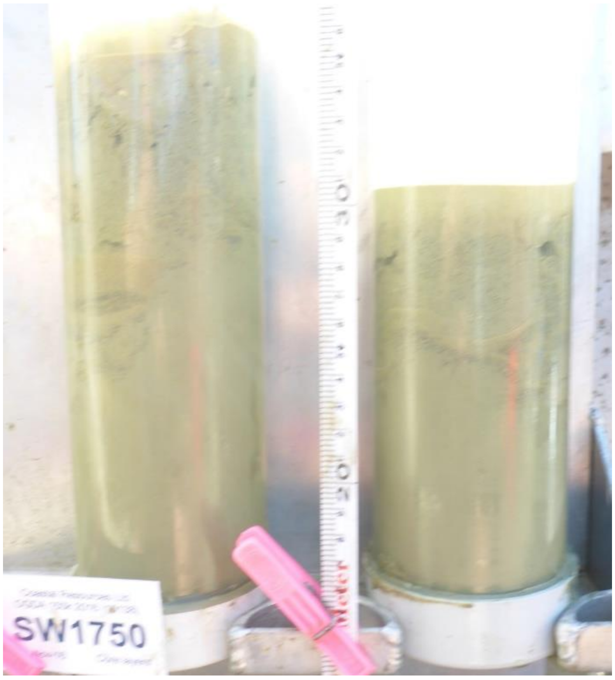


Figure 8.24 Sediment Gravity Cores – SW 1750, 23 November 2016

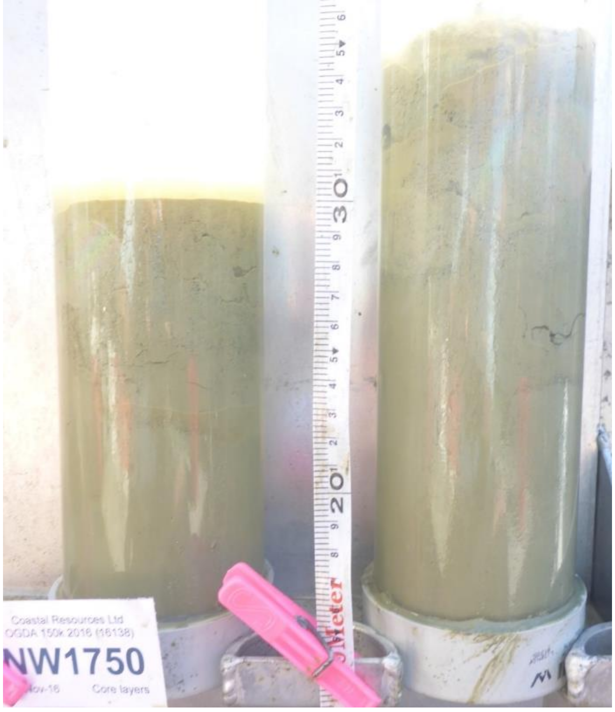


Figure 8.25 Sediment Gravity Cores – NW 1750, 23 November 2016

Figure 8.26 Sediment Gravity Cores - Control A, 23 November 2016

Figure 8.27 Sediment Gravity Cores - Control B, 23 November 2016

Figure 8.28 Sediment Gravity Cores - Control C, 23 November 2016

Appendix 4 Post Disposal Sediment Core Depth Data

Table 8.1 Sediment Core Depths (mm), August 2013, Post 10,000 m³ Disposal

<table>
<tr><th rowspan="2" colspan="2">Site</th><th rowspan="2">Date</th><th colspan="3">Depth of Core</th><th colspan="3">Depth of Mixing</th><th rowspan="2">Comments</th></tr>
<tr><th>A</th><th>B</th><th>Average</th><th>A</th><th>B</th><th>Average</th></tr>
<tr><td colspan="2">DC</td><td>August 2013</td><td>290</td><td>300</td><td>295.0</td><td>-</td><td>-</td><td></td><td>No obvious mixed layer, sediment darker in colour, surface interface broken, some indication of original seabed sediment at about 27 cm</td></tr>
<tr><td colspan="2" rowspan="3">DC</td><td rowspan="3">December 2013</td><td>201</td><td>319</td><td rowspan="3">220.8</td><td>-</td><td>-</td><td rowspan="3"></td><td>No obvious mixed layer, sediment darker in colour, ~ 6 cm layer of loose material on top, no indication of original seabed sediment</td></tr>
<tr><td>133</td><td>247</td><td>-</td><td>-</td><td>No obvious mixed layer, sediment darker in colour, ~ 7 cm layer of loose material on top, no indication of original seabed sediment</td></tr>
<tr><td>171</td><td>253</td><td>-</td><td>-</td><td>No obvious mixed layer, sediment darker in colour, ~ 7 cm layer of loose material on top, no indication of original seabed sediment</td></tr>
<tr><td rowspan="12">250</td><td rowspan="3">N</td><td rowspan="3">December 2013</td><td>132</td><td>159</td><td rowspan="3">148.0</td><td>66</td><td>80</td><td rowspan="3">60.3</td><td>mixing layer slightly darker and coarser</td></tr>
<tr><td>143</td><td>129</td><td>32</td><td>51</td><td>mixing layer slightly darker and coarser, some open spaces</td></tr>
<tr><td>170</td><td>155</td><td>73</td><td>60</td><td>mixing layer slightly darker, mottled and coarser, some open spaces</td></tr>
<tr><td rowspan="3">E</td><td rowspan="3">December 2013</td><td>200</td><td>160</td><td rowspan="3">167.1</td><td>93</td><td>49</td><td rowspan="3">64.3</td><td>mixing layer slightly darker, mottled and coarser, some open spaces, ~ 1 cm layer loose material on top</td></tr>
<tr><td>160</td><td>167</td><td>69</td><td>50</td><td>mixing layer slightly darker, mottled and coarser, some open spaces, ~ 1 cm layer loose material on top</td></tr>
<tr><td>155</td><td>161</td><td>70</td><td>54</td><td>mixing layer slightly darker, mottled and coarser, some open spaces, ~ 1 cm layer loose material on top</td></tr>
<tr><td rowspan="3">S</td><td rowspan="3">December 2013</td><td>143</td><td>147</td><td rowspan="3">149.9</td><td>51</td><td>58</td><td rowspan="3">62.2</td><td>mixing layer slightly darker and coarser</td></tr>
<tr><td>146</td><td>150</td><td>70</td><td>60</td><td>mixing layer slightly darker and coarser, some open spaces</td></tr>
<tr><td>163</td><td>150</td><td>61</td><td>73</td><td>mixing layer slightly darker and coarser, some open spaces</td></tr>
<tr><td rowspan="3">W</td><td rowspan="3">December 2013</td><td>164</td><td>124</td><td rowspan="3">154.1</td><td>59</td><td>57</td><td rowspan="3">54.4</td><td>mixing layer slightly darker and coarser</td></tr>
<tr><td>174</td><td>140</td><td>47</td><td>43</td><td>mixing layer slightly darker and coarser</td></tr>
<tr><td>156</td><td>166</td><td>65</td><td>55</td><td>mixing layer slightly darker and coarser</td></tr>
<tr><td rowspan="4">500</td><td>N</td><td rowspan="4">August 2013</td><td>165</td><td>140</td><td>152.5</td><td>70</td><td>70</td><td>70.0</td><td>surface layer slightly darker and coarser</td></tr>
<tr><td>E</td><td>120</td><td>165</td><td>142.5</td><td>80</td><td>75</td><td>77.5</td><td>surface layer slightly darker and coarser</td></tr>
<tr><td>S</td><td>180</td><td>150</td><td>165.0</td><td>50</td><td>50</td><td>50.0</td><td>surface layer slightly darker and coarser</td></tr>
<tr><td>W</td><td>170</td><td>190</td><td>180.0</td><td>70</td><td>75</td><td>72.5</td><td>surface layer slightly darker, mottled and coarser, some open spaces</td></tr>
<tr><td rowspan="4">1000</td><td>N</td><td rowspan="4">August 2013</td><td>115</td><td>150</td><td>132.5</td><td>35</td><td>35</td><td>35.0</td><td>surface layer slightly darker and coarser</td></tr>
<tr><td>E</td><td>165</td><td>145</td><td>155.0</td><td>50</td><td>55</td><td>52.5</td><td>surface layer slightly darker and coarser</td></tr>
<tr><td>S</td><td>150</td><td>145</td><td>147.5</td><td>65</td><td>60</td><td>62.5</td><td>surface layer slightly darker and coarser</td></tr>
<tr><td>W</td><td>195</td><td>170</td><td>182.5</td><td>95</td><td>70</td><td>82.5</td><td>surface layer slightly darker and coarser, some open spaces</td></tr>
<tr><td rowspan="4">1500</td><td>N</td><td rowspan="4">August 2013</td><td>140</td><td>155</td><td>147.5</td><td>55</td><td>65</td><td>60.0</td><td>surface layer slightly darker and coarser</td></tr>
<tr><td>E</td><td>125</td><td>160</td><td>142.5</td><td>70</td><td>65</td><td>67.5</td><td>surface layer slightly mottled and coarser</td></tr>
<tr><td>S</td><td>150</td><td>180</td><td>165.0</td><td>70</td><td>75</td><td>72.5</td><td>surface layer slightly darker, mottled and coarser, some open spaces</td></tr>
<tr><td>W</td><td>145</td><td>185</td><td>165.0</td><td>65</td><td>130</td><td>97.5</td><td>surface layer slightly darker, mottled and coarser, some open spaces</td></tr>
<tr><td rowspan="4">1750</td><td>NE</td><td rowspan="4">August 2013</td><td>160</td><td>190</td><td>175.0</td><td>80</td><td>80</td><td>80.0</td><td>surface layer slightly darker, mottled and coarser, some open spaces</td></tr>
<tr><td>SE</td><td>145</td><td>140</td><td>142.5</td><td>55</td><td>45</td><td>50.0</td><td>surface layer mottled, some open spaces</td></tr>
<tr><td>SW</td><td>180</td><td>140</td><td>160.0</td><td>70</td><td>65</td><td>67.5</td><td>surface layer slightly darker, mottled and coarser, some open spaces</td></tr>
<tr><td>NW</td><td>195</td><td>175</td><td>185.0</td><td>95</td><td>65</td><td>80.0</td><td>surface layer mottled, some open spaces</td></tr>
<tr><td rowspan="3">Control</td><td>A</td><td rowspan="3">August 2013</td><td>170</td><td>140</td><td>155.0</td><td>60</td><td>70</td><td>65.0</td><td>surface layer slightly darker, mottled and coarser, some open spaces</td></tr>
<tr><td>B</td><td>155</td><td>170</td><td>162.5</td><td>55</td><td>70</td><td>62.5</td><td>surface layer slightly darker, mottled and coarser, some open spaces</td></tr>
<tr><td>C</td><td>155</td><td>160</td><td>157.5</td><td>70</td><td>120</td><td>95.0</td><td>surface layer slightly darker and coarser, some open spaces</td></tr>
</table>

Table 8.2 Sediment Core Depths (mm), April 2015, Post 50,000 m^3 Disposal

Site		Depth of Core			Depth of Mixing			Comments
		A	B	Average	A	B	Average	
DC		112	133	**122.4**	-	-		No obvious mixed layer, sediment darker in colour, surface interface broken
500	N	170	223	**196.8**	53	96	**74.5**	surface layer slightly darker and coarser
	E	182	166	**174.0**	65	52	**58.4**	surface layer slightly darker and coarser
	S	159	183	**170.7**	65	59	**62.0**	surface layer slightly darker, mottled and coarser, some open spaces
	W	179	160	**169.3**	77	59	**68.0**	surface layer slightly darker and coarser
1000	N	174	183	**178.3**	93	54	**73.9**	surface layer slightly darker, mottled and coarser
	E	194	164	**179.4**	75	65	**70.1**	surface layer slightly darker, mottled and coarser, some open spaces
	S	176	172	**174.1**	74	83	**78.7**	surface layer slightly darker, mottled and coarser, some open spaces
	W	190	203	**196.1**	78	96	**87.0**	surface layer slightly darker and coarser, some open spaces
1500	N	157	196	**176.5**	78	69	**73.5**	surface layer slightly darker and coarser
	E	152	196	**174.0**	54	69	**61.5**	surface layer slightly darker, mottled and coarser, some open spaces
	S	186	190	**187.6**	52	62	**56.7**	surface layer slightly darker, mottled and coarser, some open spaces
	W	193	198	**195.5**	68	57	**62.5**	surface layer slightly darker, mottled and coarser
1750	NE	183	171	**177.4**	55	43	**48.8**	surface layer slightly darker, and coarser
	SE	171	167	**169.2**	70	50	**59.7**	surface layer slightly darker, mottled and coarser, some open spaces
	SW	183	188	**185.4**	85	73	**79.3**	surface layer slightly darker, mottled and coarser, some open spaces
	NW	198	182	**189.9**	91	61	**75.8**	surface layer mottled, some open spaces
Control	A	150	148	**149.0**	67	63	**65.4**	surface layer slightly darker, mottled and coarser
	B	217	194	**205.3**	69	57	**63.2**	surface layer slightly darker, mottled and coarser, some open spaces
	C	183	194	**189.0**	57	60	**58.6**	surface layer slightly darker and coarser

Table 8.3 Sediment Core Depths (mm), August 2015, Post 100,000 m^3 Disposal

Site		Depth of Core			Depth of mixing			Comments
		A	B	Average	A	B	Average	
DC 150 E		225		**225.2**	-	-		No obvious mixed layer, sediment darker in colour, surface interface broken, some open spaces
250	**N**	204		**204.1**	98		**97.7**	surface layer slightly darker, mottled and coarser, some open spaces
	E	194		**193.8**	81		**80.9**	surface layer darker and coarser
	S	183		**182.8**	78		**77.6**	surface layer darker, and coarser
	W	198		**198.5**	96		**96.2**	surface layer darker and coarser
500	**N**	195	199	**196.8**	64	76	**70.1**	surface layer slightly darker, mottled and coarser
	E	162	168	**165.2**	61	73	**66.9**	surface layer slightly darker, mottled and coarser, some open spaces
	S	142	207	**174.7**	63	79	**71.1**	surface layer slightly darker, mottled and coarser, some open spaces
	W	186	192	**188.9**	74	47	**60.5**	surface layer darker and coarser
1000	**N**	168	185	**176.8**	86	51	**68.4**	surface layer slightly darker, mottled and coarser
	E	158	162	**160.1**	57	71	**63.9**	surface layer slightly darker, mottled and coarser, some open spaces
	S	138	169	**153.8**	44	69	**56.7**	surface layer slightly darker, mottled and coarser, some open spaces
	W	213	215	**214.1**	85	69	**77.0**	surface layer darker, mottled, some open spaces
1500	**N**	156	164	**160.1**	75	79	**77.0**	surface layer slightly darker, mottled and coarser, some open spaces
	E	157	153	**154.9**	71	76	**73.5**	surface layer slightly darker, mottled and coarser
	S	154	169	**161.6**	70	65	**67.6**	surface layer slightly darker, mottled and coarser
	W	155	174	**164.6**	77	53	**64.9**	surface layer slightly darker, mottled and coarser
1750	**NE**	129	150	**139.4**	62	52	**56.7**	surface layer mottled, and coarser, some open spaces
	SE	168	166	**166.6**	58	70	**64.3**	surface layer mottled and coarser
	SW	213	227	**219.9**	81	97	**89.2**	surface layer mottled and coarser, some open spaces
	NW	184	191	**187.5**	53	56	**54.4**	surface layer mottled, some open spaces
Control	**A**	182	203	**192.3**	70	93	**81.3**	surface layer mottled and coarser, some open spaces
	B	175	181	**178.2**	82	70	**76.0**	surface layer slightly darker, mottled and coarser, some open spaces
	C	188	196	**192.3**	80	85	**82.4**	surface layer slightly darker, mottled and coarser, some open spaces

Summary	**Average**	CL	**Average**	CL	
DC	**225**				
250	**195**	14.4	**88**	16.4	
500	**181**	18.3	**67**	8.8	
1000	**176**	22.4	**66**	12.7	
1500	**160**	6.4	**71**	7.1	
1750	**178**	27.0	**66**	13.3	
Control	**188**	10.9	**80**	9.3	

Table 8.4 Sediment Core Depths (mm), November 2016, Post 150,000 m^3 Disposal

Site		Depth of Core			Depth of mixing			Comments
		A	B	Average	A	B	Average	
DC		263	280	**271.3**	263	280	**271.3**	No obvious mixed layer, sediment darker in colour, likely all disposal material, surface interface broken
100 m	**N**	172		**171.7**	172		**171.7**	No obvious mixed layer, sediment darker in colour, some clay present, likely all disposal material, surface interface broken
	S	296		**296.3**	296		**296.3**	No obvious mixed layer, sediment darker in colour, likely all disposal material
250 m	**N**	231		**230.9**	73		**73.2**	surface layer slightly darker and coarser, surface layer similar to 500 m and beyond, unlikely disposal material
	E	224		**223.7**	195		**194.9**	surface layer slightly darker, mottled and coarser, surface layer likely disposal material, surface broken
	S	213		**213.2**	81		**80.9**	surface layer slightly darker and coarser, surface layer similar to 500 m and beyond, unlikely disposal material
	W	232		**232.5**	158		**157.7**	surface layer slightly darker and mottled, surface layer may be disposal material
375 m	**N**	210		**210.0**	83		**82.5**	surface layer slightly darker and coarser, surface layer similar to 500 m and beyond, unlikely disposal material
	S	164		**164.0**	73		**72.9**	surface layer slightly darker and coarser, surface layer similar to 500 m and beyond, unlikely disposal material
500 m	**N**	179	175	**177.0**	70	75	**72.7**	surface layer slightly darker and coarser, unlikely disposal material
	E	176	181	**178.9**	60	73	**66.5**	surface layer slightly darker and coarser, unlikely disposal material
	S	173	199	**186.1**	62	69	**65.8**	surface layer slightly darker and coarser, unlikely disposal material
	W	186	204	**194.7**	58	73	**65.5**	surface layer slightly darker and coarser, unlikely disposal material
1000 m	**N**	166	171	**168.7**	61	61	**61.2**	surface layer slightly darker, mottled and coarser, unlikely disposal material
	E	169	174	**171.8**	68	56	**62.4**	surface layer slightly darker, mottled and coarser, some open spaces, unlikely disposal material
	S	192	198	**194.9**	75	83	**78.8**	surface layer slightly darker, mottled and coarser, some open spaces, unlikely disposal material
	W	204	184	**193.9**	89	84	**86.8**	surface layer slightly darker and coarser, some open spaces, unlikely disposal material
1500 m	**N**	178	155	**166.4**	76	66	**70.7**	surface layer slightly darker and coarser, unlikely disposal material
	E	171	173	**172.1**	70	73	**71.7**	surface layer slightly darker, mottled and coarser, unlikely disposal material
	S	208	208	**208.3**	80	73	**76.4**	surface layer slightly darker, mottled and coarser, some open spaces, unlikely disposal material
	W	208	163	**185.6**	108	63	**85.6**	surface layer slightly darker, mottled and coarser, unlikely disposal material
1750 m	**NE**	165	176	**170.4**	52	71	**61.7**	surface layer slightly darker, and coarser, unlikely disposal material
	SE	211	176	**193.5**	74	70	**72.2**	surface layer slightly darker, mottled and coarser, some open spaces, unlikely disposal material
	SW	216	162	**189.2**	68	74	**71.2**	surface layer slightly darker, mottled and coarser, some open spaces, unlikely disposal material
	NW	158	208	**183.1**	64	68	**66.1**	surface layer mottled, some open spaces, unlikely disposal material
Control	**A**	178	194	**186.2**	78	75	**76.6**	surface layer slightly darker, mottled and coarser, no disposal material
	B	197	182	**189.4**	74	74	**73.7**	surface layer slightly darker, mottled and coarser, some open spaces, no disposal material
	C	190	197	**193.7**	66	65	**65.5**	surface layer slightly darker and coarser, no disposal material

Summary	Average	CL	Average	CL
DC	**271**	111.2	**271**	111.2
100 m	**234**	791.7	**234**	791.7
250 m	**225**	13.9	**127**	94.5
375m	**187**	292.4	**78**	61.2
500 m	**184**	9.5	**68**	5.3
1000 m	**182**	11.9	**72**	10.3
1500 m	**183**	18.2	**76**	11.6
1750 m	**184**	20.1	**68**	5.9
Control	**190**	8.5	**72**	5.6

Appendix 5 Post Disposal Sediment Particle Size Data

Table 8.5 Sediment grain size data for sites sampled before and after the pilot disposal of dredged material at the proposed site

Site	%Clay (<0.0039 mm)		%Very fine silt (0.0039 - 0.0078 mm)		%Fine silt (0.0078 - 0.0156 mm)		%Medium silt (0.0156 - 0.031 mm)		%Coarse silt (0.031 - 0.063 mm)		%Silt and Clay (<0.063 mm)		%Very fine sand (0.063 - 0.125 mm)		%Fine Sand (0.125 - 0.25 mm)		%Medium Sand (0.25 - 0.5 mm)		%Coarse Sand (0.5 - 1 mm)		%Very Coarse Sand (>1 mm)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
E-1	21.38	17.14	6.73	5.55	8.33	6.88	11.23	9.51	15.67	13.46	63.34	52.55	15.67	15.15	10.83	15.65	5.02	11.05	3.01	4.33	1.89	0.89
E2	5.37	18.13	8.05	5.86	12.70	7.71	18.84	10.78	20.49	14.69	65.44	57.17	16.88	16.94	12.66	14.90	4.80	6.92	0.21	2.61	0.00	1.05
E5	4.80	4.82	7.41	7.56	10.83	11.17	14.69	16.43	16.06	19.01	53.80	58.99	18.19	17.53	19.77	15.95	8.03	6.99	0.21	0.54	0.00	0.00
G1	18.76	3.93	6.58	6.52	8.18	10.68	10.55	15.67	13.75	16.69	57.83	53.48	16.61	17.24	16.15	18.79	7.82	9.21	1.20	1.28	0.00	0.00
G2	**5.41**	**4.10**	**7.89**	**6.44**	**11.58**	**10.31**	**14.77**	**15.74**	**15.02**	**18.05**	**54.68**	**54.64**	**17.09**	**17.81**	**18.19**	**17.55**	**8.17**	**8.29**	**1.40**	**1.47**	**0.48**	**0.25**
G3	6.26	3.71	9.52	5.89	14.17	8.89	18.48	13.21	18.23	14.72	66.65	46.42	15.11	15.61	12.16	20.14	5.01	13.29	0.82	3.87	0.25	0.66
H-2	21.55	4.13	6.46	6.84	7.56	10.02	10.07	13.53	14.50	15.46	60.14	49.98	15.80	15.59	13.49	17.17	8.00	12.95	2.26	4.09	0.05	0.22
H-1	4.49	15.88	7.30	5.63	11.41	6.96	16.67	9.64	17.79	13.28	57.66	51.40	14.82	15.28	13.72	16.39	8.98	12.19	3.81	4.29	1.01	0.10
H1	**17.75**	**15.64**	**5.92**	**5.63**	**7.48**	**7.34**	**9.69**	**10.03**	**12.72**	**13.46**	**53.55**	**52.10**	**16.14**	**17.97**	**17.53**	**18.28**	**9.80**	**8.00**	**2.44**	**2.29**	**0.15**	**1.02**
H2	**4.08**	**17.08**	**6.61**	**6.70**	**10.97**	**9.09**	**16.19**	**11.07**	**16.37**	**12.09**	**54.22**	**56.02**	**15.58**	**15.90**	**16.94**	**17.63**	**8.73**	**7.85**	**3.03**	**1.47**	**1.50**	**0.75**
H2G2	**-**	**4.26**	**-**	**7.06**	**-**	**10.78**	**-**	**15.75**	**-**	**17.84**	**-**	**55.69**	**-**	**16.61**	**-**	**16.92**	**-**	**9.39**	**-**	**1.37**	**-**	**0.00**
H2I2	**-**	**17.35**	**-**	**5.81**	**-**	**7.05**	**-**	**9.21**	**-**	**11.78**	**-**	**51.20**	**-**	**15.81**	**-**	**19.91**	**-**	**11.21**	**-**	**1.49**	**-**	**0.00**
H3	**3.88**	**5.35**	**5.83**	**8.08**	**8.41**	**12.41**	**11.61**	**17.87**	**12.43**	**18.48**	**42.15**	**62.18**	**16.48**	**15.37**	**24.05**	**14.39**	**14.67**	**7.30**	**2.65**	**0.77**	**0.00**	**0.00**
H5	4.59	4.78	7.38	7.52	11.17	11.75	15.64	16.97	15.89	18.04	54.67	59.05	13.70	16.07	15.28	15.49	9.96	8.10	4.23	1.28	2.15	0.00
I1	19.77	3.65	6.08	5.44	7.26	7.71	9.32	10.74	12.69	11.89	55.12	39.42	17.81	16.42	18.62	24.79	7.50	15.98	0.52	3.34	0.00	0.06
I2	**5.43**	**3.85**	**8.31**	**6.10**	**12.15**	**9.38**	**14.97**	**14.05**	**15.39**	**16.16**	**56.25**	**49.54**	**17.39**	**17.58**	**17.54**	**19.67**	**7.68**	**10.99**	**1.13**	**2.22**	**0.00**	**0.00**
I3	4.33	4.07	7.26	6.70	11.54	11.25	17.37	17.90	19.17	19.50	59.66	59.43	15.85	15.52	14.03	14.09	7.56	7.77	2.16	2.59	0.74	0.60
K-1	4.39	15.21	6.64	4.96	9.55	6.12	11.89	8.24	13.84	11.31	46.32	45.85	18.49	17.16	20.72	21.60	11.12	12.61	2.82	2.45	0.53	0.00
K2	3.52	11.79	5.97	4.14	9.35	5.77	13.81	8.53	15.05	12.07	47.70	42.29	15.86	19.30	21.05	24.72	13.50	12.37	1.89	1.05	0.00	0.00
K5	5.12	3.68	7.60	5.94	10.96	9.07	13.93	13.40	14.55	14.70	52.17	46.79	16.06	12.80	19.31	16.53	11.00	15.48	1.47	7.04	0.00	1.36
X1	-	17.70	-	5.55	-	7.17	-	9.91	-	12.08	-	52.41	-	12.72	-	17.01	-	13.95	-	3.51	-	0.04
X2	-	4.73	-	7.13	-	11.16	-	16.49	-	17.77	-	57.27	-	17.80	-	16.68	-	6.78	-	1.21	-	0.24
X3	-	21.36	-	7.47	-	9.30	-	12.01	-	15.08	-	65.21	-	15.62	-	11.93	-	4.42	-	1.32	-	1.09
X4	5.16	18.24	7.58	8.03	11.99	11.21	17.30	14.40	17.64	15.76	59.68	67.65	16.47	14.60	15.74	11.00	7.13	5.24	0.98	1.24	0.00	0.00
X5	5.03	5.41	8.62	8.51	13.69	13.14	20.18	18.94	21.70	20.14	69.22	66.14	15.99	15.46	10.12	10.03	3.44	3.38	0.92	2.68	0.31	2.30
X6	5.09	17.76	7.97	6.30	12.32	8.09	18.94	10.50	22.24	13.73	66.57	56.39	17.49	18.23	11.35	17.45	4.35	6.83	0.24	0.83	0.00	0.00
Average	8.39	10.14	7.22	6.44	10.55	9.25	14.58	13.10	16.25	15.28	56.99	54.20	16.36	16.23	16.15	17.10	8.20	9.56	1.78	2.33	0.43	0.41

*Bolded data are either at or within 500 m of the disposal location (Site H2).

Table 8.6 Surficial Sediment Particle Size, August 2013, Post 10,000 m^3 Disposal

Grain size		DC	Percentage of total sample																		
			500				1000				1500				1750				Control		
(mm)	Class		N	E	S	W	N	E	S	W	N	E	S	W	NE	SE	SW	NW	A	B	C
> 3.35	Gravel																				
3.35 - 2.00	Granules	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00 - 1.18	Very Coarse Sand	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
1.18 - 0.600	Coarse Sand	1.3	1.0	1.5	0.8	1.6	1.3	0.8	0.9	0.8	1.3	0.0	1.8	0.6	1.9	1.0	1.2	1.9	1.3	2.8	1.8
0.600 - 0.300	Medium Sand	3.4	9.9	10.0	8.7	9.3	9.6	9.2	9.6	8.6	10.6	9.7	11.3	7.5	10.7	9.9	9.8	10.5	8.9	14.6	10.3
0.300 - 0.150	Fine Sand	7.5	17.7	15.9	16.1	15.4	15.8	15.9	14.8	15.3	15.7	17.4	15.8	15.1	15.6	15.7	15.3	14.5	13.2	16.5	13.3
0.150 - 0.063	Very Fine Sand	9.2	12.5	12.2	11.7	11.7	11.8	11.6	10.3	11.7	11.4	11.3	10.4	11.9	11.9	10.1	10.6	12.2	10.5	9.8	9.6
0.063 - 0.0313	Coarse Silt	22.5	19.9	21.6	21.7	21.4	21.0	21.5	21.6	21.1	20.8	20.8	20.5	21.7	20.7	20.5	22.8	22.7	22.4	19.7	21.4
0.0313 - 0.0156	Medium Silt	16.5	12.6	13.3	14.6	13.9	14.1	14.5	14.9	14.5	14.0	13.5	13.5	14.5	13.3	14.5	15.1	14.2	15.0	12.6	14.8
0.0156 - 0.0078	Fine Silt	16.2	11.7	11.8	13.0	12.3	13.0	13.2	13.6	13.5	12.9	12.5	12.2	13.6	12.1	13.5	12.7	12.3	13.9	11.2	13.8
0.0078 - 0.0039	Very Fine Silt	10.8	7.3	7.0	7.3	7.3	7.4	7.4	7.7	7.8	7.3	7.6	7.4	8.1	7.1	7.9	6.9	6.6	8.1	6.6	8.1
< 0.0039	Clay	12.4	7.3	6.7	6.1	7.0	6.1	6.0	6.5	6.6	6.0	7.4	7.2	7.0	6.7	6.9	5.7	5.1	6.6	6.2	7.0
< 0.063	**Silt and Clay**	**78.3**	**58.9**	**60.4**	**62.7**	**62.0**	**61.6**	**62.5**	**64.4**	**63.6**	**61.0**	**61.7**	**60.8**	**64.9**	**59.9**	**63.4**	**63.2**	**60.9**	**65.9**	**56.2**	**65.1**
Mean Size		**0.023**	**0.040**	**0.041**	**0.039**	**0.039**	**0.040**	**0.039**	**0.039**	**0.038**	**0.041**	**0.039**	**0.041**	**0.036**	**0.041**	**0.039**	**0.040**	**0.042**	**0.038**	**0.047**	**0.039**
Grain size description		**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**

Table 8.7 Surficial Sediment Particle Size, April 2015, Post 50,000 m^3 Disposal

Grain size		DC	Percentage of total sample																		
			500				1000				1500				1750				Control		
(mm)	Class		N	E	S	W	N	E	S	W	N	E	S	W	NE	SE	SW	NW	A	B	C
> 3.35	Gravel																				
3.35 - 2.00	Granules	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00 - 1.18	Very Coarse Sand	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.18 - 0.600	Coarse Sand	6.8	0.3	0.3	0.2	0.2	0.4	0.8	1.2	0.7	1.7	1.5	0.7	0.9	1.0	1.6	0.8	0.9	0.3	0.3	0.6
0.600 - 0.300	Medium Sand	16.0	6.5	8.7	7.1	7.7	8.6	9.3	10.6	9.1	13.3	8.6	10.0	7.3	10.8	11.4	8.6	9.2	8.7	9.3	9.3
0.300 - 0.150	Fine Sand	19.3	14.5	15.3	15.4	15.2	15.5	16.8	16.8	15.2	17.8	15.5	16.9	14.2	17.1	17.4	16.5	14.8	15.3	16.7	15.8
0.150 - 0.063	Very Fine Sand	12.4	13.0	12.6	12.7	13.3	12.9	13.2	12.0	11.9	11.9	13.0	11.8	12.7	13.0	12.1	12.4	12.4	10.8	11.0	10.8
0.063 - 0.0313	Coarse Silt	8.9	12.0	11.0	11.2	11.6	11.6	10.8	10.6	11.1	10.3	11.1	10.6	11.8	11.1	10.0	10.7	11.9	11.6	10.8	11.1
0.0313 - 0.0156	Medium Silt	6.7	12.4	11.7	12.1	11.3	11.4	11.0	10.7	11.7	9.4	10.6	11.0	12.3	10.3	10.1	11.5	11.6	12.9	11.9	12.1
0.0156 - 0.0078	Fine Silt	6.0	13.9	13.4	13.6	12.5	12.6	12.3	11.8	13.1	10.2	11.9	12.2	13.6	11.2	11.3	13.2	12.9	14.8	13.6	13.8
0.0078 - 0.0039	Very Fine Silt	6.0	12.6	12.3	12.6	11.9	12.0	11.5	11.4	12.1	10.3	11.8	11.7	12.3	10.8	11.1	12.6	12.3	13.1	12.6	12.9
< 0.0039	Clay	14.0	14.9	14.7	15.2	16.2	15.2	14.4	15.0	15.1	15.1	15.9	15.2	14.9	14.7	15.1	13.8	14.0	12.5	13.8	13.6
< 0.063	**Silt and Clay**	**41.6**	**65.7**	**63.1**	**64.6**	**63.5**	**62.7**	**60.0**	**59.4**	**63.1**	**55.3**	**61.4**	**60.6**	**64.9**	**58.1**	**57.6**	**61.8**	**62.7**	**64.9**	**62.7**	**63.6**
Mean Size		**0.058**	**0.026**	**0.028**	**0.026**	**0.026**	**0.028**	**0.030**	**0.031**	**0.028**	**0.035**	**0.028**	**0.030**	**0.026**	**0.032**	**0.032**	**0.029**	**0.029**	**0.028**	**0.029**	**0.029**
Grain size description		**mS**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**

Table 8.8 Surficial Sediment Particle Size, August 2015, Post 100,000 m³ Disposal

Grain size (mm)	Class	DC	500 N	500 E	500 S	500 W	1000 N	1000 E	1000 S	1000 W	1500 N	1500 E	1500 S	1500 W	1750 NE	1750 SE	1750 SW	1750 NW	Control A	Control B	Control C
		Percentage of total sample																			
> 3.35	Gravel																				
3.35 - 2.00	Granules	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00 - 1.18	Very Coarse Sand	0.6	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.18 - 0.600	Coarse Sand	7.5	2.2	1.0	1.3	3.7	1.0	1.1	1.0	1.3	2.7	1.5	0.9	1.4	2.1	1.0	0.8	2.3	1.6	1.4	1.0
0.600 - 0.300	Medium Sand	17.0	9.4	7.7	9.3	11.0	8.2	8.8	9.2	9.1	9.3	9.6	9.3	7.1	8.9	9.7	8.6	8.9	9.7	11.0	7.4
0.300 - 0.150	Fine Sand	17.7	15.9	16.1	16.2	16.0	14.5	16.0	15.5	15.6	12.8	16.3	15.5	12.7	14.2	15.7	15.9	11.5	13.4	15.2	12.9
0.150 - 0.063	Very Fine Sand	12.2	12.6	13.2	12.5	12.9	12.4	12.7	12.0	13.0	11.4	12.8	11.5	12.1	12.6	11.6	12.3	11.0	10.1	10.4	11.5
0.063 - 0.0313	Coarse Silt	20.4	28.9	29.6	29.5	25.7	30.8	29.8	29.7	29.5	31.4	28.4	30.2	31.6	30.1	30.5	31.7	31.7	31.5	30.8	32.2
0.0313 - 0.0156	Medium Silt	2.9	4.8	5.0	5.1	4.0	5.3	5.1	5.1	4.9	5.1	4.9	5.3	5.2	5.0	5.3	5.3	5.2	5.5	5.3	5.6
0.0156 - 0.0078	Fine Silt	7.7	11.8	12.7	12.6	10.4	13.3	12.9	13.0	12.3	12.3	12.6	13.2	13.1	12.3	13.0	12.7	12.9	13.5	12.8	14.1
0.0078 - 0.0039	Very Fine Silt	6.1	7.1	7.7	7.2	7.2	7.7	7.4	7.7	7.4	7.3	7.5	7.6	8.1	7.4	7.2	7.0	8.1	7.7	7.1	8.3
< 0.0039	Clay	8.1	7.3	7.0	6.2	8.8	6.8	6.3	6.8	6.9	7.6	6.6	6.6	8.3	7.4	6.0	5.8	8.5	6.9	6.0	7.2
< 0.063	**Silt and Clay**	**45.0**	**59.9**	**62.0**	**60.6**	**56.0**	**63.9**	**61.5**	**62.3**	**61.0**	**63.7**	**59.9**	**62.8**	**66.3**	**62.1**	**62.0**	**62.5**	**66.3**	**65.3**	**62.0**	**67.3**
Mean Size		**0.065**	**0.040**	**0.038**	**0.040**	**0.043**	**0.038**	**0.039**	**0.039**	**0.039**	**0.039**	**0.040**	**0.039**	**0.035**	**0.039**	**0.040**	**0.040**	**0.037**	**0.039**	**0.041**	**0.036**
Grain size description		**zS**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**(g)sM**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**

Table 8.9 Surficial Sediment Particle Size, November 2016, Post 150,000 m³ Disposal

Grain size (mm)	Class	DC	500 m N	500 m E	500 m S	500 m W	1000 m N	1000 m E	1000 m S	1000 m W	1500 m N	1500 m E	1500 m S	1500 m W	1750 m NE	1750 m SE	1750 m SW	1750 m NW	Control A	Control B	Control C
		Percentage of total sample																			
> 3.35	Gravel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.35 - 2.00	Granules	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00 - 1.18	Very Coarse Sand	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.18 - 0.600	Coarse Sand	0.0	0.0	0.0	0.6	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
0.600 - 0.300	Medium Sand	1.1	4.0	2.4	6.4	6.0	5.5	5.7	4.2	4.4	5.0	6.2	5.3	3.5	4.8	4.8	3.9	4.0	5.4	0.7	5.6
0.300 - 0.150	Fine Sand	5.3	13.9	15.6	14.8	15.3	14.8	14.6	12.7	12.5	13.9	15.4	13.4	12.3	13.9	16.1	13.6	12.4	13.0	17.4	14.6
0.150 - 0.063	Very Fine Sand	11.3	18.4	18.8	19.5	18.5	18.1	17.0	16.9	17.1	17.8	18.7	15.6	16.6	18.3	17.2	16.9	16.8	14.5	22.1	14.8
0.063 - 0.0313	Coarse Silt	12.2	12.0	11.8	11.8	11.4	11.9	11.5	12.1	12.3	12.5	11.8	11.6	12.1	12.2	11.2	12.0	12.8	12.1	12.1	11.8
0.0313 - 0.0156	Medium Silt	13.1	12.3	12.5	11.0	11.1	11.8	12.0	12.5	12.4	11.7	11.5	12.7	12.6	12.0	11.9	12.7	12.8	13.2	11.8	12.8
0.0156 - 0.0078	Fine Silt	15.3	13.7	14.2	12.3	12.3	13.2	13.6	14.2	13.9	13.1	12.9	14.2	14.1	13.5	13.5	14.2	14.2	14.8	13.1	14.3
0.0078 - 0.0039	Very Fine Silt	15.6	12.1	12.3	11.1	11.3	11.7	12.0	12.8	12.7	12.0	11.2	12.6	13.0	12.0	11.9	12.5	12.4	12.9	11.1	12.4
< 0.0039	Clay	26.3	13.6	12.4	12.6	13.8	13.1	13.5	14.7	14.8	14.0	12.5	14.4	15.8	13.4	13.5	14.2	14.7	14.0	11.7	13.7
< 0.063	**Silt and Clay**	**82.4**	**63.8**	**63.2**	**58.8**	**59.9**	**61.6**	**62.6**	**66.2**	**66.0**	**63.3**	**59.8**	**65.6**	**67.6**	**63.1**	**62.0**	**65.6**	**66.8**	**66.9**	**59.8**	**64.9**
Mean Size		**0.012**	**0.027**	**0.028**	**0.033**	**0.031**	**0.030**	**0.029**	**0.025**	**0.025**	**0.028**	**0.032**	**0.026**	**0.024**	**0.028**	**0.029**	**0.026**	**0.025**	**0.026**	**0.031**	**0.028**
Grain size description		**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**	**sZ**

Table 8.10 Two Way Analysis of Variance between Sites and Disposal Volumes for Sand Sized particles.

Dependent Variable: **Sand**
Normality Test: Passed (P = 0.121)
Equal Variance Test: Passed (P = 0.360)

Source of Variation	DF	SS	MS	F	P
volume	3	711.867	237.289	37.030	<0.001
Site	5	34.014	6.803	1.062	0.391
volume x Site	15	1374.211	91.614	14.297	<0.001
Residual	56	358.848	6.408		
Total	79	1917.767	24.276		

Main effects cannot be properly interpreted if significant interaction is determined. This is because the size of a factor's effect depends upon the level of the other factor.

The effect of different levels of volume depends on what level of Site is present. There is a statistically significant interaction between volume and Site. (P = <0.001)

Power of performed test with alpha = 0.0500: for volume : 1.000
Power of performed test with alpha = 0.0500: for Site : 0.0619
Power of performed test with alpha = 0.0500: for volume x Site : 1.000

Least square means for **volume** :

Group	Mean
10	35.228
50	41.437
100	40.317
150	33.309

Std Err of LS Mean = 0.644

Least square means for **Site** :

Group	Mean	SEM
DC	38.183	1.266
500	38.443	0.633
1000	37.358	0.633
1500	37.523	0.633
1750	37.638	0.633
Control	36.294	0.731

Least square means for **volume x Site** :

Group	Mean	SEM
10 x DC	21.710	2.531
10 x 500	39.018	1.266
10 x 1000	36.983	1.266
10 x 1500	37.908	1.266
10 x 1750	38.155	1.266
10 x Control	37.597	1.462
50 x DC	58.420	2.531
50 x 500	35.777	1.266
50 x 1000	38.715	1.266
50 x 1500	39.450	1.266
50 x 1750	39.980	1.266
50 x Control	36.280	1.462
100 x DC	54.960	2.531
100 x 500	40.362	1.266
100 x 1000	37.835	1.266
100 x 1500	36.807	1.266
100 x 1750	36.767	1.266
100 x Control	35.170	1.462
150 x DC	17.640	2.531
150 x 500	38.615	1.266
150 x 1000	35.897	1.266
150 x 1500	35.925	1.266
150 x 1750	35.647	1.266
150 x Control	36.130	1.462

All Pairwise Multiple Comparison Procedures (Holm-Sidak method):
Overall significance level = 0.05

Comparisons for factor: **volume**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
50 vs. 150	8.128	8.918	<0.001	0.009	Yes
100 vs. 150	7.008	7.689	<0.001	0.010	Yes
50 vs. 10	6.209	6.812	<0.001	0.013	Yes
100 vs. 10	5.089	5.584	<0.001	0.017	Yes
10 vs. 150	1.919	2.106	0.040	0.025	No
50 vs. 100	1.120	1.229	0.224	0.050	No

Comparisons for factor: **Site**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
500 vs. Control	2.149	2.223	0.030	0.003	No
1750 vs. Control	1.343	1.390	0.170	0.004	No
DC vs. Control	1.888	1.292	0.202	0.004	No
1500 vs. Control	1.228	1.271	0.209	0.004	No
500 vs. 1000	1.086	1.213	0.230	0.005	No
1000 vs. Control	1.063	1.100	0.276	0.005	No
500 vs. 1500	0.921	1.029	0.308	0.006	No
500 vs. 1750	0.806	0.900	0.372	0.006	No
DC vs. 1000	0.825	0.583	0.562	0.007	No
DC vs. 1500	0.660	0.466	0.643	0.009	No
DC vs. 1750	0.545	0.385	0.702	0.010	No
1750 vs. 1000	0.280	0.313	0.756	0.013	No
1500 vs. 1000	0.165	0.184	0.854	0.017	No
500 vs. DC	0.261	0.184	0.855	0.025	No
1750 vs. 1500	0.115	0.128	0.898	0.050	No

Comparisons for factor: **Site within 10**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
500 vs. DC	17.308	6.115	<0.001	0.003	Yes
1750 vs. DC	16.445	5.811	<0.001	0.004	Yes
1500 vs. DC	16.198	5.723	<0.001	0.004	Yes
Control vs. DC	15.887	5.435	<0.001	0.004	Yes
1000 vs. DC	15.273	5.396	<0.001	0.005	Yes
500 vs. 1000	2.035	1.137	0.260	0.005	No
500 vs. Control	1.421	0.735	0.465	0.006	No
1750 vs. 1000	1.173	0.655	0.515	0.006	No
500 vs. 1500	1.110	0.620	0.538	0.007	No
1500 vs. 1000	0.925	0.517	0.607	0.009	No
500 vs. 1750	0.863	0.482	0.632	0.010	No
Control vs. 1000	0.614	0.318	0.752	0.013	No
1750 vs. Control	0.558	0.289	0.774	0.017	No
1500 vs. Control	0.311	0.161	0.873	0.025	No
1750 vs. 1500	0.247	0.138	0.891	0.050	No

Comparisons for factor: **Site within 50**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
DC vs. 500	22.643	8.000	<0.001	0.003	Yes
DC vs. Control	22.140	7.574	<0.001	0.004	Yes
DC vs. 1000	19.705	6.962	<0.001	0.004	Yes
DC vs. 1500	18.970	6.703	<0.001	0.004	Yes
DC vs. 1750	18.440	6.515	<0.001	0.005	Yes
1750 vs. 500	4.202	2.348	0.022	0.005	No
1500 vs. 500	3.672	2.052	0.045	0.006	No
1750 vs. Control	3.700	1.914	0.061	0.006	No
1000 vs. 500	2.937	1.641	0.106	0.007	No
1500 vs. Control	3.170	1.640	0.107	0.009	No
1000 vs. Control	2.435	1.259	0.213	0.010	No
1750 vs. 1000	1.265	0.707	0.483	0.013	No
1500 vs. 1000	0.735	0.411	0.683	0.017	No
1750 vs. 1500	0.530	0.296	0.768	0.025	No
Control vs. 500	0.503	0.260	0.796	0.050	No

Comparisons for factor: **Site within 100**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
DC vs. Control	19.790	6.770	<0.001	0.003	Yes
DC vs. 1750	18.192	6.428	<0.001	0.004	Yes
DC vs. 1500	18.152	6.414	<0.001	0.004	Yes
DC vs. 1000	17.125	6.051	<0.001	0.004	Yes
DC vs. 500	14.597	5.158	<0.001	0.005	Yes
500 vs. Control	5.192	2.686	0.010	0.005	No
500 vs. 1750	3.595	2.008	0.049	0.006	No
500 vs. 1500	3.555	1.986	0.052	0.006	No
500 vs. 1000	2.528	1.412	0.163	0.007	No
1000 vs. Control	2.665	1.378	0.174	0.009	No
1500 vs. Control	1.637	0.847	0.401	0.010	No
1750 vs. Control	1.597	0.826	0.412	0.013	No
1000 vs. 1750	1.067	0.596	0.553	0.017	No
1000 vs. 1500	1.027	0.574	0.568	0.025	No
1500 vs. 1750	0.0400	0.0223	0.982	0.050	No

Comparisons for factor: **Site within 150**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
500 vs. DC	20.975	7.411	<0.001	0.003	Yes
1500 vs. DC	18.285	6.461	<0.001	0.004	Yes
1000 vs. DC	18.258	6.451	<0.001	0.004	Yes
1750 vs. DC	18.008	6.363	<0.001	0.004	Yes
Control vs. DC	18.490	6.326	<0.001	0.005	Yes
500 vs. 1750	2.968	1.658	0.103	0.005	No
500 vs. 1000	2.718	1.518	0.135	0.006	No
500 vs. 1500	2.690	1.503	0.139	0.006	No
500 vs. Control	2.485	1.285	0.204	0.007	No
Control vs. 1750	0.483	0.250	0.804	0.009	No
1500 vs. 1750	0.278	0.155	0.877	0.010	No
1000 vs. 1750	0.250	0.140	0.889	0.013	No
Control vs. 1000	0.233	0.120	0.905	0.017	No
Control vs. 1500	0.205	0.106	0.916	0.025	No
1500 vs. 1000	0.0275	0.0154	0.988	0.050	No

Comparisons for factor: **volume within DC**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
50 vs. 150	40.780	11.391	<0.001	0.009	Yes
100 vs. 150	37.320	10.425	<0.001	0.010	Yes
50 vs. 10	36.710	10.254	<0.001	0.013	Yes
100 vs. 10	33.250	9.288	<0.001	0.017	Yes
10 vs. 150	4.070	1.137	0.260	0.025	No
50 vs. 100	3.460	0.966	0.338	0.050	No

Comparisons for factor: **volume within 500**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
100 vs. 50	4.585	2.561	0.013	0.009	No
10 vs. 50	3.240	1.810	0.076	0.010	No
150 vs. 50	2.838	1.585	0.119	0.013	No
100 vs. 150	1.747	0.976	0.333	0.017	No
100 vs. 10	1.345	0.751	0.456	0.025	No
10 vs. 150	0.403	0.225	0.823	0.050	No

Comparisons for factor: **volume within 1000**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
50 vs. 150	2.817	1.574	0.121	0.009	No
100 vs. 150	1.937	1.082	0.284	0.010	No
50 vs. 10	1.732	0.968	0.337	0.013	No
10 vs. 150	1.085	0.606	0.547	0.017	No
50 vs. 100	0.880	0.492	0.625	0.025	No
100 vs. 10	0.852	0.476	0.636	0.050	No

Comparisons for factor: **volume within 1500**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
50 vs. 150	3.525	1.969	0.054	0.009	No
50 vs. 100	2.642	1.476	0.145	0.010	No
10 vs. 150	1.983	1.108	0.273	0.013	No
50 vs. 10	1.542	0.862	0.393	0.017	No
10 vs. 100	1.100	0.615	0.541	0.025	No
100 vs. 150	0.883	0.493	0.624	0.050	No

Comparisons for factor: **volume within 1750**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
50 vs. 150	4.332	2.420	0.019	0.009	No
50 vs. 100	3.212	1.795	0.078	0.010	No
10 vs. 150	2.508	1.401	0.167	0.013	No
50 vs. 10	1.825	1.020	0.312	0.017	No
10 vs. 100	1.388	0.775	0.442	0.025	No
100 vs. 150	1.120	0.626	0.534	0.050	No

Comparisons for factor: **volume within Control**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
10 vs. 100	2.427	1.174	0.245	0.009	No
10 vs. 150	1.467	0.710	0.481	0.010	No
10 vs. 50	1.317	0.637	0.527	0.013	No
50 vs. 100	1.110	0.537	0.593	0.017	No
150 vs. 100	0.960	0.464	0.644	0.025	No
50 vs. 150	0.150	0.0726	0.942	0.050	No

Table 8.11 Two Way Analysis of Variance between Sites and Disposal Volumes for Silt Sized particles.

Dependent Variable: **Silt**
Normality Test: Passed (P = 0.119)
Equal Variance Test: Passed (P = 0.337)

Source of Variation	DF	SS	MS	F	P
volume	3	1384.420	461.473	82.224	<0.001
Site	5	169.603	33.921	6.044	<0.001
volume x Site	15	827.783	55.186	9.833	<0.001
Residual	56	314.295	5.612		
Total	79	2505.281	31.712		

Main effects cannot be properly interpreted if significant interaction is determined. This is because the size of a factor's effect depends upon the level of the other factor.

The effect of different levels of volume depends on what level of Site is present. There is a statistically significant interaction between volume and Site. (P = <0.001)

Power of performed test with alpha = 0.0500: for volume : 1.000
Power of performed test with alpha = 0.0500: for Site : 0.980
Power of performed test with alpha = 0.0500: for volume x Site : 1.000

Least square means for **volume** :

Group	Mean
10	57.259
50	44.043
100	52.513
150	50.924

Std Err of LS Mean = 0.603

Least square means for **Site** :

Group	Mean	SEM
DC	46.618	1.185
500	50.949	0.592
1000	52.163	0.592
1500	51.569	0.592
1750	52.029	0.592
Control	53.781	0.684

Least square means for **volume x Site** :

Group	Mean	SEM
10 x DC	65.920	2.369
10 x 500	54.215	1.185
10 x 1000	56.705	1.185
10 x 1500	55.180	1.185
10 x 1750	55.745	1.185
10 x Control	55.787	1.368
50 x DC	27.550	2.369
50 x 500	48.982	1.185
50 x 1000	46.375	1.185
50 x 1500	45.265	1.185
50 x 1750	45.635	1.185
50 x Control	50.450	1.368
100 x DC	36.920	2.369
100 x 500	52.322	1.185
100 x 1000	55.467	1.185
100 x 1500	55.932	1.185
100 x 1750	56.315	1.185
100 x Control	58.123	1.368
150 x DC	56.080	2.369
150 x 500	48.277	1.185
150 x 1000	50.102	1.185
150 x 1500	49.900	1.185
150 x 1750	50.422	1.185
150 x Control	50.763	1.368

All Pairwise Multiple Comparison Procedures (Holm-Sidak method):
Overall significance level = 0.05

Comparisons for factor: **volume**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
10 vs. 50	13.216	15.494	<0.001	0.009	Yes
100 vs. 50	8.471	9.931	<0.001	0.010	Yes
150 vs. 50	6.881	8.068	<0.001	0.013	Yes
10 vs. 150	6.334	7.426	<0.001	0.017	Yes
10 vs. 100	4.745	5.563	<0.001	0.025	Yes
100 vs. 150	1.589	1.863	0.068	0.050	No

Comparisons for factor: **Site**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
Control vs. DC	7.163	5.237	<0.001	0.003	Yes
1000 vs. DC	5.545	4.187	<0.001	0.004	Yes
1750 vs. DC	5.412	4.086	<0.001	0.004	Yes
1500 vs. DC	4.952	3.739	<0.001	0.004	Yes
500 vs. DC	4.332	3.271	0.002	0.005	Yes
Control vs. 500	2.831	3.130	0.003	0.005	Yes
Control vs. 1500	2.211	2.444	0.018	0.006	No
Control vs. 1750	1.751	1.936	0.058	0.006	No
Control vs. 1000	1.618	1.789	0.079	0.007	No
1000 vs. 500	1.213	1.448	0.153	0.009	No
1750 vs. 500	1.080	1.289	0.203	0.010	No
1500 vs. 500	0.620	0.740	0.462	0.013	No
1000 vs. 1500	0.593	0.708	0.482	0.017	No
1750 vs. 1500	0.460	0.549	0.585	0.025	No
1000 vs. 1750	0.133	0.159	0.874	0.050	No

Comparisons for factor: **Site within 10**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
DC vs. 500	11.705	4.419	<0.001	0.003	Yes
DC vs. 1500	10.740	4.055	<0.001	0.004	Yes
DC vs. 1750	10.175	3.842	<0.001	0.004	Yes
DC vs. Control	10.133	3.704	<0.001	0.004	Yes
DC vs. 1000	9.215	3.479	<0.001	0.005	Yes
1000 vs. 500	2.490	1.486	0.143	0.005	No
1750 vs. 500	1.530	0.913	0.365	0.006	No
1000 vs. 1500	1.525	0.910	0.367	0.006	No
Control vs. 500	1.572	0.869	0.389	0.007	No
1500 vs. 500	0.965	0.576	0.567	0.009	No
1000 vs. 1750	0.960	0.573	0.569	0.010	No
1000 vs. Control	0.918	0.508	0.614	0.013	No
1750 vs. 1500	0.565	0.337	0.737	0.017	No
Control vs. 1500	0.607	0.335	0.739	0.025	No
Control vs. 1750	0.0417	0.0230	0.982	0.050	No

Comparisons for factor: **Site within 50**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
Control vs. DC	22.900	8.371	<0.001	0.003	Yes
500 vs. DC	21.432	8.092	<0.001	0.004	Yes
1000 vs. DC	18.825	7.107	<0.001	0.004	Yes
1750 vs. DC	18.085	6.828	<0.001	0.004	Yes
1500 vs. DC	17.715	6.688	<0.001	0.005	Yes
Control vs. 1500	5.185	2.866	0.006	0.005	No
Control vs. 1750	4.815	2.661	0.010	0.006	No
Control vs. 1000	4.075	2.252	0.028	0.006	No
500 vs. 1500	3.717	2.219	0.031	0.007	No
500 vs. 1750	3.347	1.998	0.051	0.009	No
500 vs. 1000	2.608	1.557	0.125	0.010	No
Control vs. 500	1.468	0.811	0.421	0.013	No
1000 vs. 1500	1.110	0.663	0.510	0.017	No
1000 vs. 1750	0.740	0.442	0.660	0.025	No
1750 vs. 1500	0.370	0.221	0.826	0.050	No

Comparisons for factor: **Site within 100**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
Control vs. DC	21.203	7.751	<0.001	0.003	Yes
1750 vs. DC	19.395	7.323	<0.001	0.004	Yes
1500 vs. DC	19.012	7.178	<0.001	0.004	Yes
1000 vs. DC	18.547	7.003	<0.001	0.004	Yes
500 vs. DC	15.402	5.815	<0.001	0.005	Yes
Control vs. 500	5.801	3.206	0.002	0.005	Yes
1750 vs. 500	3.993	2.383	0.021	0.006	No
1500 vs. 500	3.610	2.155	0.035	0.006	No
1000 vs. 500	3.145	1.877	0.066	0.007	No
Control vs. 1000	2.656	1.468	0.148	0.009	No
Control vs. 1500	2.191	1.211	0.231	0.010	No
Control vs. 1750	1.808	0.999	0.322	0.013	No
1750 vs. 1000	0.848	0.506	0.615	0.017	No
1500 vs. 1000	0.465	0.278	0.782	0.025	No
1750 vs. 1500	0.383	0.228	0.820	0.050	No

Comparisons for factor: **Site within 150**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
DC vs. 500	7.803	2.946	0.005	0.003	No
DC vs. 1500	6.180	2.333	0.023	0.004	No
DC vs. 1000	5.978	2.257	0.028	0.004	No
DC vs. 1750	5.658	2.136	0.037	0.004	No
DC vs. Control	5.317	1.944	0.057	0.005	No
Control vs. 500	2.486	1.374	0.175	0.005	No
1750 vs. 500	2.145	1.280	0.206	0.006	No
1000 vs. 500	1.825	1.089	0.281	0.006	No
1500 vs. 500	1.623	0.969	0.337	0.007	No
Control vs. 1500	0.863	0.477	0.635	0.009	No
Control vs. 1000	0.661	0.365	0.716	0.010	No
1750 vs. 1500	0.523	0.312	0.756	0.013	No
1750 vs. 1000	0.320	0.191	0.849	0.017	No
Control vs. 1750	0.341	0.188	0.851	0.025	No
1000 vs. 1500	0.202	0.121	0.904	0.050	No

Comparisons for factor: **volume within DC**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
10 vs. 50	38.370	11.453	<0.001	0.009	Yes
10 vs. 100	29.000	8.656	<0.001	0.010	Yes
150 vs. 50	28.530	8.516	<0.001	0.013	Yes
150 vs. 100	19.160	5.719	<0.001	0.017	Yes
10 vs. 150	9.840	2.937	0.005	0.025	Yes
100 vs. 50	9.370	2.797	0.007	0.050	Yes

Comparisons for factor: **volume within 500**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
10 vs. 150	5.938	3.544	<0.001	0.009	Yes
10 vs. 50	5.233	3.124	0.003	0.010	Yes
100 vs. 150	4.045	2.415	0.019	0.013	No
100 vs. 50	3.340	1.994	0.051	0.017	No
10 vs. 100	1.893	1.130	0.263	0.025	No
50 vs. 150	0.705	0.421	0.675	0.050	No

Comparisons for factor: **volume within 1000**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
10 vs. 50	10.330	6.167	<0.001	0.009	Yes
100 vs. 50	9.093	5.428	<0.001	0.010	Yes
10 vs. 150	6.603	3.941	<0.001	0.013	Yes
100 vs. 150	5.365	3.203	0.002	0.017	Yes
150 vs. 50	3.727	2.225	0.030	0.025	No
10 vs. 100	1.238	0.739	0.463	0.050	No

Comparisons for factor: **volume within 1500**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
100 vs. 50	10.667	6.368	<0.001	0.009	Yes
10 vs. 50	9.915	5.919	<0.001	0.010	Yes
100 vs. 150	6.033	3.601	<0.001	0.013	Yes
10 vs. 150	5.280	3.152	0.003	0.017	Yes
150 vs. 50	4.635	2.767	0.008	0.025	Yes
100 vs. 10	0.752	0.449	0.655	0.050	No

Comparisons for factor: **volume within 1750**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
100 vs. 50	10.680	6.375	<0.001	0.009	Yes
10 vs. 50	10.110	6.035	<0.001	0.010	Yes
100 vs. 150	5.893	3.518	<0.001	0.013	Yes
10 vs. 150	5.323	3.177	0.002	0.017	Yes
150 vs. 50	4.787	2.858	0.006	0.025	Yes
100 vs. 10	0.570	0.340	0.735	0.050	No

Comparisons for factor: **volume within Control**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
100 vs. 50	7.673	3.967	<0.001	0.009	Yes
100 vs. 150	7.360	3.805	<0.001	0.010	Yes
10 vs. 50	5.337	2.759	0.008	0.013	Yes
10 vs. 150	5.023	2.597	0.012	0.017	Yes
100 vs. 10	2.337	1.208	0.232	0.025	No
150 vs. 50	0.313	0.162	0.872	0.050	No

Table 8.12 Two Way Analysis of Variance between Sites and Disposal Volumes for Clay Sized particles.

Dependent Variable: **Clay**
Normality Test: Passed (P = 0.230)
Equal Variance Test: Passed (P = 0.257)

Source of Variation	DF	SS	MS	F	P
volume	3	952.250	317.417	524.977	<0.001
Site	5	91.933	18.387	30.410	<0.001
volume x Site	15	108.741	7.249	11.990	<0.001
Residual	56	33.859	0.605		
Total	79	1376.325	17.422		

Main effects cannot be properly interpreted if significant interaction is determined. This is because the size of a factor's effect depends upon the level of the other factor.

The effect of different levels of volume depends on what level of Site is present. There is a statistically significant interaction between volume and Site. (P = <0.001)

Power of performed test with alpha = 0.0500: for volume : 1.000
Power of performed test with alpha = 0.0500: for Site : 1.000
Power of performed test with alpha = 0.0500: for volume x Site : 1.000

Least square means for **volume** :

Group	Mean
10	7.513
50	14.520
100	7.168
150	15.767

Std Err of LS Mean = 0.198

Least square means for **Site** :

Group	Mean	SEM
DC	15.200	0.389
500	10.608	0.194
1000	10.480	0.194
1500	10.906	0.194
1750	10.333	0.194
Control	9.925	0.224

Least square means for **volume x Site** :

Group	Mean	SEM
10 x DC	12.370	0.778
10 x 500	6.768	0.389
10 x 1000	6.313	0.389
10 x 1500	6.913	0.389
10 x 1750	6.100	0.389
10 x Control	6.617	0.449
50 x DC	14.030	0.778
50 x 500	15.240	0.389
50 x 1000	14.910	0.389
50 x 1500	15.285	0.389
50 x 1750	14.385	0.389
50 x Control	13.270	0.449
100 x DC	8.120	0.778
100 x 500	7.315	0.389
100 x 1000	6.697	0.389
100 x 1500	7.250	0.389
100 x 1750	6.917	0.389
100 x Control	6.707	0.449
150 x DC	26.280	0.778
150 x 500	13.108	0.389
150 x 1000	14.000	0.389
150 x 1500	14.175	0.389
150 x 1750	13.930	0.389
150 x Control	13.107	0.449

All Pairwise Multiple Comparison Procedures (Holm-Sidak method):
Overall significance level = 0.05

Comparisons for factor: **volume**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
150 vs. 100	8.599	30.714	<0.001	0.009	Yes
150 vs. 10	8.253	29.480	<0.001	0.010	Yes
50 vs. 100	7.352	26.262	<0.001	0.013	Yes
50 vs. 10	7.007	25.028	<0.001	0.017	Yes
150 vs. 50	1.247	4.453	<0.001	0.025	Yes
10 vs. 100	0.345	1.234	0.222	0.050	No

Comparisons for factor: **Site**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
DC vs. Control	5.275	11.750	<0.001	0.003	Yes
DC vs. 1750	4.867	11.196	<0.001	0.004	Yes
DC vs. 1000	4.720	10.859	<0.001	0.004	Yes
DC vs. 500	4.593	10.565	<0.001	0.004	Yes
DC vs. 1500	4.294	9.879	<0.001	0.005	Yes
1500 vs. Control	0.981	3.302	0.002	0.005	Yes
500 vs. Control	0.683	2.298	0.025	0.006	No
1500 vs. 1750	0.573	2.082	0.042	0.006	No
1000 vs. Control	0.555	1.869	0.067	0.007	No
1500 vs. 1000	0.426	1.548	0.127	0.009	No
1750 vs. Control	0.408	1.374	0.175	0.010	No
1500 vs. 500	0.298	1.084	0.283	0.013	No
500 vs. 1750	0.274	0.998	0.323	0.017	No
1000 vs. 1750	0.147	0.534	0.595	0.025	No
500 vs. 1000	0.128	0.464	0.645	0.050	No

Comparisons for factor: **Site within 10**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
DC vs. 1750	6.270	7.212	<0.001	0.003	Yes
DC vs. 1000	6.058	6.968	<0.001	0.004	Yes
DC vs. 500	5.603	6.444	<0.001	0.004	Yes
DC vs. Control	5.753	6.408	<0.001	0.004	Yes
DC vs. 1500	5.458	6.278	<0.001	0.005	Yes
1500 vs. 1750	0.812	1.478	0.145	0.005	No
500 vs. 1750	0.667	1.214	0.230	0.006	No
1500 vs. 1000	0.600	1.091	0.280	0.006	No
Control vs. 1750	0.517	0.870	0.388	0.007	No
500 vs. 1000	0.455	0.828	0.411	0.009	No
Control vs. 1000	0.304	0.512	0.611	0.010	No
1500 vs. Control	0.296	0.498	0.620	0.013	No
1000 vs. 1750	0.213	0.386	0.701	0.017	No
1500 vs. 500	0.145	0.264	0.793	0.025	No
500 vs. Control	0.151	0.254	0.800	0.050	No

Comparisons for factor: **Site within 50**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
1500 vs. Control	2.015	3.393	0.001	0.003	Yes
500 vs. Control	1.970	3.317	0.002	0.004	Yes
1000 vs. Control	1.640	2.761	0.008	0.004	No
1750 vs. Control	1.115	1.877	0.066	0.004	No
1500 vs. 1750	0.900	1.637	0.107	0.005	No
500 vs. 1750	0.855	1.555	0.126	0.005	No
1500 vs. DC	1.255	1.444	0.154	0.006	No
500 vs. DC	1.210	1.392	0.169	0.006	No
1000 vs. DC	0.880	1.012	0.316	0.007	No
1000 vs. 1750	0.525	0.955	0.344	0.009	No
DC vs. Control	0.760	0.846	0.401	0.010	No
1500 vs. 1000	0.375	0.682	0.498	0.013	No
500 vs. 1000	0.330	0.600	0.551	0.017	No
1750 vs. DC	0.355	0.408	0.685	0.025	No
1500 vs. 500	0.0450	0.0818	0.935	0.050	No

Comparisons for factor: **Site within 100**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
DC vs. 1000	1.423	1.636	0.107	0.003	No
DC vs. Control	1.413	1.574	0.121	0.004	No
DC vs. 1750	1.203	1.383	0.172	0.004	No
500 vs. 1000	0.617	1.123	0.266	0.004	No
500 vs. Control	0.608	1.024	0.310	0.005	No
1500 vs. 1000	0.552	1.005	0.319	0.005	No
DC vs. 1500	0.870	1.001	0.321	0.006	No
DC vs. 500	0.805	0.926	0.358	0.006	No
1500 vs. Control	0.543	0.915	0.364	0.007	No
500 vs. 1750	0.398	0.723	0.473	0.009	No
1500 vs. 1750	0.333	0.605	0.548	0.010	No
1750 vs. 1000	0.220	0.400	0.691	0.013	No
1750 vs. Control	0.211	0.355	0.724	0.017	No
500 vs. 1500	0.0650	0.118	0.906	0.025	No
Control vs. 1000	0.00917	0.0154	0.988	0.050	No

Comparisons for factor: **Site within 150**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
DC vs. 500	13.173	15.152	<0.001	0.003	Yes
DC vs. Control	13.173	14.672	<0.001	0.004	Yes
DC vs. 1750	12.350	14.206	<0.001	0.004	Yes
DC vs. 1000	12.280	14.125	<0.001	0.004	Yes
DC vs. 1500	12.105	13.924	<0.001	0.005	Yes
1500 vs. 500	1.067	1.942	0.057	0.005	No
1500 vs. Control	1.068	1.799	0.077	0.006	No
1000 vs. 500	0.892	1.623	0.110	0.006	No
1000 vs. Control	0.893	1.504	0.138	0.007	No
1750 vs. 500	0.822	1.496	0.140	0.009	No
1750 vs. Control	0.823	1.386	0.171	0.010	No
1500 vs. 1750	0.245	0.446	0.658	0.013	No
1500 vs. 1000	0.175	0.318	0.751	0.017	No
1000 vs. 1750	0.0700	0.127	0.899	0.025	No
500 vs. Control	0.000833	0.00140	0.999	0.050	No

Comparisons for factor: **volume within DC**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
150 vs. 100	18.160	16.514	<0.001	0.009	Yes
150 vs. 10	13.910	12.649	<0.001	0.010	Yes
150 vs. 50	12.250	11.140	<0.001	0.013	Yes
50 vs. 100	5.910	5.374	<0.001	0.017	Yes
10 vs. 100	4.250	3.865	<0.001	0.025	Yes
50 vs. 10	1.660	1.510	0.137	0.050	No

Comparisons for factor: **volume within 500**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
50 vs. 10	8.472	15.409	<0.001	0.009	Yes
50 vs. 100	7.925	14.414	<0.001	0.010	Yes
150 vs. 10	6.340	11.531	<0.001	0.013	Yes
150 vs. 100	5.793	10.535	<0.001	0.017	Yes
50 vs. 150	2.132	3.878	<0.001	0.025	Yes
100 vs. 10	0.547	0.996	0.324	0.050	No

Comparisons for factor: **volume within 1000**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
50 vs. 10	8.597	15.637	<0.001	0.009	Yes
50 vs. 100	8.213	14.936	<0.001	0.010	Yes
150 vs. 10	7.687	13.982	<0.001	0.013	Yes
150 vs. 100	7.302	13.281	<0.001	0.017	Yes
50 vs. 150	0.910	1.655	0.104	0.025	No
100 vs. 10	0.385	0.700	0.487	0.050	No

Comparisons for factor: **volume within 1500**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
50 vs. 10	8.372	15.227	<0.001	0.009	Yes
50 vs. 100	8.035	14.614	<0.001	0.010	Yes
150 vs. 10	7.262	13.209	<0.001	0.013	Yes
150 vs. 100	6.925	12.595	<0.001	0.017	Yes
50 vs. 150	1.110	2.019	0.048	0.025	No
100 vs. 10	0.337	0.614	0.542	0.050	No

Comparisons for factor: **volume within 1750**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
50 vs. 10	8.285	15.068	<0.001	0.009	Yes
150 vs. 10	7.830	14.241	<0.001	0.010	Yes
50 vs. 100	7.468	13.581	<0.001	0.013	Yes
150 vs. 100	7.013	12.754	<0.001	0.017	Yes
100 vs. 10	0.817	1.487	0.143	0.025	No
50 vs. 150	0.455	0.828	0.411	0.050	No

Comparisons for factor: **volume within Control**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
50 vs. 10	6.653	10.479	<0.001	0.009	Yes
50 vs. 100	6.563	10.338	<0.001	0.010	Yes
150 vs. 10	6.490	10.222	<0.001	0.013	Yes
150 vs. 100	6.400	10.080	<0.001	0.017	Yes
50 vs. 150	0.163	0.257	0.798	0.025	No
100 vs. 10	0.0900	0.142	0.888	0.050	No

Appendix 6 Post Disposal Sediment Quality Data

Table 8.13 Surficial Sediment Quality, August 2013, Post 10,000 m^3 Disposal (Dry Weight)

Tests	units	Site																			MSANZ Table 5		AC			ANZECC ISQG	
		DC	500				1000				1500				1750				Control								
			N	E	S	W	N	E	S	W	N	E	S	W	NE	SE	SW	NW	A	B	C	ER-L	ER-M	Green	Amber	Red	Low	High
Dry Matter	g/100g	47	54	52	52	54	49	51	52	52	52	52	52	49	52	51	52	48	50	51	52							
Total Sediment, Total Recoverable Metals																											
Arsenic	mg/kg dry wt	7.5	5.8	4.8	4.9	4.9	5.1	5.3	5.6	5.3	5.2	5.7	6.2	5	5	6	6	4.7	4.8	6.4	6.1	8.2	70				20	70
Cadmium		0.064	0.148	0.129	0.119	0.137	0.146	0.126	0.143	0.12	0.13	0.121	0.113	0.152	0.138	0.135	0.138	0.124	0.127	0.112	0.142	1.5	10	0.7	0.7 - 1.2	1.2	1.5	10
Chromium		24	24	23	25	24	23	24	24	24	24	26	26	24	23	26	26	24	23	27	26	80	370	52	52 - 80	80	80	370
Copper		36	4.9	5.1	5	5.5	4.8	4.9	4.9	4.8	4.9	4.6	4.7	5.2	4.6	4.8	4.7	5.4	5.1	4.7	4.8	65	270	19	19 - 34	34	65	270
Lead		23	4.2	4.4	4.6	4.5	4.3	4.5	4.6	4.4	4.5	4.5	4.6	4.4	4.5	4.7	4.4	4.8	4.6	5	4.7	50	220	30	30 - 50	50	50	220
Mercury		0.12	0.04	0.05	0.042	0.039	0.042	0.042	0.031	0.04	0.04	0.043	0.06	0.042	0.046	0.039	0.034	0.046	0.035	0.049	0.046	0.15	1				0.15	1
Nickel		24	14.4	14.7	14.1	14.3	14.3	14.1	14.6	14	13.9	13.9	13.9	15.1	14.3	14.7	14.5	15.3	15.2	14.8	14.8	21	52				21	52
Zinc		80	29	30	31	30	29	30	30	30	29	30	30	31	29	31	31	30	29	31	30	200	410	124	124 - 150	150	200	410

Table 8.14 Additional Surficial Sediment Quality, December 2013, Post 10,000 m^3 Disposal (Dry Weight)

Tests	units	Site															MSANZ Table 5		ANZECC ISQG	
		DC			250															
					N			E			S			W						
		A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	ER-L	ER-M	Low	High
Total Sediment, Total Recoverable Metals																				
Nickel	mg/kg dry wt	8.8	10.9	8.7	14.5	14.3	14.2	16.4	15.9	14.0	15.0	14.1	14.6	13.9	14.2	14.4	21	52	21	52

Table 8.15 Surficial Sediment Quality, April 2015, Post 50,000 m^3 Disposal (Dry Weight)

Tests	units	Site																					MSANZ Table 5		AC			ANZECC ISQG	
		DC	500				1000				1500				1750				Control						Green	Amber	Red		
			N	E	S	W	N	E	S	W	N	E	S	W	NE	SE	SW	NW	A	B	C		ER-L	ER-M				Low	High
Dry Matter	g/100g	67	52	52	52	53	52	54	54	52	53	55	52	50	54	53	52	50	52	55	53								
Total Sediment, Total Recoverable Metals																													
Arsenic	mg/kg dry wt	3.6	4.0	5.0	5.0	4.0	4.0	4.0	4.0	4.0	4.2	3.8	5.0	4.0	4.7	5.0	4.0	3.0	5.0	6.5	5.0		8.2	70				20	70
Cadmium		0.034	0.119	0.116	0.141	0.148	0.129	0.142	0.141	0.124	0.133	0.114	0.134	0.109	0.146	0.143	0.127	0.122	0.115	0.136	0.128		1.5	10	0.7	0.7 - 1.2	1.2	1.5	10
Chromium		18	22	22	24	22	22	23	24	23	23	23	24	23	23	24	23	21	23	25	24		80	370	52	52 - 80	80	80	370
Copper		14.3	4.7	5.0	5.0	7.4	4.7	4.8	4.7	5.1	4.8	4.7	4.8	5.0	4.6	4.3	4.6	4.9	4.9	4.6	4.6		65	270	19	19 - 34	34	65	270
Lead		5.4	4.3	4.6	4.5	4.3	4.1	4.6	4.6	4.5	4.3	4.4	4.7	4.6	4.1	4.3	4.4	4.3	4.9	4.7	4.7		50	220	30	30 - 50	50	50	220
Mercury		0.045	0.054	0.064	0.076	0.048	0.062	0.065	0.050	0.065	0.048	0.067	0.081	0.052	0.042	0.054	0.045	0.048	0.070	0.060	0.068		0.15	1				0.15	1
Nickel		8.9	15.6	15.6	16.4	15.9	15.7	16.1	16.1	16.8	15.9	16.1	16.3	16.0	16.3	15.8	15.9	16.5	16.3	16.1	16.3		21	52				21	52
Zinc		31	29	30	30	31	29	30	30	30	29	29	31	30	29	30	30	28	30	31	30		200	410	124	124 - 150	150	200	410
Total Sediment, Total Petroleum Hydrocarbons (TPH)																													
C7 - C9	mg/kg dry wt	< 20	< 14	< 13	< 14	< 13	< 13	< 13	< 13	< 14	< 13	< 13	< 13	< 14	< 13	< 13	< 13	< 14	< 13	< 13	< 13								
C10 - C14		< 40	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30								
C15 - C36		< 80	< 60	< 60	< 60	< 60	< 60	< 60	< 60	< 60	< 50	< 50	< 60	< 60	< 50	< 60	< 60	< 60	< 60	< 50	< 60								
Total TPH		< 140	< 100	< 100	< 100	< 90	< 100	< 90	< 90	< 100	< 90	< 90	< 90	< 100	< 90	< 90	< 100	< 100	< 100	< 90	< 90							280	550

Table 8.16 Surficial Sediment Quality, August 2015, Post 100,000 m^3 Disposal (Dry Weight)

Tests	units	Site																					MSANZ Table 5		AC			ANZECC ISQG	
		DC	500				1000				1500				1750				Control						Green	Amber	Red		
			N	E	S	W	N	E	S	W	N	E	S	W	NE	SE	SW	NW	A	B	C		ER-L	ER-M				Low	High
Dry Matter	g/100g	64	50	52	51	61	52	50	53	53	51	52	52	50	51	52	49	47	52	51	50								
Total Sediment, Total Recoverable Metals																													
Arsenic	mg/kg dry wt	4.0	4.6	3.7	4.8	3.9	4.0	4.6	5.6	4.5	4.5	5.0	5.1	4.2	5.3	5.4	4.8	4.1	6.1	6.5	4.5		8.2	70				20	70
Cadmium		0.047	0.108	0.122	0.094	0.063	0.130	0.114	0.125	0.100	0.114	0.133	0.125	0.125	0.136	0.127	0.099	0.119	0.118	0.108	0.119		1.5	10	0.7	0.7 - 1.2	1.2	1.5	10
Chromium		34	25	22	24	21	24	24	26	26	24	25	25	23	25	26	25	23	26	27	24		80	370	52	52 - 80	80	80	370
Copper		14.8	5.2	5.4	5.2	7.7	4.9	5.2	5.0	6.4	5.0	4.9	5.3	5.7	4.9	5.0	5.0	5.5	4.9	4.8	5.0		65	270	19	19 - 34	34	65	270
Lead		8.7	4.5	4.1	4.2	4.1	4.2	4.4	4.2	4.5	4.2	4.2	4.3	4.2	4.0	4.3	4.3	4.3	4.3	4.6	4.4		50	220	30	30 - 50	50	50	220
Mercury		0.065	0.066	0.048	0.057	0.049	0.048	0.056	0.045	0.063	0.054	0.050	0.050	0.054	0.052	0.049	0.058	0.051	0.183	0.119	0.082		0.15	1				0.15	1
Nickel		13.9	14.3	13.6	13.2	11.4	13.9	14.1	14.4	14.0	14.0	14.4	14.7	14.0	14.2	14.4	14.1	15.0	14.2	14.6	13.9		21	52				21	52
Zinc		42	34	32	32	31	31	33	33	35	32	32	34	32	31	33	33	32	33	35	32		200	410	124	124 - 150	150	200	410
Total Sediment, Total Petroleum Hydrocarbons (TPH)																													
C7 - C9	mg/kg dry wt	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30								
C10 - C14		< 50	< 60	< 60	< 60	< 50	< 60	< 60	< 50	< 50	< 60	< 60	< 60	< 60	< 50	< 50	< 60	< 60	< 60	< 60	< 60								
C15 - C36		< 90	< 110	< 110	< 110	< 90	< 110	< 110	< 100	< 100	< 120	< 110	< 110	< 110	< 100	< 100	< 110	< 110	< 110	< 110	< 110								
Total TPH		< 160	< 180	< 190	< 190	< 150	< 190	< 180	< 170	< 170	< 200	< 190	< 180	< 180	< 180	< 170	< 190	< 200	< 180	< 180	< 180							280	550

Table 8.17 Surficial Sediment Quality, November 2016, Post 150,000 m^3 Disposal (Dry Weight)

Tests	units	Site																			MSANZ Table 5		AC			ANZECC ISQG	
		DC	500 m				1000 m				1500 m				1750 m				Control								
			N	E	S	W	N	E	S	W	N	E	S	W	NE	SE	SW	NW	A	B	C	ER-L	ER-M	Green	Amber	Red	Low	High
Dry Matter	g/100g	34	48	49	50	60	50	49	49	52	48	51	49	52	48	50	48	48	49	49	50							
Total Sediment, Total Recoverable Metals																												
Arsenic	mg/kg dry wt	9.5	4.0	3.6	3.9	4.0	5.0	5.0	4.1	3.6	4.0	4.0	5.0	3.0	4.0	5.0	4.0	3.0	5.0	5.0	5.1	8.2	70				20	70
Cadmium		0.081	0.170	0.160	0.120	0.100	0.110	0.130	0.130	0.094	0.121	0.090	0.110	0.122	0.130	0.115	0.116	0.102	0.100	< 0.100	0.120	1.5	10	0.7	0.7 - 1.2	1.2	1.5	10
Chromium		22	22	21	21	22	20	23	23	20	20	20	23	20	22	23	22	17	22	24	25	80	370	52	52 - 80	80	80	370
Copper		29.0	5.5	5.1	5.0	5.0	8.4	4.9	5.0	5.2	4.7	4.2	4.7	5.6	4.7	4.6	4.9	4.4	5.0	4.8	5.1	65	270	19	19 - 34	34	65	270
Lead		26.0	4.4	4.2	4.1	4.2	4.2	4.4	4.4	4.0	3.9	3.8	4.1	5.2	4.1	4.2	4.2	3.6	4.4	4.5	4.8	50	220	30	30 - 50	50	50	220
Mercury		0.123	0.048	0.046	0.037	0.038	0.038	0.052	0.043	0.045	0.046	0.040	0.037	0.045	0.042	0.067	0.050	0.053	0.047	0.050	0.046	0.15	1				0.15	1
Nickel		10.0	16.3	15.1	14.4	16.1	14.8	15.8	16.2	14.4	15.0	14.3	15.8	16.0	15.7	15.4	15.6	13.9	17.1	16.3	17.2	21	52				21	52
Zinc		95	30	29	28	29	30	31	30	28	27	26	30	29	28	30	30	25	29	31	32	200	410	124	124 - 150	150	200	410
Total Sediment, Total Petroleum Hydrocarbons (TPH)																												
C7 - C9	mg/kg dry wt	< 19	< 14	< 30	< 30	< 11	< 14	< 13	< 14	< 13	< 14	< 13	< 14	< 13	< 14	< 13	< 14	< 14	< 14	< 13	< 13							
C10 - C14		< 40	< 30	< 60	< 60	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30							
C15 - C36		< 80	< 60	< 110	< 110	< 50	< 60	< 60	< 60	< 50	< 60	< 60	< 60	< 50	< 60	< 60	< 60	< 60	< 60	< 60	< 60							
Total TPH		< 140	< 100	< 190	< 190	< 80	< 100	< 90	< 100	< 90	< 100	< 90	< 100	< 90	< 100	< 90	< 100	< 100	< 100	< 90	< 100						280	550

Appendix 7 Benthic Biota Data

Table 8.18 Biota Count Of Benthic Core Samples Collected In June 2009 And January 2010 Prior To Disposal Of Dredged Material At The Site. (numbers per 70 mm diameter core) (from University of Waikato (2011e))

Taxa — EEZ900012 Site No.s		1500 W			500 W		500 N	1500 N	DC		500 S	1500 S		500 E			1500 E		Con	Con	Con
Site	**E-1**	**E2**	**E5**	**G1**	**G2**	**G3**	**H1**	**H-1**	**H2**	**H-2**	**H3**	**H5**	**I1**	**I2**	**I3**	**K-1**	**K2**	**K5**	**X1**	**X2**	**X3**
PHYLUM ANNELIDA																					
CLASS POLYCHAETA																					
Aglaophamus macroura			1		1				1							1					
Cirratulidae												1									
Eunice sp.	1																	1			
Flabelligeridae																		1			
Lumbrinereis sp.																					1
Pectinaria australis											tube only										
Prionospio sp.												1						1			
Spionidae			1			1			1	1	1							1		1	3
Polychaeta (damaged/pieces)												1						2	2		
PHYLUM NEMERTEA																					
Nemertian																	1				
PHYLUM MOLLUSCA																					
CLASS BIVALVIA																					
Dosinia sp.																1					
Nucula nitidula									1				1								
Nucula nitidulaformis				1																	
CLASS SCAPHOPODA																					
Dentalium (Antalis) nanum		2				1							2		3			1			
PHYLUM ARTHROPODA																					
CLASS CRUSTACEA																					
ORDER AMPHIPODA																					
Atylidae														1							
Phoxocephalidae sp. 1													1								1
ORDER OSTRACODA																					
Ostracoda sp.					1																
ORDER TANAIDACEA																					
Tanaid sp.								1													
PHYLUM COELENTERATA																					
CLASS ANTHOZOA																					
Edwardsia sp.															1						
PHYLUM FORAMINIFERA *																					
CLASS FORAMINIFERA																					
ORDER ASTORHIZIDA																					
Agglutinate tubes, broken, *Rhabdammina*										2											
ORDER LITUOLIDA																					
Ammodiscus sp.													1		1						
ORDER TEXTULARIIDA																					
Aggerostramen sp.			1			1		1	1			1					1	3		1	

Taxa	EEZ900012 Site No.s		1500 W			500 W		500 N	1500 N	DC		500 S	1500 S		500 E			1500 E		Con	Con	Con
	Site	E-1	E2	E5	G1	G2	G3	H1	H-1	H2	H-2	H3	H5	I1	I2	I3	K-1	K2	K5	X1	X2	X3
ORDER MILIODIDA																						
Nummoloculina contraria					1							1		1		1		1				
Pyrgo sp.			1	1	5		2		1	4		3	1	4	1	3	1		1	1	1	1
Quinqueloculina suborbicularis				1	1	1				3												
Triloculina insignis		1	1		1					1	1			1			1	1		1		5
ORDER LAGENIDA																						
Lenticulina sp.		5	8	10	11	11	1	10	11	15	7	15	5	13	7	8	12	2	10	4	2	12
Nodosaria intermittens / vertebralis			1	1	1								1				1					
ORDER ROTALIIDA																						
Cibicidoides sp 1		27	20	9	54	14	6	32	59	34	36	32	7	60	38	37	144	38	32	3	4	1
Cibicidoides sp 2		6	5	3	12	3		2	9	8	6	6	2	12	8		11	8	2			4
Foraminifera - spine like		2	4	1	3	5		1	6	4	1	2		2		5	1	6	3	1	1	
Total Number Of Species/Taxa		**6**	**8**	**10**	**10**	**7**	**6**	**4**	**7**	**11**	**7**	**7**	**9**	**11**	**5**	**8**	**9**	**8**	**12**	**6**	**6**	**8**
Total Number Of Individuals		**42**	**42**	**29**	**90**	**36**	**12**	**45**	**88**	**73**	**54**	**60**	**20**	**98**	**55**	**59**	**173**	**58**	**58**	**12**	**10**	**28**
Shannon- Wiener		**1.14**	**1.56**	**1.78**	**1.36**	**1.51**	**1.47**	**0.80**	**1.10**	**1.67**	**1.12**	**1.31**	**1.84**	**1.35**	**0.94**	**1.28**	**0.69**	**1.18**	**1.59**	**1.63**	**1.61**	**1.66**

* = No attempt has been made to distinguish live from dead specimens.

Table 8.19 Biota Count Of Benthic Core Samples Collected In June 2010 Following Disposal Of Dredged Material At The Site (numbers per 70 mm diameter core) (From University of Waikato (2011e))

Taxa	EEZ900012 Site No.s		1500 W			500 W		500 N	1500 N	DC				500 S	1500 S		500 E			1500 E		Con	Con	Con	Con	Con	Con
	Site	E-1	E2	E5	G1	G2	G3	H1	H-1	H2	H-2	H2/G2	H2/I2	H3	H5	I1	I2	I3	K-1	K2	K5	X1	X2	X3	X4	X5	X6
PHYLUM ANNELIDA																											
CLASS POLYCHAETA																											
Aglaophamus macroura			1							1		1			1												
Aricidea sp.							1																				
Capitellidae																							3				
Cirratulidae							1																				1
Lumbrinereis sp.													1									1					1
Marphysa sp.			1		1			1										1									
Maldanidae			1									1		1		1										1	1
Orbinia sp.																					1						
Spionidae							1				2													1			
Syllidae							1																			1	
Polychaeta (damaged/pieces)				1					1	1	2		1						2	1		1	1	1			1
PHYLUM NEMERTEA																											
Nemertian								2			1																
PHYLUM MOLLUSCA																											
CLASS BIVALVIA																											
Nucula nitidula			1					1			1			1													
Spectamen plicatulum																				1							
CLASS SCAPHOPODA																											
Dentalium (Antalis) nanum				1					1				1					1									

Taxa	E-1	E2	E5	G1	G2	G3	H1	H-1	H2	H-2	H2/G2	H2/I2	H3	H5	I1	I2	I3	K-1	K2	K5	X1	X2	X3	X4	X5	X6
EEZ900012 Site No.s		1500 W			500 W		500 N	1500 N	DC				500 S	1500 S		500 E			1500 E		Con	Con	Con	Con	Con	Con
PHYLUM ARTHROPODA																										
CLASS CRUSTACEA																										
ORDER AMPHIPODA																										
Lysianassidae		1															1								1	
Phoxocephalidae sp. 2																									1	
Amphipod species (damaged)		1																								
ORDER DECAPODA																										
Lyreidus tridentatus			1																							
ORDER CUMACEA																										
Cumacean sp.																1										
ORDER OSTRACODA																										
Ostracoda sp.																			1							
ORDER TANAIDACEA																										
Tanaid sp.																									1	
PHYLUM ECHINODERMATA																										
CLASS OPHIUROIDEA																										
Amphiura sp.																										1
PHYLUM PORIFERA																										
CLASS DEMOSPONGIAE																										
Sponge – orange / tan						1																				
PHYLUM FORAMINIFERA *																										
CLASS FORAMINIFERA																										
ORDER LITUOLIDA																										
Ammodiscus sp.					2						1			1		1	1	1	1							
Cribrostomoides / Haplophragmoides										1																
ORDER TEXTULARIIDA																										
Aggerostramen sp.		2				3		1			1	1	1				1			1						
Textularia stricta		1				1																				
ORDER MILIODIDA																										
Nummoloculina contraria				2						1	1	1	2											2		
Pyrgo sp.	1	3			2		1	1								1		2	2		3	1				2
Quinqueloculina suborbicularis								1											1							1
Triloculina insignis		2	1				2		1				1	3		2	2					1				
Miliodida foraminifera						1																				
ORDER LAGENIDA																										
Lenticulina sp.	4	10	4	6	7	8	17	10	9	17	8	18	18	6	4	21	10	7	10	6	3	3	3	1	6	2
Nodosaria intermittens / vertebralis		1				1		1		1									1	2		1				
ORDER ROTALIIDA																										
Cibicidoides sp 1	15	34	19	29	18	62	59	21	26	53	31	67	32	12	26	55	23	81	43	28	3	1	3	2	3	
Cibicidoides sp 2	2	10	2	3	3	3	11	1	5	8	2	6	7	8	7	11	2	10	4	5		1			1	1
Foraminifera - spine like	2			2	1	5	4	5	1	5	1		2		2	4	1	3	2	1		1				1
Total Number Of Species/Taxa	**5**	**14**	**7**	**6**	**6**	**13**	**9**	**10**	**7**	**11**	**9**	**8**	**9**	**6**	**5**	**8**	**10**	**7**	**11**	**7**	**5**	**9**	**4**	**3**	**8**	**10**
Total Number Of Individuals	**24**	**69**	**29**	**43**	**33**	**89**	**98**	**43**	**44**	**92**	**47**	**96**	**65**	**31**	**40**	**96**	**43**	**106**	**67**	**44**	**11**	**13**	**8**	**5**	**15**	**12**
Shannon- Wiener	**1.14**	**1.74**	**1.20**	**1.10**	**1.32**	**1.26**	**1.28**	**1.55**	**1.23**	**1.41**	**1.20**	**0.98**	**1.42**	**1.48**	**1.06**	**1.26**	**1.48**	**0.90**	**1.32**	**1.20**	**1.50**	**2.06**	**1.26**	**1.05**	**1.77**	**2.25**

* = No attempt has been made to distinguish live from dead specimens.

Table 8.20 Benthic Biota Monitoring Data August 2013 (numbers per four 70 mm diameter cores, numbers per square metre)

Taxa	DC				1500																Control			
					N				E				S				W							
	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²
PHYLUM ANNELIDA																								
CLASS POLYCHAETA																								
Ampharetidae			1	22		1		22	2		1	65		3		65					1	2		65
Aricidea sp.														1	1	43								
Capitellidae					1	3		87			3	65	2	1		65								
Cirratulidae		1		22		1	2	65	2			43	1	2	1	87	1		1	43			1	22
Glycera americana																					1			22
Hesionidae					1		6	152					2		2	87		2	1	65	1	2	4	152
Heteromastus filiformis	1	1	3	108	3	1	2	130					1			22		1		22				
Hyalinoecia sp.					1			22						3		65					3	1		87
Lumbrinereis sp.			1	22	1		3	87	1	1	2	87	2			43		1		22	1			22
Marphysa sp.		1	1	43	1	3	1	108							1	22					1	2		65
Maldanidae		1		22	1	5	5	238							1	22		4	1	108				
Nephtys sp.						1	1	43																
Nereidae																						1		22
Onuphidae					1	7		173	1		3	87	1			22								
Paraonidae									1			22			1	22	1	1		43				
Phyllodocidae					2	1		65																
Phylo sp.													2			43							1	22
Poeobiidae										1		22												
Prionospio sp.			2	43	6	4	10	433	3	1		87	3	3	3	195	1		3	87		1		22
Sabellidae	1			22	1	1		43			1	22	1			22							1	22
Scalibregmidae															1	22								
Sigalionidae					1	3	2	130										1		22				
Spionidae										1		22												
Syllidae										1		22												
Trichobranchidae											1	22												
PHYLUM NEMERTEA																								
Nemertian	1		2	65	1		1	43	1			22									1		1	43
PHYLUM PLATYHELMINTHES																								
CLASS TURBELLARIA																								
Polycladida																		1		22				
PHYLUM SIPUNCULA																								
CLASS SIPUNCULIDEA																								
Sipunculid A						1		22			1	22	1			22								
Sipunculid B					2		3	108			1	22		1		22		2	2	87				
PHYLUM MOLLUSCA																								
CLASS GASTROPODA																								
Microvoluta marginata					1			22																
Pleurobranchaea muculata					1			22																
Unidentified Gastropod																	2	1		65				

Taxa	DC				1500																Control			
					N				E				S				W							
	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²
CLASS BIVALVIA																								
Corbula zelandica							1	22																
Nucula nitidula						2	1	65		1		22										1	2	65
Nuculana bellula																					1			22
PHYLUM ARTHROPODA																								
CLASS CRUSTACEA																								
ORDER AMPHIPODA																								
Ampeliscidae					2	1		65			1	22						1	1	43			1	22
Corophium sp.					1		1	43	1		1	43			1	22								
Eusiridae																	1			22		1		22
Haustoriidae					3	1	1	108							2	43						2		43
Ischyroceridae									1		3	87	1			22	1			22		2	1	65
Liljeborgia sp.							1	22	1	1		43	1			22		2		43				
Lysianassidae						1	1	43							1	22								
Phoxocephalidae A			1	22	2	1	2	108			1	22						2	1	65			1	22
Phoxocephalidae C																		2		43		1		22
Phoxocephalidae D										1		22												
Unidentified Amphipod					1			22																
ORDER ISOPODA																								
Asellota									1			22											1	22
Munna sp.														1	1	43						1	2	65
Paranthura flagellata			1	22																		1		22
ORDER DECAPODA																								
Unidentified Shrimp																		1		22		1		22
ORDER CUMACEA																								
Cumacean A							1	22			1	22		4	2	130	2			43	3	1	1	108
Cumacean B																		1		22				
ORDER MYSIDACEA																								
Mysid						1		22																
ORDER OSTRACODA																								
Ostracod A					1	2	1	87										1		22		1	1	43
Ostracod B					1		3	87							2	43								
Ostracod C															1	22								
ORDER TANAIDACEA																								
Tanaidacea sp.							2	43					1		1	43			1	22		1	1	43
CLASS MAXILLOPODA																								
Copepod									1			22												
PHYLUM ECHINODERMATA																								
CLASS OPHIUROIDEA																								
Amphiura sp.	1			22	2			43						1		22	1		1	43	1		1	43
PHYLUM PORIFERA																								
Unidentified sponge – sandy, flask-shaped					1		4	108			1	22						1		22		1		22

Taxa	DC				1500																Control			
					N				E				S				W							
	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²
PHYLUM CHORDATA																								
CLASS VERTEBRATA																								
Unidentified teleost										1		22												
PHYLUM FORAMINIFERA																								
CLASS POLYTHALAMEA																								
ORDER ASTORHIZIDA																								
? Rhabdammina													1			22								
Aggerostramen sp.					36	7	91	2902	2	1	21	520	10	6	3	411	3	4		152	5	2	17	520
Ammodiscus A						1	5	130		1	1	43	1	1	2	87								
Ammodiscus B													1			22							1	22
ORDER LITUOLIDA																								
Cribrostomoides / Haplophragmoides	2			43		1	1	43	1			22												
ORDER LAGENIDA																								
Astacolus sp.	1			22					1			22	1			22								
Lenticulina sp.	17	2		411	3	1	16	433	8	6	15	628	12	8	7	585	9	19	9	801	6	11	16	715
Nodosaria vertebralis			1	22		1	5	130			1	22			5	108					1		2	65
ORDER ROTALIIDA																								
Cibicidoides sp.																							1	22
Unidentified Foraminifera – dome shaped			1	22	1			22		1		22		1	1	43	1			22	1		2	65
Total Number Of Species/Taxa	**7**	**5**	**10**	**17**	**28**	**25**	**28**	**42**	**16**	**13**	**18**	**34**	**19**	**14**	**21**	**37**	**11**	**19**	**10**	**27**	**14**	**20**	**21**	**35**
Total Number Of Individuals	**24**	**6**	**14**	**953**	**79**	**52**	**173**	**6583**	**28**	**18**	**59**	**2274**	**45**	**36**	**40**	**2620**	**23**	**48**	**21**	**1992**	**27**	**36**	**59**	**2642**
Shannon- Wiener	**1.11**	**1.56**	**2.21**	**2.16**	**2.39**	**2.92**	**2.06**	**2.55**	**2.47**	**2.29**	**2.11**	**2.67**	**2.44**	**2.36**	**2.81**	**2.97**	**2.01**	**2.33**	**1.88**	**2.50**	**2.36**	**2.62**	**2.32**	**2.76**

Table 8.21 Benthic Biota Monitoring Data April 2015 (numbers per two 100 mm diameter cores, numbers per square metre)

Taxa	DC				1500																Control			
					N				E				S				W							
	A	B	C	Ave/m^2	A	B	C	Ave/m^2	A	B	C	Ave/m^2	A	B	C	Ave/m^2	A	B	C	Ave/m^2	A	B	C	Ave/m^2
PHYLUM ANNELIDA																								
CLASS POLYCHAETA																								
Aglaophamus macroura																	1	1		42				
Ampharetidae									1		2	64		3		64	1			21	1	1		42
Aricidea sp										1		21												
Boccardia sp									1			21												
Capitellidae					2	3	4	191	2	2		85	3	3	2	170	2	1	3	127	1	2	1	85
Cirratulidae					1	2		64					1	1	1	64	1			21				
Eunice sp.					1			21			1	21					1	1		42				
Flabelligeridae sp. A					2			42																
Flabelligeridae sp. B						1		21	1			21												
Hesionidae							1	21																
Heteromastus filiformis					2			42	1			21	1		1	42								
Marphysa sp.						1	1	42	1	1		42	1		1	42							1	21
Maldanidae					2			42	1			21	1			21			2	42				
Nephtys sp.									1			21												
Orbinia sp.					1			21							1	21								
Paraonidae						1		21							1	21		1		21				
Phyllodocidae									1			21												
Poeobiidae																							1	21
Prionospio sp.							2	42						1		21					3			64
Rhamphobranchium sp.					1			21																
Sabellidae														2		42							2	42
Spionidae																			1	21	3	1	1	106
Syllidae											1	21	1			21								
Sphaerosyllis sp.	1			21	2		2	85	1		2	64	1	3	1	106					1			21
Indeterminate - damaged pieces										1		21		2		42								
PHYLUM NEMERTEA																								
Nemertian													5		1	127	1			21				
PHYLUM SIPUNCULA																								
CLASS SIPUNCULIDEA																								
Sipunculid worm A																	2		1	64	1	1	1	64
PHYLUM MOLLUSCA																								
CLASS GASTROPODA																								
Zeacolpus sp.											1	21												
Unidet. Gastropod (damaged)						2	1	64	1			21		1		21			2	42	2	1		64
CLASS BIVALVIA																								
Nucula nitidula									1	1		42	2			42	1			21				
Unidet mussel spat																	1			21				
CLASS SCAPHOPODA																								
Dentalium (Antalis) nanum					1			21			2	42												

Taxa	DC				1500																Control			
					N				E				S				W							
	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²
PHYLUM ARTHROPODA																								
CLASS CRUSTACEA																								
ORDER AMPHIPODA																								
Ampeliscidae																					1			21
Amphilochidae																						1		21
Atylidae														2		42					3			64
Ischyroceridae										1		21		1	2	64					1	1		42
Liljeborgia sp.																			1	21		1		21
Lysianassidae													5			106								
Melitdae																			1	21				
Oedicerotidae									1			21												
Paradexamine pacifica																		2		42				
Phoxocephalidae A					1			21		1		21		1	1	42								
Phoxocephalidae D					1			21						1	1	42					1		1	42
Urothoidae							1	21	1		2	64		1	4	106		1		21				
Unidentified Amphipod species	1			21						1		21					1			21				
ORDER ISOPODA																								
Asellota							2	42		1	1	42			1	21					1	1		42
Astacilla fusiformis										1	1	42											1	21
Munna sp.						4		85	1		3	85	1		1	42	1	2		64		1	1	42
Paranthura flagellata					1		1	42							1	21								
Sphaeroma sp.										1		21												
ORDER CUMACEA																								
Cumacean A					1	2	1	85			1	21	1	1		42						2		42
ORDER MYSIDACEA																								
Mysid																			1	21				
ORDER OSTRACODA																								
Ostracod A						1	1	42					1	1	1	64					1			21
Ostracod C					2	1		64					1		1	42			1	21		1		21
Ostracod D							1	21						2		42	1			21	1		1	42
ORDER TANAIDACEA																								
Tanaidacea sp							1	21	2		1	64												
PHYLUM COELENTERATA																								
CLASS ANTHOZOA																								
Edwardsia sp.											1	21						1		21			1	21
PHYLUM ECHINODERMATA																								
CLASS OPHIUROIDEA																								
Amphiura sp.						2	1	64							1	21								
PHYLUM FORAMINIFERA																								
CLASS FORAMINIFERA																								
ORDER LITUOLIDA																								
Ammodiscus A					1	1		42											1	21		2	1	64
Ammodiscus B															1	21								

Taxa	DC				1500																Control			
					N				E				S				W							
	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²
ORDER TEXTULARIIDA																								
Textularia stricta													1			21								
ORDER MILIODIDA																								
Nummuloculina contraria					2	4	4	212					3		4	149	7			149		2	2	85
Pyrogo sp			9	191	32	38	64	2844	40	32	17	1889	14	7	26	997	10	34	30	1570	26	15	25	1401
Quinqueloculina suborbicularis			4	85	72	26	52	3183	44	4	8	1188	10	7	32	1040	12	12	8	679	9	12	11	679
Trioculina insignis						6		127			5	106	6	1		149	2	10	28	849	11	2	5	382
ORDER LAGENIDA																								
Astacolus sp.													1			21						1	2	64
Lenticulina sp			80	1698	802	290	440	32510	560	672	170	29751	334	138	264	15618	157	192	340	14621	107	302	312	15300
Nodosaria intermittens/vertebralis			1	21	1	2		64									2	2	5	191	4	3		149
ORDER ROTALIIDA																								
Cibicidoides sp 1			85	1804	134	90	40	5602	36	52	26	2419	36	27	24	1846	25	12	26	1337	20	32	28	1698
Cibicidoides sp 2			27	573	78	42	72	4074	44	20	12	1613	36	19	18	1549	12	18	8	806	10	23	14	997
Elphidium sp A			1	21	158	6	100	5602	12	12		509	8			170					2	3	5	212
Elphidium sp B			1	21		2		42	4		1	106							4	85		1		21
Planularia sp.			1	21		1	4	106		4		85	4			85		4		85				
Undet. Foram - dome shaped							3	64																
Undet. Foram - flat sim otolith									2	4		127											3	64
Total Number Of Species/Taxa	**2**	**0**	**9**	**11**	**24**	**23**	**23**	**41**	**24**	**19**	**20**	**40**	**25**	**22**	**25**	**42**	**20**	**16**	**18**	**34**	**22**	**24**	**22**	**37**
Total Number Of Individuals	**2**	**0**	**209**	**4478**	**1301**	**528**	**799**	**55768**	**760**	**812**	**258**	**38834**	**478**	**225**	**392**	**23237**	**241**	**294**	**463**	**21178**	**210**	**412**	**420**	**22112**
Shannon- Wiener	**0.69**		**1.31**	**1.36**	**1.34**	**1.58**	**1.56**	**1.52**	**1.12**	**0.79**	**1.41**	**1.07**	**1.32**	**1.56**	**1.35**	**1.46**	**1.43**	**1.35**	**1.14**	**1.35**	**1.86**	**1.19**	**1.15**	**1.38**

Table 8.22 Benthic Biota Monitoring Data August 2015 following 100,000 m^3 Spoil Disposal (numbers per two 100 mm diameter cores, numbers per square metre)

Taxa	DC				1500																Control			
					N				E				S				W							
	A	B	C	Ave/m^2	A	B	C	Ave/m^2	A	B	C	Ave/m^2	A	B	C	Ave/m^2	A	B	C	Ave/m^2	A	B	C	Ave/m^2
PHYLUM ANNELIDA																								
CLASS POLYCHAETA																								
Aglaophamus macroura					1			21	1			21												
Ancistrosyllis sp.	5			106																				
Aricidea sp.														1		21								
Armandia maculata		1		21						1		21												
Boccardia sp.					1			21																
Capitellidae													1			21								
Cirratulidae	1	1		42																				
Glycinde (Goniada) trifida						1		21																
Heteromastus filiformis					1			21																
Lumbrinereis sp.	2		1	64																				
Marphysa sp.		2		42	1	2	2	106	2	1		64	1		1	42			2	42	1			21
Maldanidae						1		21													2			42
Orbinia sp.					1			21																
Paraonidae						1		21	1			21												
Paraonidae B	1		6	149																		1		21
Polynoidae	1			21																			1	21
Prionospio sp.						1		21																
Rhamphobrachium sp.		1		21							1	21												
Scalibregmatidae	1			21																				
Serpulidae														1		21								
Syllidae									1			21												
Sphaerosyllis sp.	1	1		42													1			21		1		21
Trichobranchidae																						1		21
Unident. damaged pieces													1			21						1		21
PHYLUM NEMERTEA																								
Nemertian	1			21		1	1	42	1			21						1		21			1	21
PHYLUM PLATYHELMINTHES																								
CLASS TURBELLARIA																								
Polycladida													1			21								
PHYLUM SIPUNCULA																								
CLASS SIPUNCULIDEA																								
Sipunculid worm A					1			21									1			21				

Taxa	DC				1500																Control			
					N				E				S				W							
	A	B	C	Ave/m^2	A	B	C	Ave/m^2	A	B	C	Ave/m^2	A	B	C	Ave/m^2	A	B	C	Ave/m^2	A	B	C	Ave/m^2
PHYLUM MOLLUSCA																								
CLASS GASTROPODA																								
Amalda novaezelandiae						1		21											1	21				
Austrofusus glans																							1	21
Microvoluta marginata																						1		21
Solariella tryphenensis																		1		21				
Zeatrophon ambiguus																			1	21				
Unident. Gastropod					3	1		85			1	21	1	1		42	1	1		42				
CLASS BIVALVIA																								
Nucula hartvigiana			1	21																			1	21
Nucula nitidula	1			21	2			42									1	1		42				
Unident. juveniles																						1		21
CLASS SCAPHOPODA																								
Antalis nana																						1		21
PHYLUM ARTHROPODA																								
CLASS CRUSTACEA																								
ORDER AMPHIPODA																								
Ampeliscidae						1		21													1			21
Amphilochidae					1			21															2	42
Atylidae		1		21		1		21													1		1	42
Caprella sp.		1		21																				
Corophium sp.					1			21																
Eusiridae																							1	21
Liljeborgia sp.							1	21																
Lysianassidae											1	21						1		21			1	21
Phoxocephalidae A									2			42												
Phoxocephalidae D																		3		64				
Phoxocephalidae E		3		64		1		21					1			21		1		21	1			21
Urothoidae	1			21							1	21												
Unident. Amphipod species							1	21			1	21	1			21		1		21			1	21
ORDER ISOPODA																								
Asellota	1			21	2	3	2	149													1	1		42
Neastacilla fusiformis	1			21						4	1	106	1			21								
Munna sp.																		2		42				
Paranthura flagellata											1	21											1	21
ORDER DECAPODA																								
Lyreidus tridentatus							1	21																
ORDER CUMACEA																								
Cumacean A		1	1	42	1		2	64					1			21	1	1	1	64	3		2	106
Cumacean B									1			21												

Taxa	DC				1500																Control			
					N				E				S				W							
	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²
ORDER OSTRACODA																								
Ostracod A	1		2	**64**	1	1		**42**	1			**21**	1			**21**	3	2		**106**			2	**42**
Ostracod B			1	**21**																				
Ostracod C					2	1	1	**85**																
Ostracod D																						1		**21**
ORDER TANAIDACEA																								
Tanaidacea sp.	1	1		**42**											1	**21**	1	1		**42**				
PHYLUM COELENTERATA																								
CLASS ANTHOZOA																								
Sphenotrochus ralphae																					1			**21**
PHYLUM ECHINODERMATA																								
CLASS OPHIUROIDEA																								
Amphiura sp.																			2	**42**	2	1	1	**85**
CLASS ECHINOIDEA																								
Peronella hinemoae															1	**21**								
PHYLUM PORIFERA																								
CLASS DEMOSPONGIAE																								
Undent. sponge			1	**21**						1	1	**42**			1	**21**		4	2	**127**				
PHYLUM CHORDATA																								
CLASS ASCIDIACEA																								
ORDER PLEUROGONA																								
Botryllus schlosseri																					1			**21**
CLASS THALIACEA																								
ORDER SALPIDA																								
Salpidae (blastozooids)		1		**21**											1	**21**								
PHYLUM FORAMINIFERA																								
CLASS FORAMINIFERA																								
ORDER LITUOLIDA																								
Ammodiscus sp. A		1		**21**		1		**21**	2		1	**64**						2		**42**				
ORDER MILIODIDA																								
Nummoloculina contraria		1	1	**42**	1	2	13	**340**	3		2	**106**	2	1		**64**	2	2	2	**127**	1		3	**85**
Pyrgo sp.	20	12	26	**1231**	21	33	25	**1676**	36	84	24	**3056**	9	21	15	**955**	24	16	15	**1167**	18	31	23	**1528**
Quinqueloculina suborbicularis	10	3	28	**870**	26	13	24	**1337**	24	12	14	**1061**	9	9	12	**637**	10	26	19	**1167**	14	10	17	**870**
Triloculina insignis	10		6	**340**	15	15	2	**679**		6	20	**552**		7	1	**170**	2		7	**191**	2	2	5	**191**
Undent. Miliodida																							1	**21**
ORDER LAGENIDA																								
Astacolus sp.					1			**21**																
Lenticulina sp.	254	132	158	**11544**	247	268	256	**16361**	372	394	422	**25210**	169	177	179	**11141**	139	192	207	**11417**	183	221	305	**15045**
Nodosaria vertebralis						3		**64**		2		**42**	4			**85**					9	9		**382**
Planularia sp.	2			**42**					1	1		**42**					6		1	**149**				

Taxa	DC				1500																Control			
					N				E				S				W							
	A	B	C	Ave/m^2	A	B	C	Ave/m^2	A	B	C	Ave/m^2	A	B	C	Ave/m^2	A	B	C	Ave/m^2	A	B	C	Ave/m^2
ORDER ROTALIIDA																								
Cibicidoides sp. 1	32	45	30	**2271**	45	36	41	**2589**	56	40	86	**3862**	15	13	21	**1040**	28	62	27	**2483**	20	18	27	**1379**
Alabamina sp.	22	25	20	**1422**	35	27	25	**1846**	16	30	38	**1783**	15	15	18	**1019**	22	34	19	**1592**	30	24	23	**1634**
Elphidium sp. A	2	1	2	**106**	49	35	45	**2737**	28	4	16	**1019**	1	2	5	**170**	4			**85**	1	5	17	**488**
Undent. Foram - flat sim otolith		2		**42**																				
Total Number Of Species/Taxa	**22**	**20**	**15**	**36**	**23**	**24**	**16**	**37**	**17**	**13**	**17**	**28**	**18**	**11**	**12**	**25**	**16**	**20**	**14**	**29**	**19**	**18**	**22**	**38**
Total Number Of Individuals	**371**	**236**	**284**	**18908**	**459**	**450**	**442**	**28669**	**548**	**580**	**631**	**37327**	**234**	**248**	**256**	**15661**	**246**	**354**	**306**	**19226**	**292**	**330**	**437**	**22473**
Shannon- Wiener	**1.32**	**1.50**	**1.55**	**1.53**	**1.68**	**1.58**	**1.52**	**1.63**	**1.24**	**1.14**	**1.23**	**1.25**	**1.20**	**1.12**	**1.16**	**1.21**	**1.57**	**1.55**	**1.26**	**1.52**	**1.46**	**1.31**	**1.30**	**1.40**

Table 8.23 Benthic Biota Monitoring Data 23 November 2016 following 150,000 m³ Spoil Disposal
(numbers per two 100 mm diameter cores, numbers per square metre)

Taxa	DC				500 m															
					N				E				S				W			
	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²
PHYLUM ANNELIDA																				
CLASS POLYCHAETA																				
Ampharetidae													1			21				
Aonides sp.																				
Aricidea sp.							1	21	1			21								
Capitellidae																				
Cirratulidae					1			21		2		42		2		42				
Dorvilleidae																				
Flabelligeridae A						1		21		1		21			1	21	1			21
Hesionidae															4	85				
Heteromastus filiformis						1	1	42												
Hyalinoecia sp.							1	21							1	21		1		21
Laonice sp.							1	21												
Lumbrinereis sp.					1		1	42						1	1	42	1	4	1	127
Marphysa sp.							1	21												
Maldanidae					1			21	1	1		42	2	2		85				
Naineris sp.													1			21				
Orbinia sp.																				
Paraonidae					1			21		1		21								
Phyllodocidae																				
Phylo sp.																				
Prionospio sp.					1	2		64						1		21				
Rhamphobrachium sp.																				
Sabellidae										2		42								
Sigalionidae						1		21												
Spionidae						1	1	42												
Spionidae B											1	21								
Syllidae						1		21						1		21				
Sphaerosyllis sp.					1		1	42		3		64		1	1	42	1	1	1	64
Terebellidae													1			21				
Unident. - damaged pieces																				
PHYLUM NEMERTEA																				
Nemertian						1		21												
PHYLUM SIPUNCULA																				
CLASS SIPUNCULIDEA																				
Sipunculid worm A															1	21				
Sipunculid worm B																				
PHYLUM MOLLUSCA																				
CLASS GASTROPODA																				
Uberella barrierensis																				
CLASS BIVALVIA																				
Cuspidaria willetti																				
Nucula hartvigiana						1		21		2		42								
Nucula nitidula										1		21								
Unident. mussel spat										1		21								
PHYLUM ARTHROPODA																				
CLASS CRUSTACEA																				
ORDER AMPHIPODA																				
Ampeliscidae																				
Amphilochidae					1			21												
Caprella sp.															2	42				
Haustoriidae							1	21												
Liljeborgia sp.																				
Lysianassidae						1		21	1			21			1	21				
Phoxocephalidae A					3			64					1			21				
Phoxocephalidae D					2		1	64	1			21								
Urothoidae									1			21								
Unident. Amphipod species																				
ORDER ISOPODA																				
Asellota									2			42		1	1	42				
Munna sp.					1		1	42					1			21				
Paranthura flagellata						1		21		1		21		1		21		2		42
ORDER CUMACEA																				
Cumacean A						1		21						1		21		1		21
ORDER MYSIDACEA																				
Mysid			1	21															1	21
ORDER OSTRACODA																				
Ostracod A							1	21										1		21
Ostracod C																				
Ostracod E																				
ORDER TANAIDACEA																				
Tanaidacea spp						1		21	1			21			1	21				

Taxa	DC				500 m															
					N				E				S				W			
	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²
PHYLUM COELENTERATA																				
CLASS ANTHOZOA																				
Edwardsia sp.																				
PHYLUM ECHINODERMATA																				
CLASS OPHIUROIDEA																				
Amphiura sp.							1	21					1	1		42			2	42
CLASS HOLOTHUROOIDEA																				
Trochodota sp.					1	1		42		1		21						1		21
PHYLUM PORIFERA																				
CLASS DEMOSPONGIAE																				
Unident. sponge - sandy, flask-shaped																				
PHYLUM FORAMINIFERA																				
CLASS FORAMINIFERA																				
ORDER LITUOLIDA																				
Ammodiscus sp. A										1		21			1	21				
Ammodiscus sp. B																				
Cribrostomoides / Haplophragmoides																				
ORDER MILIODIDA																				
Nummoloculina contraria					4	1		106	2	1	1	85		1	3	85			2	42
Pyrgo spp			1	21	6	5	4	318	18	3	5	552	4	6	5	318	5	7	9	446
Quinqueloculina suborbicularis					5	2		149	4	5	3	255	1	3	2	127		4	2	127
Triloculina insignis						3		64	4	1	2	149	1	1	1	64			1	21
ORDER LAGENIDA																				
Lenticulina spp					80	102	55	5029	144	89	110	7279	120	114	108	7257	52	94	44	4032
ORDER ROTALIIDA																				
Calcarina sp.																				
Cibicidoides sp. 1					8	4	11	488	6	3	2	233	17	3	8	594	11	16	10	785
Alabamina					8	9	8	531	13	5	4	467	27	7	17	1082	10	17	15	891
Elphidium sp. A																				
Elphidium sp. B											1	21		1		21			1	21
Planularia sp.					2	1	1	85												
Unident. Foram - dome shaped																				
Unident. Foram - spine like																				
Unident. Foram - flat sim otolith																				
Total Number Of Species/Taxa	0	0	2	2	18	21	18	37	14	19	9	27	13	18	18	31	7	12	12	18
Total Number Of Individuals	0	0	2	42	127	141	92	7639	199	124	129	9592	178	148	159	10292	81	149	89	6769
Shannon- Wiener	0.00	0.00	0.69	0.69	1.58	1.32	1.60	1.61	1.14	1.36	0.70	1.16	1.14	1.12	1.36	1.30	1.15	1.34	1.63	1.44

Taxa	1500 m																Control			
	N				E				S				W							
	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²
PHYLUM ANNELIDA																				
CLASS POLYCHAETA																				
Ampharetidae	1			21																
Aonides sp.																	1			21
Aricidea sp.		1		21						1		21	1			21				
Capitellidae			1	21						1		21					1			21
Cirratulidae	1			21	1			21		1		21			1	21				
Dorvilleidae							1	21												
Flabelligeridae A	1			21		1	1	42		1		21								
Hesionidae																		1		21
Heteromastus filiformis																				
Hyalinoecia sp.	1	2		64	1			21			1	21					1	2	3	127
Laonice sp.																				
Lumbrinereis sp.	2			42	1	2	2	106		5	1	127							3	64
Marphysa sp.	3			64					1	1		42	1		1	42		1		21
Maldanidae			1	21					3			64	1		1	42	4	3		149
Naineris sp.						1		21												
Orbinia sp.																		1	1	42
Paraonidae		1		21			1	21												
Phyllodocidae					1			21	1	1		42								
Phylo sp.														1		21				
Prionospio sp.		2		42					1			21	2			42				
Rhamphobrachium sp.										3		64								
Sabellidae																				
Sigalionidae		1		21	1			21									1			21
Spionidae	1	1		42		1	1	42	3	1	1	106		1	1	42	2	1		64
Spionidae B	1			21																
Syllidae																	1			21
Sphaerosyllis sp.		2		42	3			64					1	1		42				
Terebellidae																				
Unident. - damaged pieces					1			21					1			21				
PHYLUM NEMERTEA																				
Nemertian									1			21								

Taxa	1500 m																Control			
	N				E				S				W							
	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²	A	B	C	Ave/m²
PHYLUM SIPUNCULA																				
CLASS SIPUNCULIDEA																				
Sipunculid worm A	2			42																
Sipunculid worm B																		1		21
PHYLUM MOLLUSCA																				
CLASS GASTROPODA																				
Uberella barrierensis														1		21				
CLASS BIVALVIA																				
Cuspidaria willetti							1	21												
Nucula hartvigiana																			1	21
Nucula nitidula																				
Unident. mussel spat																				
PHYLUM ARTHROPODA																				
CLASS CRUSTACEA																				
ORDER AMPHIPODA																				
Ampeliscidae	1			21		1		21												
Amphilochidae													1			21				
Caprella sp.																				
Haustoriidae		1		21					1			21								
Liljeborgia sp.						1		21	1		1	42								
Lysianassidae							2	42												
Phoxocephalidae A		1		21			1	21	1			21								
Phoxocephalidae D						2	1	64	1			21	1			21	2	1		64
Urothoidae																				
Unident. Amphipod species							1	21						1		21	2		1	64
ORDER ISOPODA																				
Asellota							1	21									1			21
Munna sp.					1			21							1	21			1	21
Paranthura flagellata	2		1	64															1	21
ORDER CUMACEA																				
Cumacean A	1	1		42			1	21									1			21
ORDER MYSIDACEA																				
Mysid			1	21										1		21			1	21
ORDER OSTRACODA																				
Ostracod A			1	21					1		1	42	1	1		42				
Ostracod C																		1		21
Ostracod E						1		21												
ORDER TANAIDACEA																				
Tanaidacea spp																				
PHYLUM COELENTERATA																				
CLASS ANTHOZOA																				
Edwardsia sp.																		1		21
PHYLUM ECHINODERMATA																				
CLASS OPHIUROIDEA																				
Amphiura sp.	1			21		2		42		1	1	42					1		1	42
CLASS HOLOTHUROOIDEA																				
Trochodota sp.			2	42		1		21	2	2	1	106								
PHYLUM PORIFERA																				
CLASS DEMOSPONGIAE																				
Unident. sponge - sandy, flask-shaped	1			21			1	21						1		21	2		1	64
PHYLUM FORAMINIFERA																				
CLASS FORAMINIFERA																				
ORDER LITUOLIDA																				
Ammodiscus A		1		21			1	21			1	21	1			21	1		1	42
Ammodiscus B	1			21							1	21								
Cribrostomoides / Haplophragmoides									1			21					1		1	42
ORDER MILIODIDA																				
Nummoloculina contraria		3		64		2	1	64	3	4	2	191	1	3	2	127	2	4		127
Pyrgo spp	7	5	5	361	6	13	10	615	11	18	4	700	9	9	7	531	37	20	5	1316
Quinqueloculina suborbicularis	3	2		106	8	2	2	255	4	7	1	255	6	1	4	233	16	8	5	615
Triloculina insignis	1	1		42	1			21	2	2	1	106	1	3	1	106	6		6	255
ORDER LAGENIDA																				
Lenticulina spp	65	67	39	3629	87	81	121	6133	149	137	90	7979	74	91	90	5411	75	92	66	4944
ORDER ROTALIIDA																				
Calcarina sp.																				
Cibicidoides sp. 1	7	21	7	743	74	23	22	2525	27	7	13	997	14	5	24	912	15	11	2	594
Alabamina	15	6	17	806	36	26	23	1804	14	13	6	700	10	7	6	488	21	15	18	1146
Elphidium sp. A	1	1	2	85	1	1	1	64							2	42			1	21
Elphidium sp. B					2	1		64		2		42	1			21		1		21
Planularia sp.	3	1		85		2	2	85												
Unident. Foram - dome shaped																				
Unident. Foram - spine like																				
Unident. Foram - flat sim otolith																				
Total Number Of Species/Taxa	23	20	11	37	16	19	22	37	20	19	16	31	18	15	13	27	22	17	19	35
Total Number Of Individuals	122	121	77	6791	225	164	198	12457	228	208	126	11926	127	127	141	8382	194	164	119	10122
Shannon- Wiener	1.91	1.71	1.55	1.91	1.56	1.72	1.51	1.70	1.41	1.45	1.22	1.45	1.61	1.23	1.30	1.47	2.02	1.63	1.73	1.93